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Risk factors for work-related musculoskeletal disordersamong workers in the footwear industry: a cross-sectional study

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The aim of the study was to investigate the influence of biomechanical, psychosocial, environmental and individual factors on local and multisite work-related musculoskeletal disorder (WMSD) symptoms among workers at a footwear manufacturing company. The sample comprised 267 workers. The results showed that: (a) age, sedentary lifestyle, inappropriate posture and perceived effort were associated with symptoms in the shoulders, and the combination of these factors increased the odds four-fold; (b) inappropriate posture, perceived effort and bullying were related to symptoms in the wrists, and the combination of these factors increased the odds seven-fold; (c) inappropriate posture, perceived effort, length of work at the company and low social support were associated with multisite symptoms, and their combination increased the odds up to 30-fold. Therefore, mainly biomechanical and psychosocial factors were associated with WMSD symptoms, and their combinations increased the odds of occurrence.

Keywords: work-related musculoskeletal disorder; footwear industry; work

1. Introduction

Work-related musculoskeletal disorders (WMSDs) are a group of diseases that primarily affect the upper limbs and the cervical and lumbar spine, causing tendon, muscle, joint, bone, nerve, vessel and ligament injuries that manifest as discomfort, local stiffness, muscle weakness, numbness and local and multisite pain. These WMSDs contribute to a reduced work ability and increased numbers of disability retirement requests and absenteeism [1–5].

WMSDs have multifactorial origins, including physical, psychosocial and individual factors [3,6–8]. The consideration of interactions between factors other than those stressed in the scientific literature, such as environmental factors, may lead to findings relevant for the prevention of WMSDs in emerging countries, because many classic models have been designed for studies conducted in high-income countries with better working conditions [9]. Hermawati et al. [10] were surprised that most studies on ergonomics in developing countries did not take environmental factors into account, given that most jobs were performed in warm and wet environments as a function of the tropical climates of such countries, which increased discomfort. Thus, new findings may be reached when considering environmental risks in the models, since factors associated with environmental temperature may alter the degree of tolerance of individuals to other facts modifying the overall assessment of the workstations [11].

In addition, the working conditions [12,13], social inequality [14] and risk management policies to which workers are subjected [15] in developing countries may influence the results of studies, which represents a considerable gap in scientific knowledge.

Carnes et al. [16] and Haukka et al. [17] found that several risk factors contributed to musculoskeletal pain in multiple parts of the body rather than in a single area. An analysis of the interactions between risk factors for multisite pain may yield significant results, because the number of concomitant symptoms of WMSDs is larger than that of local symptoms [18]. The aim of the present study conducted at a shoe manufacturing company was to investigate the influence of biomechanical, psychosocial, environmental and individual factors on the development of local and multisite WMSD symptoms among workers.

2. Materials and methods

2.1. *Sample selection*

The present study was conducted at a Brazilian manufacturer of shoes. At the time of the study, 1647 workers were employed by the company. Based on Hedayat and

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Sinha [19], the sample size (n) for a finite population was determined as follows:

$$n = \frac{N \times Z_{\alpha}^{2} \times p \times q}{d^{2} \times (N - 1) + Z_{\alpha}^{2} \times p \times q},$$

where N = total population; $Z_{\alpha}^{2} = 1962$ at 95% confidence interval (CI); p = expected frequency (when this is unknown a value of 50% is used, maximizing the sample size); $q = 1–p$; d = acceptable error ($d = 5.55\%$ for 95% CI and $p = 0.50$). A minimum of 263 workers was estimated to be necessary to provide a representative sample of the studied population:

$$n = \frac{1.647 \times 1.962^{2} \times 0.5 \times 0.5}{0.0555^{2} \times (1.647 - 1) + 1.962^{2} \times 0.5 \times 0.5} = 262.30.$$

The sample size was also estimated by adopting a priori of 80% ($\alpha = 5\%$ and $\beta = 20\%$) [20], assuming an expected effect of 0.15 [21] with 32 risk factors in the increased model and four risk factors in the compacted model. This procedure was performed with the aid of the 1mSupport [22] package of R version 3.4.4 [23], which was determined with a minimum sample size of 183.85 individuals.

The inclusion criteria were as follows: age 18 years or older; not being in the training stage for the job; and not being on sick leave due to WMSDs or work accidents, having hypertension, being pregnant or being in poor health. A total of 322 workers were considered eligible for the present study, but 55 refused participation.

The present article results from the integration of two studies independently conducted in the same footwear manufacturing unit over the same period of time with the same workers. The procedures for both studies were approved by the research ethics committee of the Federal University of Paraíba. The studies complied with the Committee of Ethics in Research with Human Beings Resolutions No. 466 and 510.

2.2. Collected data

2.2.1. *Individual factors*

The individual factors comprised sociodemographic and occupational variables. The sociodemographic variables considered were *gender*, *age*, *height*, *body weight*, *marital status*, *performance of physical activity*, *regular consumption of alcohol*, *smoking*, *children* and *educational level*. *Body weight* and *height* were used to calculate the *body mass index* (BMI), which for the purpose of sample characterization was categorized as underweight or thinness (BMI < 18), normal weight (18 < BMI < 24), overweight (24 < BMI < 28) and obese (BMI > 28). The presence of *sleep disorders* was investigated based on an item in the effort–reward imbalance (ERI) questionnaire [24]. The occupational variables included *length of work* at the company and whether the participants regularly performed one function (monofunctional) or more functions (multifunctional).

2.2.2. *Psychosocial factors*

The following dimensions were considered with regard to the psychosocial variables: *psychological demands*, *control of own tasks*, *job insecurity*, *social support from supervisors* and *social support from coworkers* as per the job content questionnaire (JCQ) [25]; *reward* and *overcommitment* as per the ERI questionnaire [24]; and items on *job dissatisfaction*, *stress*, *bullying*, *sexual harassment*, *discrimination* and *physical violence* suggested by Silva et al. [26]. The JCQ psychosocial variable scores were calculated according to the item weights as suggested in the original instrument; median values were used to define high or low exposure to risk factors [27]. The ERI variable scores were calculated by adding the scores attributed to the items in each individual dimension; mean values were used to define high or low exposure to the analyzed risk factors [28]. The items relative to psychosocial factors were answered on a 4-point Likert scale.

2.2.3. *Biomechanical factors*

Biomechanical factors were evaluated by ERI items and the occupational repetitive actions (OCRA) method. ERI items [24] were used to investigate *perceived effort*; the total score was calculated by adding the scores on the individual items, and mean values were used to define high or low *perceived effort*. Mean values of scores were used to define high or low exposition to biomechanical risks.

The OCRA method was used to quantify the ergonomic risk of WMSDs in the upper limbs. OCRA includes multipliers for strength, posture, repetitiveness, recovery period, total length of repetitive work and complementary factors (accuracy, compression, impact, sudden movements, temperature, use of gloves, slippery surfaces on handled objects and vibration). Acceptable risk was defined as OCRA < 2.2, low risk as 2.2 < OCRA < 4.5, medium risk as 4.5 < OCRA < 9 and high risk as OCRA > 9. The OCRA index results from the quotient between observed technical actions and the technical actions recommended by the method. The result from technical actions comes from the analysis of the risk factors. Each one of these factors generates an independent score according to the typology or exposure time to the factor within the time of the activity cycle [29].

In this regard, *posture* and *movements of upper limbs* were assessed based on the range of motion of the shoulder, elbow, wrist and hand joints, considering the movements of flexion, extension, abduction, pronation, supination, radial deviating, ulnar deviation and gross and delicate grip. As *repetitive work*, the repetition of gestures and postures was considered from 51% of the cycle time of activities whose cycle comprised the period of time between 1 and 15 s. *Force* was subjectively assessed through the psychophysical scale of Borg. This scale varies from 0.5 to 5.0 in order to indicate the strength level declared by workers for each technical action performed during work, which ranges from *no effort* to an *extremely strong effort*. Regarding the complementary factors, it was considered whether the exposure holds one-third, two-thirds or all cycle time of the activity [29].

Furthermore, *speed* and/or maintenance of *inappropriate posture* were also considered. The *speed* factor score was expressed by the number of technical actions (in minutes) performed by workers, considering work that demands more than 30 actions/min [29]. Maintenance of *inappropriate posture* considered the range of motion assumed from an erect trunk position, which, when higher than 20°, indicated some risk to the worker [30]. These scores were obtained through the weighted average of the time for which the segment remained in each posture.

2.2.4. *Environmental factors*

The environmental variables considered were *noise*, *exposure to heat* and *lighting*. *Exposure to heat* was measured with a heat stress meter (TGD 400; Instrutherm, Brazil) with accuracy ±0.5 °C. The device was placed at a fixed point close to the subject and away from doors and windows without interfering with the subject's mobility. After a 30-min waiting time for the device's thermometers to adapt, data were collected every minute over an 8-h period distributed across shifts [31,32]. Exposure to heat was estimated using the wet-bulb globe temperature index (WBGT), which was calculated according to the equation described in Regulatory Standard No. NR 15:1978 [33]. The *equivalent noise level* was measured with a sound-level meter (2250-L-200; Brüel and Kjær, Denmark), accuracy ±2 dB, *A*-weighted curve and slow response circuit. The device was placed at the height of the subject's ear canal more than 1 m away from the furniture, ceiling, walls and floor. The measurement procedures used were based on Brazilian Standard No. NBR 10151:2000 [34]. *Lighting* was assessed with a lux meter (Phywe Lux 07137-00; Phywe, Germany) with accuracy ±3%. The device was placed 1 m above the ground following Standard No. NBR 8995-1:2013 [35]. Measurements were made from 8:00 to 12:00 and from 13:00 to 17:00. The mean values of the data collected with the aforementioned devices were used to define low or high exposure to environmental factors.

2.2.5. *WMSD symptoms*

The intensity of musculoskeletal pain was quantified through a modified version of the Nordic questionnaire [36] answered on a 4-point Likert scale: 1 = *no pain*, which represents the absence of pain or tingling; 2 = *mild pain*, where these symptoms do not compromise the accomplishment of daily life activities; 3 = *moderate pain*, where these symptoms compromise the accomplishment of daily life activities; 4 = *severe pain*, where these symptoms, besides compromising daily life activities, were also the reason for consulting a health professional.

The questionnaire includes a chart representing the human body to indicate the body areas (cervical, thoracic spine, lumbar, shoulders, elbows, forearms, wrists, hands, hips, knees and feet) with WMSD symptoms. Although the Nordic questionnaire does not provide a clinical diagnosis, it enables one to identify symptoms related to WMSDs in different body areas [37].

2.3. ***Statistical analysis***

The statistical analysis was performed with R version 3.4.4 [23]. First, the internal consistency of the collected data was investigated with Cronbach's α. Descriptive statistics were used to characterize the sample, work and risk factors to which the workers were exposed. The collinearity of the variables was assessed with the variance inflation factor (VIF).

The association between each independent variable and the dependent variable was investigated using simple ordinal logistic regression models and multiple ordinal logistic regression. The odds for each variable increasing the odds of occurrence of a WMSD symptom in one of the analyzed body areas is expressed as the odds ratio (OR).

The interaction between risk variables with $p < 0.05$ in the multiple ordinal logistic regression models was investigated. For this purpose, the workers were grouped into categories as a function of the risk factors to which they were exposed; the reference group included workers not exposed to any of the risk factors considered in the analyzed interactions. The reference group served as the basis for investigation of significant differences in the risk of developing WMSDs when workers were simultaneously exposed to two or more risk factors. The OR was extracted from the logistic regression models to express the effect of the interaction between two or more risk factors on increasing the odds of WMSD symptoms in the analyzed body areas.

Next, the association between independent variables and the group of WMSD symptoms or multisite WMSD symptoms was investigated. The OR extracted from the ordinal logistic regression models expresses the odds of a worker reporting multisite WMSD symptoms when exposed to risk factors. The reference group included workers who reported pain in no or one body area.

Finally, the interactions of factors with significant influences ($p < 0.05$) on the development of multisite symptoms vis-à-vis the development of multisite WMSD symptoms were investigated. The reference group included workers who reported pain in no/one body area.

Outliers were detected in the regression models; however, they were only excluded when they behaved as high-leverage points. According to Cordeiro and Demétrio [38], a point is considered to have high leverage when it is inconsistent and influences the regression model; thus, its inconsistency is ensured when the standardized residual is outside the [−2;2] interval, and its influence is ensured when its value is greater than $2p/n$, where p = number of independent variables; n = sample size [39]. High-leverage points are observations made in a study that may change OR estimates by deviating them from the general trend (concerning the relationship between the dependent and independent variables) identified for the largest part of the dataset.

Regarding the validity of the generalized linear and ordinal logistic regression models, verifying the quality of the fit measures is always useful to determine how well a model describes the relationships between dependent and independent variables. Model accuracy is a measure that can be used for this purpose. Given the values of independent variables, this measure classifies observations and compares the observed responses to those predicted by the model. The percentage of correct classifications expresses the model accuracy. However, in the case of ordinal logistic regression models, this measure should be carefully analyzed, because although high accuracy indicates that the model is truly adequate to assess the relationships between variables, low accuracy does not necessarily indicate the opposite situation [26]. Figure 1 summarizes the statistical analysis steps.

3. Results

The JQC, ERI questionnaire and Nordic questionnaire exhibited Cronbach's α between 0.61 and 0.84, 0.60 and 0.71, and 0.81 and 0.86, respectively, which indicated good internal consistency of the collected data [40]. For most factors, the VIF was close to 1, with higher values for the factors *overcommitment* and *social support from supervisors* (VIF = 5.988), *age* and *having children* (VIF = 2.041) and *age* and *length of work* (VIF = 2.415). Therefore, the factors did not exhibit collinearity.

3.1. General characteristics

The sample comprised 267 workers; their characteristics are summarized in Tables 1–3. Most participants were male (53.56%), aged 21–30 years (40.45%), normal weight (49.06%), performed physical activity (64.79%), had children (52.81%), were not smokers (92.51%), did not regularly consume alcohol (74.16%), were married (52.06%), had completed secondary school (85.02%), had worked at the company for 13–60 months (52.43%), were

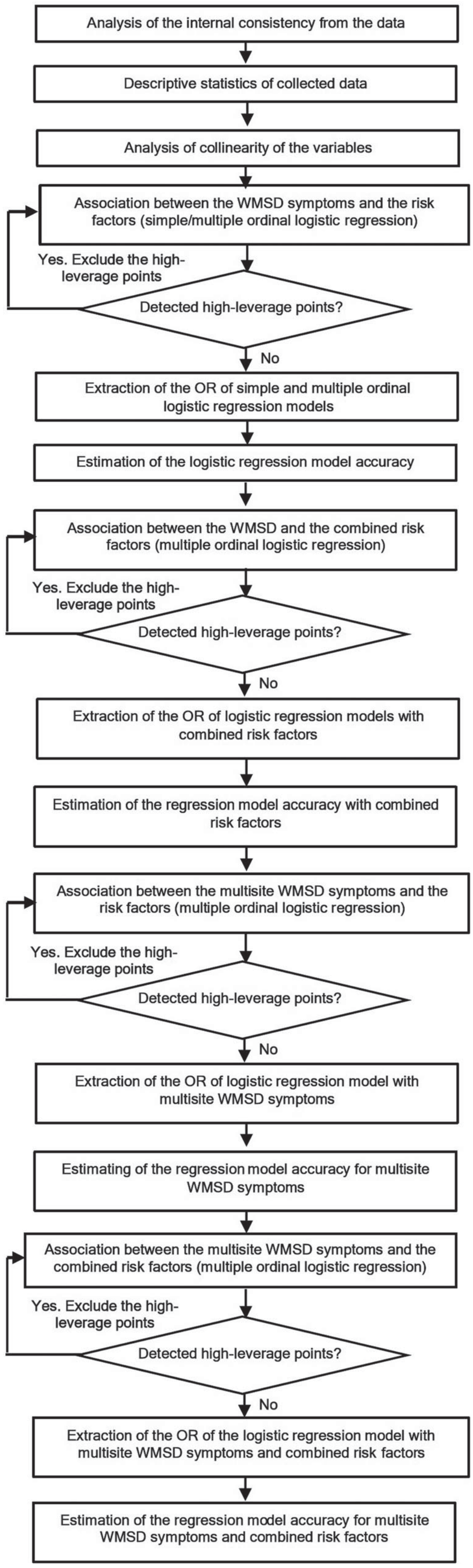

Figure 1. Statistical analysis steps.
Note: OR = odds ratio; WMSD = work-related musculoskeletal disorder.
Source: Study data (2018).

Table 1. Sociodemographic and occupational characteristics of the sample.

Sociodemographic and occupational data		*n* (%)
Gender	Male	143 (53.56)
	Female	124 (46.44)
Age (years)	18–20	54 (20.22)
	21–30	108 (40.45)
	31–40	73 (27.34)
	41–50	23 (8.61)
	>50	9 (3.37)
Body mass index	Underweight	14 (5.24)
	Normal weight	131 (49.06)
	Overweight	94 (35.21)
	Obesity	28 (10.49)
Educational level	Incomplete primary	4 (1.50)
	Complete primary	19 (7.12)
	Secondary education	227 (85.02)
	Incomplete higher education	13 (4.87)
	Complete higher education	4 (1.50)
Physical activity	Yes	173 (64.79)
	No	94 (35.21)
Presence of children	Yes	141 (52.81)
	No	126 (47.19)
Use of cigarettes	Smoker	20 (7.49)
	Non-smoker	247 (92.51)
Use of alcohol	Yes	69 (25.84)
	No	198 (74.16)
Civil status	Married	139 (52.06)
	Single	128 (47.94)
Sleep disorders	No	87 (32.58)
	Almost never	108 (40.45)
	Sometimes	60 (22.47)
	Always	12 (4.49)
Length of service (months)	≤12.0	59 (22.10)
	13–60	140 (52.43)
	61–120	28 (10.49)
	121–180	8 (3.00)
	181–240	22 (8.24)
Number of functions at company	Monofunctional	197 (73.78)
	Multifunctional	70 (26.22)

Source: Study data (2018).

monofunctional (85.02%) and almost never had sleep problems (40.45%).

In their job activities, most participants did not need to remain with their upper limbs in inadequate positions during 50% of the working hours (71.54%), did not apply excessive strength (68.54%) and did not adopt an inappropriate posture (55.81%). These findings agree with the low OCRA index (32.21%) found for most of the activities the participants performed at work. However, 55.06% of the participants reported high perceived effort while performing their tasks, 88.89% performed them at high speed and 82.40% needed to perform repetitive movements for more than 50% of their working hours.

Regarding the psychosocial factors, positive characteristics such as perceived high control over tasks (55.06%), social support from supervisors (41.20%) and coworkers (74.53%), fair reward for work done (59.93%) and absence of sexual harassment (91.39%) or bullying (85.39%) were highly prevalent. In turn, the negative characteristics reported were high psychological demands (57.68%), job insecurity (55.43%), overcommitment (50.94%) and job dissatisfaction (53.93%).

Table 2. Psychosocial characteristics of the sample.

Psychosocial factor		*n* (%)
Control of tasks	Low control	120 (44.94)
	High control	147 (55.06)
Social support from supervisors	High support	110 (41.20)
	Low support	157 (58.80)
Psychological demands	Low demands	113 (42.32)
	High demands	154 (57.68)
Job insecurity	Yes	148 (55.43)
	No	119 (44.57)
Social support from coworkers	Low support	68 (25.47)
	High support	199 (74.53)
Reward	Unfair reward	107 (40.07)
	Fair reward	160 (59.93)
Overcommitment	Yes	136 (50.94)
	No	131 (49.06)
Job dissatisfaction	Satisfied	123 (46.07)
	Dissatisfied	144 (53.93)
sexual harassment	Yes	23 (8.61)
	No	244 (91.39)
Bullying	Yes	39 (14.61)
	No	228 (85.39)

Source: Study data (2018).

Table 3. Occupational variables.

Biomechanical and environmental variable		*n* (%)
Strength application	Yes	84 (31.46)
	No	183 (68.54)
Inadequate upper limb position	Yes	76 (28.46)
	No	191 (71.54)
Need for speed	Yes	240 (89.89)
	No	27 (10.11)
Inappropriate posture	Yes	118 (44.19)
	No	149 (55.81)
Repetitive work	Yes	220 (82.40)
	No	47 (17.60)
Perceived effort	Yes	120 (44.94)
	No	147 (55.06)
OCRA index	Acceptable risk	85 (31.84)
	Low risk	86 (32.21)
	Medium risk	29 (10.86)
	High risk	67 (25.09)
Noise (dB)	<81	135 (50.56)
	>81	132 (49.44)
WBGT (°C)	<26.35	124 (46.44)
	>26.35	143 (53.56)
Lightning (lx)	<414	132 (49.44)
	>414	135 (50.56)

Note: OCRA = occupational repetitive actions; WBGT = wet-bulb globe temperature index. Source: Study data (2018).

Regarding the environmental characteristics, the workers were exposed to noise below 82 dB (50.56%), a WBGT over 26.35°C (53.56%) and lighting over 414 lx (50.56%).

3.2. Local and multisite musculoskeletal symptoms

The symptoms reported by the participants are presented in Table 4. The highest prevalence of severe pain was reported in the shoulders and wrists, with 21.35% each. The highest prevalence of moderate pain corresponded to the lumbar (20.60%) and thoracic spine (19.85%), whereas the cervical area (17.23%) and wrists (16.10%) exhibited the highest rates of mild pain. Approximately 31.46% of the workers reported symptoms in more than five body areas, which denoted a multiplicity of symptoms in the analyzed population.

3.3. Simple and multiple regression models for WMSDs

Analyses of the values extracted from the simple ordinal logistic regression models for symptoms in the cervical, thoracic and lumbar areas, shoulders and elbows (Table 5) showed that the factors *upper limbs in inadequate position*, *inappropriate posture*, *perceived effort*, *overcommitment* and *low social support from supervisors* significantly increased the risk of WMSDs in these body areas. The regression models showed that factors such as *need for speed* increased the odds of symptoms in the cervical and thoracic spine more than three-fold (OR > 3.00). *Age* and *length of work* in the company increased the occurrence of symptoms. The odds of reporting WMSD symptoms in the shoulders and the cervical and thoracic spine increased 5, 3 and 2.5%, respectively, for each additional year in age. The odds of developing WMSD symptoms in the thoracic spine and elbows increased 0.5 and 0.8%, respectively, for each additional month of work in the company.

Regarding the regression model values for forearms, wrists, hands, hips, knees and ankles (Table 6), the factors *length of work* and *low social support from supervisors* significantly increased the odds of WMSD symptoms in these areas. The factors *inappropriate posture* and *inadequate upper limb position* increased the odds of symptoms in the forearms and wrists two-fold (OR > 2.00). Participants who reported that they were victims of *bullying* exhibited three times (OR > 3.00) higher odds of reporting symptoms in the hips.

Table 7 presents the values extracted from the multiple ordinal logistic regression models for symptoms in the cervical, thoracic and lumbar spine, shoulders and elbows. Considering the effects of the other factors, *inappropriate posture* increased the odds for symptoms in the cervical, thoracic and lumbar spine at least two-fold. *Low social support from supervisors* was associated with a 27, 17 and 26% increase in the odds of WMSDs in the cervical, thoracic and lumbar spine, respectively. The factor *length of work* increased the odds of WMSDs in the back and elbows by 0.5 and 0.9%, respectively, per additional month of work at the footwear manufacturing company. The factor *perceived effort* increased the odds of WMSD symptoms in the shoulders by 35% and in the elbows by 25%.

Table 4. Reported work-related musculoskeletal disorder symptoms per body area and multiple symptoms.

WMSD	Pain	*n* (%)
Cervical	No pain	153 (57.30)
	Mild pain	46 (17.23)
	Moderate pain	45 (16.85)
	Severe pain	23 (8.61)
Thoracic spine	No pain	114 (53.93)
	Mild pain	36 (13.48)
	Moderate pain	53 (19.85)
	Severe pain	34 (12.73)
Lumbar	No pain	126 (47.19)
	Mild pain	35 (13.11)
	Moderate pain	55 (20.60)
	Severe pain	51 (19.10)
Shoulders	No pain	126 (47.19)
	Mild pain	36 (13.48)
	Moderate pain	48 (17.98)
	Severe pain	57 (21.35)
Elbows	No pain	226 (84.64)
	Mild pain	15 (5.62)
	Moderate pain	9 (3.37)
	Severe pain	7 (6.37)
Forearms	No pain	195 (73.03)
	Mild pain	19 (7.12)
	Moderate pain	25 (9.36)
	Severe pain	28 (10.49)
Wrists	No pain	121 (45.32)
	Mild pain	43 (16.10)
	Moderate pain	46 (17.23)
	Severe pain	57 (21.35)
Hands	No pain	164 (61.42)
	Mild pain	34 (12.73)
	Moderate pain	29 (10.86)
	Severe pain	40 (14.98)
Hips	No pain	215 (80.52)
	Mild pain	30 (11.24)
	Moderate pain	15 (5.62)
	Severe pain	7 (2.62)
Knees	No pain	206 (77.15)
	Mild pain	27 (10.11)
	Moderate pain	20 (7.49)
	Severe pain	14 (5.24)
Feet	No pain	151 (56.55)
	Mild pain	41 (15.36)
	Moderate pain	39 (14.61)
	Severe pain	36 (13.48)
Multiple symptoms	No pain	26 (9.74)
	Pain in 1 area	31 (11.61)
	Pain in 2 or 3 areas	74 (27.72)
	Pain in 4 or 5 areas	52 (19.48)
	Pain in more than 5 areas	84 (31.46)

Note: WMSD = work related musculoskeletal disorder.
Source: Study data (2018).

Table 5. Simple regression models for the cervical, thoracic and lumbar spine, shoulders and elbows.

Independent variable	Cervical	Thoracic	Lumbar	Shoulders	Elbows
Sociodemographic factors					
Gender (male)	1.00	1.00	1.00	1.00	1.00
Gender (female)	**1.80 [1.13, 2.88]**	1.01 [0.64, 1.59]	0.99 [0.63, 1.54]	1.31 [0.84, 2.05]	**2.32 [1.17, 4.60]**
Marital status (single)	1.00	1.00	1.00	1.00	1.00
Marital status (married)	1.37 [0.86, 2.19]	**1.64 [1.03, 2.59]**	**1.69 [1.08, 2.64]**	**1.70 [1.08, 2.66]**	1.38 [0.71, 2.71]
Body mass index	1.04 [0.99, 1.10]	1.03 [0.98, 1.0]	1.02 [0.98, 1.08]	1.04 [0.99, 1.10]	1.04 [0.97, 1.12]
Age (years)	**1.03 [1.003, 1.054]**	**1.025 [1.001, 1.050]**	1.01 [0.99, 1.04]	**1.05 [1.03, 1.08]**	**1.07 [1.04, 1.11]**
Sleep disorders	**1.33 [1.02, 1.74]**	**1.46 [1.12, 1.90]**	**1.35 [1.05, 1.75]**	**1.47 [1.14, 1.91]**	1.17 [0.80, 1.71]
No physical activity	1.27 [0.78, 2.09]	1.22 [0.76, 1.96]	1.01 [0.63, 1.60]	**1.93 [1.19, 3.11]**	**2.41 [1.07, 5.48]**
Children	1.39 [0.87, 2.22]	1.55 [0.98, 2.45]	1.35 [0.86, 2.10]	**2.21 [1.40, 3.4]**	**2.43 [1.18, 5.00]**
Biomechanical factors					
Inadequate upper limb position	**1.75 [1.06, 2.89]**	**2.68 [1.62, 4.43]**	**1.80 [1.10, 2.92]**	**3.04 [1.84, 5.01]**	**2.38 [1.20, 4.70]**
Tasks demanding strength application	1.23 [0.75, 2.03]	1.12 [0.69, 1.84]	**1.82 [1.13, 2.93]**	0.95 [0.53, 1.71]	1.76 [0.89, 3.49]
Inappropriate posture	**2.54 [1.58, 4.08]**	**2.30 [1.44, 3.66]**	**2.79 [1.77, 4.42]**	**1.54 [1.15, 2.06]**	**2.67 [1.34, 5.31]**
Need for speed	**3.08 [1.22, 7.79]**	**3.20 [1.26, 8.16]**	2.12 [0.96, 4.68]	1.72 [0.82, 3.63]	2.56 [0.58, 11.21]
Perceived effort	**1.31 [1.17, 1.46]**	**1.24 [1.11, 1.38]**	**1.30 [1.17, 1.44]**	**1.37 [1.23, 1.53]**	**1.34 [1.15, 1.56]**
Occupational factors					
Length of work (months)	1.002 [0.999, 1.005]	**1.005 [1.002, 1.008]**	1.003 [0.999, 1.005]	1.003 [0.999, 1.005]	**1.008 [1.005, 1.012]**
Psychosocial factors					
Psychological demands (high)	1.00 [0.94, 1.06]	**1.07 [1.01, 1.14]**	1.01 [0.95, 1.07]	**1.11 [1.05, 1.18]**	1.05 [0.96, 1.14]
Overcommitment (yes)	**1.18 [1.09, 1.27]**	**1.14 [1.06, 1.23]**	**1.21 [1.12, 1.31]**	**1.17 [1.08, 1.26]**	**1.14 [1.06, 1.23]**
Social supervisor support (low)	**1.30 [1.17, 1.44]**	**1.22 [1.10, 1.35]**	**1.30 [1.18, 1.44]**	**1.25 [1.14, 1.38]**	**1.22 [1.10, 1.35]**
Environmental factors					
Noise (<81 dB)	1.00	1.00	1.00	1.00	1.00
Noise (>81 dB)*	0.62 [0.39, 0.98]	0.76 [0.48, 1.10]	0.87 [0.56, 1.35]	**0.59 [0.38, 0.92]**	**0.39 [0.19, 0.80]**

*The result of the model indicated that area with noise above 81 dB presents workers with lower susceptibility to musculoskeletal symptoms. This may be related to the type of work performed in these sectors, due to being an area designated to manufacture components, involving heavy machinery in the activities of pressing and preparation of rubber.
Note: Data presented as odds ratio [95% confidence interval]. Models with $p < 0.05$ are in **bold**. *Body mass index*, *age* and *length of work* were included in the model as continuous variables. Although smoking was assessed, it was not possible to obtain an estimate of its effect due to non-convergence of the model parameters' estimation algorithm when this variable was entered. Source: Study data (2018).

Among the body areas presented in Table 7, the model fit for the elbows exhibited the highest accuracy (84.64%).

Table 8 presents the results of the multiple regression models for the forearms, wrists, hands, hips, knees and feet. Women exhibited two-fold higher odds (OR = 2.93) of reporting WMSD symptoms in the knees. Victims of *bullying* exhibited two-fold higher odds of developing WMSD symptoms in the hips (OR = 2.76) and wrists (OR = 2.25). The factor *perceived effort* increased the odds of WMSD symptoms in the forearms by 31%, wrists by 20%, hands by 16%, knees by 34% and ankles by 18%. An increase of 1 in the BMI was associated with a 9% increase in the odds of the workers reporting ankle symptoms. Among the body areas presented in Table 8, the model fit for the hips exhibited the highest accuracy (80.83%).

3.4. Interactions between risk factors and local WMSD symptoms

Analyses of the results corresponding to the interactions between factors with $p < 0.05$ in the multiple regression models (Table 9) evidenced significant increases in WMSD symptoms in all analyzed body areas.

The results showed that the participants who simultaneously reported *high effort at work* and *job insecurity*, performed work with an *inadequate upper limb position* and *had worked in the company* for more than 30 months had 28 times higher odds (OR = 28.89) of reporting symptoms in the forearms. Therefore, there are indications that the interaction between these factors increases the risk of WMSDs and that this increase is larger than the effect of each factor alone. The model for the elbows represented best the relationship between the independent variables and

Table 6. Simple regression models for forearms, wrists, hands, hips, knees and ankles.

Independent variable	Forearms	Wrists	Hands	Hips	Knees	Ankles
Sociodemographic factors						
Gender (male)	1.00	1.00	1.00	1.00	1.00	1.00
Gender (female)	1. 20 [0.70, 2.05]	1.36 [0.88, 2.13]	1.01 [0.63, 1.63]	1.24 [0.68, 2.27]	**1.95 [1.10, 3.46]**	1.44 [0.91, 2.29]
Sleep disorders	1.24 [0.91, 1.69]	**1.59 [1.23, 2.07]**	1.20 [0.90, 1.60]	1.23 [0.86, 1.74]	**1.47 [1.06, 2.04]**	1.07 [0.82, 1.40]
No physical activity	**2.23 [1.20, 4.15]**	1.44 [0.90, 2.31]	1.41 [0.84, 2.36]	1.89 [0.95, 3.74]	**1.97 [1.04, 3.75]**	1.41 [0.86, 2.30]
Age	**1. 038 [1.010, 1.066]**	1.018 [0.994, 1.042]	1.023 [0.998, 1.049]	**1.034 [1.003, 1.067]**	**1.038 [1.008, 1.068]**	1.020 [0.995, 1.045]
Body mass index	1.019 [0.960, 1.081]	0.984 [0.935, 1.035]	1.026 [0.972, 1.083]	1.051 [0.983, 1.124]	**1.048 [0.980, 1.122]**	**1.072 [1.015, 1.132]**
Biomechanical factors						
Inadequate upper limb position	**2.90 [1.65, 5.08]**	**2.03 [1.25, 3.30]**	1.63 [0.97, 2.74]	1.65 [0.88, 3.12]	1.75 [0.96, 3.17]	1.03 [0.74, 1.44]
Inappropriate posture	**2.51 [1.35, 4.32]**	**2.14 [1.36, 3.37]**	**2.53 [1.56, 4.12]**	1.67 [0.91, 3.06]	**2.40 [1.36, 4.29]**	**2.12 [1.33, 3.40]**
Perceived effort	**1.34 [1.18, 1.52]**	**1.25 [1.12, 1.38]**	**1.18 [1.06, 1.31]**	1.12 [0.98, 1.28]	**1.30 [1.14, 1.48]**	**1.26 [1.13, 1.40]**
Occupational factors						
Length of work (months)	**1.006 [1.003, 1.010]**	**1.003 [1.001, 1.006]**	**1.005 [1.002, 1.008]**	**1.004 [1.001, 1.007]**	**1.004 [1.001, 1.008]**	**1.004 [1.001, 1.007]**
Psychosocial factors						
Psychological demands	**1.08 [1.10, 1.15]**	**1.07 [1.01, 1.13]**	1.03 [0.97, 1.10]	0.99 [0.92, 1.07]	1.00 [0.93, 1.08]	1.03 [0.97, 1.09]
Overcommitment	**1.15 [1.05, 1.27]**	**1.16 [1.08, 1.26]**	**1.10 [1.01, 1.19]**	1.10 [0.99, 1.21]	**1.17 [1.06, 1.29]**	**1.12 [1.04, 1.20]**
Low social supervisor support	**1.26 [1.12, 1.42]**	**1.22 [1.11, 1.35]**	**1.15 [1.04, 1.28]**	**1.20 [1.06, 1.37]**	**1.28 [1.12, 1.45]**	**1.22 [1.10, 1.34]**
Bullying	1.65 [0.82, 3.33]	**2.31 [1.25, 4.29]**	1.66 [0.87, 3.17]	**3.37 [1.64, 6.95]**	1.03 [0.46, 2.29]	1.48 [0.79, 2.76]
Job insecurity	**1.37 [1.10, 1.71]**	1.16 [0.97, 1.39]	**1.24 [1.02, 1.50]**	1.21 [0.95, 1.53]	1.11 [0.89, 1.04]	0.99 [0.83, 1.20]
Reward	0.98 [0.91, 1.05]	0.98 [0.93, 1.04]	**0.93 [0.87, 0.99]**	**0.89 [0.82, 0.96]**	0.96 [0.89, 1.04]	**0.92 [0.87, 0.98]**
Environmental factors						
WBGT (<26.35 °C)	1.00	1.00	1.00	1.00	1.00	1.00
WBGT (>26.35 °C)	1.09 [0.64, 1.86]	0.89 [0.57, 1.38]	1.11 [0.69, 1.80]	**1.95 [1.04, 3.69]**	**1.98 [1.10, 3.57]**	**1.62 [1.01, 2.59]**
Lighting (<414 lx)	1.00	1.00	1.00	1.00	1.00	1.00
Lighting (>414 lx)	**1.86 [1.08, 3.21]**	1.14 [0.73, 178]	1.13 [0.70, 1.82]	1.34 [0.73, 2.46]	1.34 [0.76, 2.38]	**1.65 [1.03, 2.62]**

Note: Data presented as odds ratio [95% confidence interval]. Models with $p < 0.05$ are in **bold**. *Body mass index*, *age* and *length of work* were included in the model as continuous variables. Although smoking was assessed, it was not possible to obtain an estimate of its effect due to non-convergence of the model parameters' estimation algorithm when this variable was entered. WBGT = wet-bulb globe temperature index. Source: Study data (2018).

Table 7. Multiple regression models for the cervical, thoracic, lumbar, shoulder and elbow areas.

Independent variable	Cervical ($n = 267$)	Thoracic spine ($n = 267$)	Lumbar ($n = 266$)	Shoulders ($n = 267$)	Elbows ($n = 267$)
Sociodemographic factors					
Gender (male)	1.00	–	–	–	–
Gender (female)	**1.82 [1.12, 2.95]**	–	–	–	–
Marital status (single)	–	–	1.00	–	–
Marital status (married)	–	–	**1.76 [1.10, 2.81]**	–	–
Age	–	–	–	**1.05 [1.03, 1.08]**	–
No physical activity	–	–	–	**1.70 [1.03, 2.80]**	–
Biomechanical factors					
Inappropriate posture	**2.26 [1.38, 3.68]**	**2.18 [1.35, 3.53]**	**2.50 [1.55, 4.02]**	–	**2.49 [1.17, 5.28]**
Inadequate upper limb position	–	–	–	**2.49 [1.48, 4.21]**	–
Perceived effort	–	–	–	**1.35 [1.20, 1.51]**	**1.25 [1.06, 1.47]**
Occupational factors					
Length of work	–	**1.005 [1.002, 1.008]**	–	–	**1.009 [1.005, 1.013]**
Psychosocial factors					
Low social supervisor support	**1.27 [1.14, 1.41]**	**1.17 [1.06, 1.30]**	**1.26 [1.13, 1.40]**	–	–

Note: Data presented as odds ratio [95% confidence interval]. Models with $p < 0.05$ are in **bold**. *Age* and *length of work* were included in the model as continuous variables. The regression model accuracy values were 58.05% for the cervical area, 53.18% for the back, 50.75% for the lumbar area, 52.06% for the shoulders and 84.64% for the elbows. One high-leverage point was removed from the model for the lumbar area. – = variable excluded from the models. Source: Study data (2018).

Table 8. Multiple regression models for the forearms, wrists, hands, hips, knees and ankles.

Independent variable	Forearms ($n = 266$)	Wrists ($n = 267$)	Hands ($n = 267$)	Hips ($n = 266$)	Knees ($n = 267$)	Ankles ($n = 267$)
Sociodemographic factors	**–**	**–**	**–**	**–**	**–**	**–**
Gender (male)	–	–	–	–	1.00	–
Gender (female)	–	–	–	–	**2.62 [1.39, 4.96]**	–
Body mass index	–	–	–	–	**-**	**1.09 [1.03, 1.15]**
Biomechanical factors	–	–	–	–	–	–
Inappropriate posture	–	**1.70 [1.06, 2.73]**	–	–	–	–
Inadequate upper limb position	**2.40 [1.32, 4.37]**	–	–	–	–	–
Perceived effort	**1.31 [1.15, 1.50]**	**1.20 [1.08, 1.34]**	**1.16 [1.04, 1.30]**	–	**1.34 [1.17, 1.54]**	**1.18 [1.04, 1.34]**
Occupational factors	**–**	**–**	**–**	**–**	**–**	**–**
Length of work	**1.006 [1.003, 1.010]**	–	**1.005 [1002, 1.008]**	–	–	–
Psychosocial factors	**–**	**–**	**–**	**–**	**–**	**–**
Low supervisor support	–	–	–	**1.19 [1.04, 1.36]**	–	**1.14 [1.01, 1.28]**
Bullying	–	**2.25 [1.20, 4.24]**	–	**2.76 [1.26, 6.05]**	–	–
Job insecurity	**1.42 [1.13, 1.78]**	–	–	–	–	–
Reward	–	–	–	–	–	**0.90 [0.85, 0.96]**
Environmental factors	–	–	–	–	–	–
WBGT (<26.35 °C)	–	–	–	1.00	1.00	–
WBGT (>26.35 °C)	–	–	–	**2.32 [1.19, 4.51]**	**3.49 [1.79, 6.78]**	–

Note: Data presented as odds ratio [95% confidence interval]. Models with $p < 0.05$ are in **bold**. *Body mass index* and *length of work* were included in the model as continuous variables. The regression model accuracy values were 72.93% for the forearms, 48.31% for the wrists, 62.71% for the hands, 80.83% for the hips, 77.15% for the knees and 55.06% for the ankles. One high-leverage point was removed from the models for the forearms and hips. – = variable excluded from the models; WBGT = wet-bulb globe temperature index. Source: Study data (2018).

the dependent variable (WMSD symptoms) with more than 80% accuracy.

3.5. Interaction between risk factors for multisite WMSD symptoms

Analyses of the risk factors that contributed to the occurrence of multisite WMSD symptoms (Table 10) evidenced that *length of work*, *perceived effort*, *inappropriate posture* and *low social support from supervisors* contributed to the development of symptoms in several body areas. Each month of work at the company increased the odds of developing multisite WMSD symptoms by 0.6%. Factors such as *perceived effort* and *low social support from supervisors* increased the odds of multisite pain by more than 20%. In turn, *inappropriate posture* increased the odds of workers reporting symptoms in several body areas two-fold.

Analysis of the interactions among risk factors (Table 11) evidenced 30 times higher odds (OR = 30.40) of developing multisite WMSD symptoms. Therefore, there are indications that the interactions between risk factors that individually contribute to the occurrence of WMSD symptoms in several body areas significantly increase the odds of developing multisite WMSDs. The combined effect of these risk factors was more harmful than their individual effects.

4. Discussion

The results of the present study showed that the need to maintain the upper limbs in an inadequate position increased the odds of WMSD symptoms in the shoulders two-fold. In a study also conducted with workers in the footwear industry, Leclerc et al. [41] found that shoulder symptoms mainly occurred when work activities required the arms to remain above shoulder level. Models fitted in other studies found that arm elevation above 60° contributed to the occurrence of shoulder symptoms, especially among women [42]. According to Aghili et al. [43], maintenance of the arms in an inadequate position is related to the design of many workstations in the footwear industry, and mechanization as such does not suffice to reduce the prevalence of musculoskeletal disorders. Therefore, interventions targeting workstations in the footwear industry based on anthropometric data and work methods are needed to reduce the occurrence of WMSDs involving the shoulders [44].

Age was also associated with shoulder symptoms. The findings reported by Veisi et al. [45] indicated

Table 9. Interactions between risk factors for work-related musculoskeletal disorders.

Interaction between independent variables	Odds ratio [95% CI]	Accuracy (%)
Gender + social support + inappropriate posture	Cervical	61.25
Gender (male) + *low social support from supervisors* (no) + *inappropriate posture* (no)	1.00	–
Gender (male) + *low social support from supervisors* (yes) + *inappropriate posture* (no)	1.28 [0.64, 2.51]	–
Gender (male) + *low social support from supervisors* (no) + *inappropriate posture* (yes)	2.31 [0.54, 3.40]	–
Gender (male) + *low social support from supervisors* (yes) + *inappropriate posture* (yes)	2.55 [0.94, 4.33]	–
Gender (female) + *low social support from supervisors* (no) + *inappropriate posture* (no)	1.28 [0.57, 2.77]	–
Gender (female) + *low social support from supervisors* (no) + *inappropriate posture* (yes)	**2.33 [1.14, 5.40]**	–
Gender (female) + *low social support from supervisors* (yes) + *inappropriate posture* (no)	**4.20 [2.10, 8.41]**	–
Gender (female) + *low social support from supervisors* (yes) + *inappropriate posture* (yes)	**11.28 [3.99, 31.89]**	–
Inappropriate posture + length of work + social support	Back	56.62
Inappropriate posture (no) + *length of work* (<30 months) + *low social support from supervisors* (no)	1.00	–
Inappropriate posture (no) + *length of work* (>30 months) + *low social support from supervisors* (no)	**2.16 [1.24, 5.97]**	–
Inappropriate posture (no) + *length of work* (<30 months) + *low social support from supervisors* (yes)	1.05 [0.88, 1.25]	–
Inappropriate posture (no) + *length of work* (>30 months) + *low social support from supervisors* (yes)	**3.92 [1.17, 13.06]**	–
Inappropriate posture (yes) + *length of work* (<30 months) + *low social support from supervisors* (no)	1.45 [0.55, 1.98]	–
Inappropriate posture (yes) + *length of work* (>30 months) + *low social support from supervisors* (no)	**4.02 [1.19, 13.61]**	–
Inappropriate posture (yes) + *length of work* (<30 months) + *low social support from supervisors* (yes)	**6.87 [2.11, 22.33]**	–
Inappropriate posture (yes) + *length of work* (>30 months) + *low social support from supervisors* (yes)	**8.47 [3.19, 22.48]**	–
Social support + inappropriate posture + marital status	Lumbar	60.00
Low social support from supervisors (no) + *inappropriate posture* (no) + *marital status* (single)	1.00	–
Low social support from supervisors (no) + *inappropriate posture* (yes) + *marital status* (single)	1.05 [0.88, 1.25]	–
Low social support from supervisors (no) + *inappropriate posture* (no) + *marital status* (married)	2.61 [0.91, 3.01]	–
Low social support from supervisors (no) + *inappropriate posture* (yes) + *marital status* (married)	**3.05 [1.88, 4.25]**	–
Low social support from supervisors (yes) + *inappropriate posture* (no) + *marital status* (single)	1.05 [0.68, 1.21]	–
Low social support from supervisors (yes) + *inappropriate posture* (yes) + *marital status* (single)	**7.18 [1.82, 28.35]**	–
Low social support from supervisors (yes) + *inappropriate posture* (no) + *marital status* (married)	**9.56 [2.56, 35.73]**	–
Low social support from supervisors (yes) + *inappropriate posture* (yes) + *marital status* (married)	**21.15 [6.64, 67.35]**	–
Physical activity + age + inappropriate posture + inadequate arm position	Shoulders	52.08
Performs regular physical activity (yes) + *age* (<27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (no)	1.00	–
Performs regular physical activity (yes) + *age* (<27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (yes)	1.54 [0.97, 1.88]	–
Performs regular physical activity (yes) + *age* (<27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (no)	1.34 [0.57, 1.92]	–
Performs regular physical activity (yes) + *age* (<27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (yes)	**3.01 [1.77, 5.12]**	–

(*Continued*).

Table 9. Continued.

Interaction between independent variables	Odds ratio [95% CI]	Accuracy (%)
Performs regular physical activity (yes) + *age* (>27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (no)	1.05 [0.78, 1.73]	–
Performs regular physical activity (yes) + *age* (>27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (yes)	**1.41 [1.02, 1.97]**	–
Performs regular physical activity (yes) + *age* (>27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (no)	**1.54 [1.25, 2.01]**	–
Performs regular physical activity (yes) + *age* (>27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (yes)	**3.55 [2.05, 7.12]**	–
Performs regular physical activity (no) + *age* (<27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (no)	1.07 [0.41, 2.01]	–
Performs regular physical activity (no) + *age* (<27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (yes)	1.21 [0.82, 1.72]	–
Performs regular physical activity (no) + *age* (<27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (no)	1.44 [0.95, 2.31]	–
Performs regular physical activity (no) + *age* (<27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (yes)	**3.43 [1.17, 9.56]**	–
Performs regular physical activity (no) + *age* (>27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (no)	1.67 [0.88, 1.99]	–
Performs regular physical activity (no) + *age* (>27 years old) + *inappropriate posture* (no) + *inadequate upper limb position* (yes)	**1.92 [1.22, 3.43]**	–
Performs regular physical activity (no) + *age* (>27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (no)	**2.09 [1.49, 5.01]**	–
Performs regular physical activity (no) + *age* (>27 years old) + *inappropriate posture* (yes) + *inadequate upper limb position* (yes)	**4.11 [1.34, 12.56]**	–
Perceived effort + inappropriate posture + length of work	Elbows	82.42
Perceived effort (no) + *inappropriate posture* (no) + *length of work* (<30 months)	1.00	–
*Perceived effor*t (no) + *inappropriate posture* (yes) + *length of work* (<30 months)	1.21 [0.82, 1.55]	–
Perceived eff ort (no) + *inappropriate posture* (no) + *length of work* (>30 months)	1.33 [0.94, 1.82]	–
Perceived effort (no) + *inappropriate posture* (yes) + *length of work* (>30 months)	**6.01 [2.82, 10.65]**	–
Perceived effort (yes) + *inappropriate posture* (no) + *length of work* (<30 months)	1.05 [0.77, 1.10]	–
Perceived effort (yes) + *inappropriate posture* (yes) + *length of work* (<30 months)	**2.25 [1.09, 2.77]**	–
Perceived effort (yes) + *inappropriate posture* (no) + *length of work* (>30 months)	**2.56 [1.01, 2.96]**	–
Perceived effort (yes) + *inappropriate posture* (yes) + *length of work* (>30 months)	**30.96 [3.87, 247.83]**	–
Perceived effort + inadequate arm position + length of work + job insecurity	Forearms	78.26
Perceived effort (no) + *inadequate arm position* (no) + *length* of work (<30 months) + *job insecurity* (no)	1.00	–
Perceived effort (no) + *inadequate arm position* (yes) + *length of work* (<30 months) + *job insecurity* (no)	1.07 [0.68, 1.22]	–
Perceived effort (no) + *inappropriate arm position* (no) + *length of work* (>30 months) + *job insecuri*ty (no)	1.12 [0.81, 1.31]	–
Perceived effort (no) + *inadequate arm position* (no) + *length of work* (<30 months) + *job insecurity* (yes)	1.21 [0.87, 1.45]	–
Perceived effort (no) + *inadequate arm position* (yes) + *length of work* (>30 months) + *job insecurity* (no)	**2.16 [1.31, 3.43]**	–
Perceived effort (no) + *inadequate arm positio*n (yes) + *length of work* (<30 months) + *job insecurity* (yes)	**1.58 [1.02, 2.76]**	–
Perceived effort (no) + *inadequate arm position* (no) + *length of work* (>30 months) + *job insecurity* (yes)	1.17 [0.98, 1.25]	–
Perceived effort (no) + *inadequate arm position* (yes) + *length of work* (>30 months) + *job insecurity* (yes)	**8.05 [3.22, 22.76]**	–
Perceived effort (yes) + *inadequate arm position* (no) + *length of work* (<30 months) + *job insecurity* (no)	0.98 [0.55, 1.47]	–
Perceived effort (yes) + *inadequate arm position* (yes) + *length of work* (<30 months) + *job insecurit*y (no)	**1.55 [1.08, 2.43]**	–
Perceived effort (yes) + *inadequate arm position* (no) + *length of work* (>30 months) + *job insecurity* (no)	2.07 [0.98, 4.01]	–

(*Continued*).

Table 9. Continued.

Interaction between independent variables	Odds ratio [95% CI]	Accuracy (%)
Perceived effort (yes) + *inadequate arm position* (no) + *length of work* (<30 months) + *job insecurity* (yes)	1.09 [0.89, 1.35]	–
Perceived effort (yes) + *inadequate arm position* (yes) + *length of work* (>30 months) + *job insecurity* (no)	**5.05 [2.77, 9.01]**	–
Perceived effort (yes) + *inadequate arm position* (yes) + *length of work* (<30 months) + *job insecurity* (yes)	**2.09 [1.54, 3.87]**	–
Perceived effort (yes) + *inadequate arm position* (no) + *length of work* (>30 months) + *job insecurity* (yes)	**4.97 [2.25, 8.02]**	–
Perceived effort (yes) + *inadequate arm position* (yes) + *length of work* (>30 months) + *job insecurity* (yes)	**28.89 [3.20, 260.57]**	–
Bullying + inappropriate posture + perceived effort	Wrists	63.89
Bullying (no) + *inappropriate posture* (no) + *perceived effort* (no)	1.00	–
Bullying (no) + *inappropriate posture* (yes) + *perceived effort* (no)	1.55 [0.89, 2.02]	–
Bullying (no) + *inappropriate posture* (no) + *perceived effort* (yes)	1.07 [0.93, 1.54]	–
Bullying (no) + *inappropriate posture* (yes) + *perceived effort* (yes)	**3.54 [1.98, 5.01]**	–
Bullying (yes) + *inappropriate posture* (no) + *perceived effort* (no)	1.01 [0.67, 1.99]	–
Bullying (yes) + *inappropriate* posture (yes) + *perceived effort* (no)	**2.67 [1.48, 4.46]**	–
Bullying (yes) + *inappropriate posture* (no) + *perceived effort* (yes)	**1.49 [1.12, 2.02]**	–
Bullying (yes) + *inappropriate posture* (yes) + *perceived effort* (yes)	**7.80 [2.52, 24.20]**	–
Perceived effort + length of work	Hands	60.27
Perceived effort (no) + *length of work* (<30 months)	1.00	–
Perceived effort (no) + *length of work* (>30 months)	1.33 [0.98, 1.69]	–
Perceived effort (yes) + *length of work* (<30 months)	1.06 [0.72, 1.81]	–
Perceived effort (yes) + *length of work* (>30 months)	**4.38 [2.22, 8.66]**	–
Social support + bullying + WBGT	Hips	77.36
Low social support from supervisors (no) + *bullying* (no) + *WBGT* (<26.35 °C)	1.00	–
Low social support from supervisors (no) + *bullying* (yes) + *WBGT* (<26.35 °C)	1.13 [0.81, 1.66]	–
Low social support from supervisors (no) + *bullying* (no) + *WBGT* (>26.35 °C)	1.37 [0.99, 2.66]	–
Low social support from supervisors (no) + *bullying* (yes) + *WBGT* (>26.35 °C)	**10.64 [1.34, 84.75]**	–
Low social support from supervisors (yes) + *bullying* (no) + *WBGT* (<26.35 °C)	1.06 [0.87, 3.54]	–
Low social support from supervisors (yes) + *bullying* (yes) + *WBGT* (<26.35 °C)	**7.35 [1.35, 40.06]**	–
Low social support from supervisors (yes) + *bullying* (no) + *WBGT* (>26.35 °C)	**4.57 [1.47, 14.21]**	–
Low social support from supervisors (yes) + *bullying* (yes) + *WBGT* (>26.35 °C)	**8.82 [2.14, 36.41]**	–
Gender + perceived effort	Knees	76.92
Gender (male) + *perceived effort* (no)	1.00	–
Gender (male) + *perceived effort* (yes)	2.31 [0.88, 3.82]	–
Gender (female) + *perceived effort* (no)	2.02 [0.91, 3.71]	–
Gender (female) + *perceived effort* (yes)	**5.43 [2.31, 12.78]**	–
Gender + WBGT	Knees	73.40
Gender (male) + *WBGT* (<26.35 °C)	1.00	–
Gender (male) + *WBGT* (>26.35 °C)	2.13 [0.97, 4.17]	–
Gender (female) + *WBGT* (<26.35 °C)	1.73 [0.99, 3.33]	–
Gender (female) + *WBGT* (>26.35 °C)	**6.13 [2.07, 18.17]**	–
Perceived effort + WBGT	Knees	74.11
Perceived effort (no) + *WBGT* (<26.35 °C)	1.00	–
Perceived effort (no) + *WBGT* (>26.35 °C)	1.65 [0.77, 2.14]	–
Perceived effort (yes) + *WBGT* (<26.35 °C)	1.32 [0.89, 1.79]	–
Perceived effort (yes) + *WBGT* (>26.35 °C)	**8.83 [3.07, 25.42]**	–
Body mass index + perceived effort + social support + reward	Ankles/feet	72.34
Body mass index (<24.54) + *perceived effort* (no) + *low social support from supervisors* (no) + *reward* (fair)	1.00	–
Body mass index (<24.54) + *perceived effort* (yes) + *low social support from supervisors* (no) + *reward* (fair)	1.12 [0.76, 1.35]	–
Body mass index (<24.54) + *perceived effort* (no) + *low social support from supervisors* (yes) + *reward* (fair)	1.03 [0.88, 1.15]	–
Body mass index (<24.54) + *perceived effort* (no) + *low social support from supervisors* (no) + *reward* (unfair)	1.10 [0.98, 1.36]	–
Body mass index (<24.54) + *perceived effort* (yes) + *low social support from supervisors* (yes) + *reward* (fair)	**2.32 [1.01, 3.36]**	–
Body mass index (<24.54) + *perceived effort* (yes) + *low social support from supervisors* (no) + *reward* (unfair)	**2.55 [1.22, 4.01]**	–

(*Continued*).

Table 9. Continued.

Interaction between independent variables	Odds ratio [95% CI]	Accuracy (%)
Body mass index (<24.54) + *perceived effort* (yes) + *low social support from supervisors* (yes) + *reward* (unfair)	**4.12 [1.79, 7.21]**	–
Body mass index (<24.54) + *perceived effort* (no) + *low social support from supervisors* (yes) + *reward* (unfair)	**1.98 [1.04, 2.66]**	–
Body mass index (>24.54) + *perceived effort* (no) + *low social support from supervisors* (no) + *reward* (fair)	1.09 [0.98, 1.16]	–
Body mass index (>24.54) + *perceived effort* (yes) + low *social support from supervisors* (no) + *reward* (fair)	**1.65 [1.03, 2.32]**	–
Body mass index (>24.54) + *perceived effort* (no) + *low social support from supervisors* (yes) + *reward* (fair)	**1.41 [1.15, 1.98]**	–
Body mass index (>24.54) + *perceived effort* (no) + *low social support from supervisors* (no) + *reward* (unfair)	1.65 [0.92, 3.01]	–
Body mass index (>24.54) + *perceived effort* (yes) + *low social support from supervisors* (yes) + *reward* (fair)	**3.33 [1.99, 5.04]**	–
Body mass index (>24.54) + *perceived effort* (yes) + *low social support from supervisors* (no) + *reward* (unfair)	**2.87 [1.45, 3.59]**	–
Body mass index (>24.54) + *perceived effort* (no) + *low social support from supervisors* (yes) + *reward* (unfair)	**3.67 [2.09, 7.65]**	–
Body mass index (>24.54) + *perceived effort* (yes) + *low social support from supervisors* (yes) + *reward* (unfair)	**5.03 [1.32, 19.12]**	–

Note: The interaction between the three risk factors relative to the knees resulted in a model with non-significant values; therefore, the three factors were evaluated in pairs. High or low exposure to the risk factors *length of service* and *age* was established based on median values, because these factors were collected as continuous variables. CI = confidence interval; WBGT = wet-bulb globe temperature index. Source: Study data (2018). Models with $p < 0.05$ are in **bold**.

Table 10. Factors that contribute to multisite work-related musculoskeletal disorder symptoms.

Independent variable		Multiple pain, odds ratio [95% CI]	Accuracy (%)
Occupational factors	*Length of work* (months)	1.006 [1.003, 1.010]	53.56
Biomechanical factors	*Perceived effort*	1.23 [1.08, 1.41]	–
	Inappropriate posture	2.67 [1.62, 4.41]	–
Psychosocial factors	*Low social support from supervisors*	1.22 [1.07, 1.38]	–

Note: Length of work was included in the regression model as a continuous variable. CI = confidence interval. Source: Study data (2018).

Table 11. Interactions among risk factors for multisite work-related musculoskeletal disorder symptoms.

Independent variable		Multiple pain, odds ratio [95% CI]	Accuracy (%)
Length of work + social support + inappropriate posture + perceived effort	*Length of work* (<30 months) + *low social support from supervisors* (no) + *inappropriate posture* (no) + *perceived effort* (no)	1.00	62.50
	Length of work (>30 months) + *low social support from supervisors* (yes) + *inappropriate posture* (yes) + *perceived effort* (yes)	30.40 [8.74, 109.97]	–

Note: High or low exposure to the risk factor length of service was established based on median values, because this factor was collected as a continuous variable. CI = confidence interval. Source: Study data (2018).

that age was a relevant individual factor, because each additional year of age increased the risk of WMSDs involving the shoulders by 4%. Stedmon et al. [46] observed that literature on the aging of industrial workers and its negative effects was scarce. Nevertheless, these authors emphasized that the knowledge/experience of older workers compensated for the reduction in physical and cognitive capacities at work and that mechanization, automation and redesign of workstations might reduce the impact of the increase in job demands resulting from the current competitive economic scenario.

Similar to the study by Eatough et al. [47], the present study found that psychosocial factors also contributed to the occurrence of WMSD symptoms. One example was the factor *bullying*, which was associated with wrist symptoms. Upon analyzing the relationship between psychosocial factors and musculoskeletal symptoms among workers in the footwear industry, Silva and Silva [48] found that bullying increased the odds of wrist symptoms among workers from both *gender* categories up to two-fold. The findings reported by Law et al. [49] suggested that bullying contributed to the creation of a poor psychosocial climate in the workplace, which was reflected as health problems. Some studies [50–52] included transcripts of narratives by workers in the footwear industry that evidenced daily exposure to humiliating situations. However, other studies suggested that adverse situations caused by psychosocial factors increased the secretion of stress-related hormones, whose degradation products accumulated in muscles and contributed to increases in muscle tension, perceived effort/workload, sensitivity to pain and the odds of muscle injury [53,54].

Among the analyzed environmental factors, only *heat* remained associated with WMSD symptoms. Vieira et al. [55] found that among environmental factors, thermal discomfort was the main cause of health complaints and significantly contributed to the occurrence of physical and psychological symptoms. Therefore, investments to improve thermal conditions at worksites in the footwear industry should be stimulated, because these improvements have positive effects on reducing the occurrence of physical symptoms [56] and increasing productivity [57]. The present study provides indications that heat contributes to the occurrence of symptoms in the hips and knees. Thus, we may hypothesize that unhealthy temperature levels in workstations compel workers to adopt a body posture that causes overload on the lower limbs, which is an issue for investigation in future studies.

The study by Widanarko et al. [3] investigated the combined effects of a large number of factors of different types (physical, psychosocial, occupational and environmental) on musculoskeletal symptoms. However, the combined effects of sociodemographic factors, such as gender, BMI and age, were only considered as an adjustment variable in the models. Studies that do not consider sociodemographic factors are susceptible to two types of error: (a) over/underestimation of the effects of the factors included in the model; (b) omission of relevant risk factors in models constructed to account for the causes of WMSDs. One example is *gender*, which has been shown to behave as a risk factor for WMSDs in several studies [8]. Wijnhoven et al. [58] lists at least four reasons to consider *gender* a risk factor: (a) biological differences; (b) the working conditions of women are usually more precarious; (c) women are more prone to report WMSD symptoms; (d) household chores and child care expose women to high-risk situations. In addition, the effect of psychosocial factors on WMSDs is more significant for women [26,59]. In countries with a strong patriarchal tradition, such as Brazil, women may also suffer from a lack of work arrangements to help them meet the demands of work and home [60,61]. Therefore, by considering *gender* in the interaction between factors, the present study provided relevant results, because the combined effect of *female gender*, *low social support from supervisors* and *inappropriate posture* increased the odds of WMSDs 11-fold, which was a much more significant increase than the increase associated with each factor alone.

Some factors were associated with multisite WMSD symptoms. Croft et al. [62] observed that occurrence of any pain was more likely in the presence of another type of pain for two reasons: (a) vulnerability originating in the central processing of pain; (b) the physical demands of the job require the use and wear of muscles and joints in different body areas. As a result, the prevalence of pain affecting more than one body area is higher than the pain of isolated symptoms [16,63]. Silva et al. [52] found that local pain increased perceived stress levels among workers, which contributed to the development of new WMSD symptoms.

In a study with workers in the footwear industry, Fernandes et al. [18] found an association between biomechanical factors and the occurrence of multisite WMSD symptoms. Among the biomechanical factors significantly associated with WMSDs, *inappropriate posture* increased the odds of occurrence of multisite symptoms at least two-fold. Notably, the results of the present study indicate that factors that apparently should cause only local injury may also elicit pain in distant body areas. In addition to the need for biomechanical compensation for inappropriate posture at other body areas [64], pain occurs independently from the site of origin of the nociceptive stimulus according to the central pain theory [62].

Perceived effort was also a risk factor for multisite pain. Workers in the footwear industry are exposed to diverse physical demands, such as activities involving pulling, lifting and pushing weights, in addition to squatting, trunk rotation and flexion [18]. Following analysis of the movements performed by workers in the footwear industry, Leite et al. [65] found that several movements increased the odds of WMSD symptoms, such as left shoulder abduction, left shoulder flexion, left forearm supination, left wrist flexion and right wrist radial/ulnar deviation beyond the normal range of motion. Haukka et al. [17] found that the number of years in the same job behaved as a risk factor for multisite pain symptoms.

The factor *low social support* increased the odds for multisite symptoms by 22%. This finding agreed with the results of Fernandes et al. [18], who found that the prevalence of these symptoms increased by 30% among workers. Borsoi et al. [50] analyzed reports of workers in Brazilian footwear manufacturing companies and detected several complaints concerning embarrassing situations and threats of layoff made by supervisors, mostly involving workers with some degree of work incapacity due to musculoskeletal diseases. The suffering of these workers was misjudged by supervisors as lack of interest, lack of responsibility and laziness. Rigotto et al. [51] asserted that such workers subjected themselves to aggression and excessive pressure by supervisors for considering the current work their only employment opportunity and source of basic workers' rights. Since supervisors represent the employer's authority, the workers' complaints are disregarded, with a consequent increase in perceived stress.

The present study has some limitations. First, the data were collected at one single point in time. Longitudinal studies may lead to sounder conclusions on the relationships between risk factors and WMSDs. Additionally, some risk factors, especially psychosocial factors, were exclusively assessed based on perceptual data. A third limitation derives from the fact that non-occupational factors were not considered in the models constructed to explain the origin of WMSDs. An example is the somatizing tendency, which according to some studies contributes to the development of multisite WMSD symptoms [66]. Fourth, all participants were nationals of the same country. Nationality and acculturation [67,68] as well as working conditions and national risk management policies may contribute to the occurrence of health problems [15]. Although smoking was assessed, it was not possible to obtain an estimate of its effect due to non-convergence of the model parameters' estimation algorithm when this variable was entered.

In conclusion, analysis of the risk factors for WMSDs among workers in the footwear industry showed that this population had high odds of developing WMSDs. Environmental factors, such as heat, which are not usually considered in models fitted to explain musculoskeletal pain were associated with the occurrence of symptoms in the lower half of the body both individually and in combination with other risk factors. Biomechanical, occupational and psychosocial factors significantly contributed to the occurrence of local and multisite symptoms. The interactions between these factors may increase the odds of WMSD symptoms up to 30-fold. Therefore, interventions seeking to minimize the impact of these factors should be prioritized, since their effects are deleterious for workers in the footwear industry.

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