Exploration of Musculoskeletal Diseases

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Ergonomic evaluation of assembly line work activity in the automotive industry: a case study

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Abstract

The automotive industry is growing worldwide with new technologies and seeking maximum cost savings. This sector is essential for the economic development of the country, with modern industries that invest in technological innovations and control of the activities of the production process. With this, the workstations become increasingly dynamic and characterized in the logic of productivity. Therefore, this study aimed to evaluate the work activity of operators of an assembly line of automotive components, from the ergonomic analysis. Through a descriptive and exploratory field study, the work activity of 30 operators of an assembly line of metallic components of the automotive industry was evaluated. Using instruments such as sociodemographic questionnaire; Nordic questionnaire; open interview, with collective questions about the development of the function, listed in an ergonomic demand items (EDIs) ranking; and complementary application of the NIOSH and OCRA methods. As a result, all respondents were male, with an average age of 30.13 ± 8.57 years, most had completed high school (76.7%), with an average working time in the company of almost two years (21.93 ± 12 months). Regarding relationships with coworkers, it was observed that the sector has a great relationship during the activities, with both colleagues and the boss. This study demonstrated a lower frequency of musculoskeletal symptoms in operators when compared to other studies. Symptoms that caused work leave were neck (3.3%), shoulders (3.3%), upper (6.7%) and lower back (6.7%), and hips/thighs (6.7%), ankle/foot (6.7%) were reported.

Keywords

Ergonomics, auto industry, risk factors of work-related musculoskeletal disorders

Introduction

The automotive industry, expanding globally with technological innovations and cost-cutting measures, necessitates the integration of ergonomic principles into production to prevent worker discomfort, pain, and cognitive strain, enhancing performance.

Padovani [1] identified 67,982 social security absences due to workplace illnesses and accidents in Brazilian automotive industries from 2005 to 2013, with musculoskeletal issues accounting for a significant portion.

A study in Curitiba found the highest absenteeism among young male production operators [2], highlighting the impact of pain and fatigue on work and life due to excessive force and posture deviations [3], emphasizing the human cost of workplace accidents and stress [4].

The inception of Fordism by Henry Ford introduced a mass production model that significantly influenced the automotive sector and its management models, leading to modern industry practices and the advent of the Fourth Industrial Revolution. The assembly line, divided into stamping, painting, and component fitting stages, has evolved from manual labor to increased automation, reducing human error and accident risks, yet some tasks still expose workers to occupational hazards [5–11].

Ergonomic application can mitigate these risks by improving workplace conditions and techniques, thus preventing injuries and enhancing productivity [12–15]. Additionally, the automotive industry's role in commercial strategy evolution, notably with the Goiana Automotive Hub in Pernambuco, demonstrates the sector's impact on job creation and technological advancement in traditionally agricultural regions, marking a successful transition towards modern manufacturing processes [16].

Case report

The Polo brought about an enormous social transformation where many of the employees hired are people who left the instability of crab fishing, cutting sugarcane or working in construction to face the challenge of making cars. The company has approximately 177 production operators, 12 of whom are women and the remaining men distributed across 3 work shifts. The majority of operators (89%) are between 20 and 39 years old. Regarding health indicators, only 4% are hypertensive, 3% are diabetic, 9% are an active smoker and 60% drink alcohol. More than half (58%) practice some type of physical activity.

The loss indicator referring to absenteeism is related to the number of days lost reported by the human resource (HR) sector, in the period from January 2019 to November 2019, the unreported combined immunodeficiency (CID) is the most recurrent, followed by H10.0 (Mucopurulent Conjunctivitis), M65.0 (Synovitis and tenosynovitis) and A04.9 (Unspecified bacterial intestinal infection).

This study employs a descriptive and exploratory approach, integrating quantitative and qualitative methods. The aim is to deepen understanding of specific population characteristics or phenomena and to explore the practical reality within specific social contexts. Methods include bibliographic surveys, questionnaires, open interviews, and systematic observations.

The research was conducted at Company J, an automotive sector supplier located in Goiana, Pernambuco, Brazil. The focus was on the RMC (Rinforzo Montante) DX (right side of the part) SX (left side of the part) assembly line, which included 30 workers across two shifts. Participants will include workers who voluntarily agree to participate, excluding those who refuse, as well as interns, scholarship recipients, and minors under 18 years old.

Data was collected through sociodemographic surveys and specific questionnaires, such as the Nordic Questionnaire for assessing musculoskeletal pains, and open interviews to identify ergonomic demand items (EDIs). Also, the Visual Analog Scale for Pain to measure perceived pain, and devices to monitor heart rate during work.

Data collection will take place in October 2019, starting with a direct approach to all line operators, informing them in detail about the study's objectives and the voluntary nature of participation. Analyses will include the interpretation of structured questionnaires based on EDIs and the evaluation of thermographic images, along with the use of specific software to analyze work conditions and participants' health.

In statistical analysis, categorical variables were presented as counts and relative frequency in percentages. Continuous variables were first assessed for normality, and parametric data was expressed as

mean ± deviation and non-parametric as median and interquartile range. For continuous data comparisons between two independent groups was applied Student *t* test or the Mann-Whitney test, according normality. Values of $P < 0.05$ were considered statistically significant. Data were analyzed using IBM SPSS Statistics software for Macintosh (Version 23.0. Armonk, NY: IBM Corp.).

Regarding operators characteristics, they were all male, with an average age of 30.13 ± 8.57 years. The group's average BMI was overweight, but very close to ideal normal values (25.69 ± 3.84 kg/m^2). The massive presence of male workers in this study is compatible with the profile of the labor market. The group of workers can be considered as young adults, as the average age is 30 years old. The majority had completed secondary education (76.7%), with an average working time at the company of almost two years (21.93 ± 12 months), a similar working time in the sector where they carried out their activities (Table 1). Marques and Silva-Junior [17], in a study carried out with truck assembly line workers, identified that the profile of the participants was male, with an average age of 35 years and an average working time in the company of 7.83 years, more than half (51.9%) did not practice physical activities and 67.1% were overweight or obese. The working time in our study is much shorter, as it is a new plant that began operations approximately 5 years ago. In relation to the body mass index close to ideal, it is a result of the food provided by the company and its educational campaigns, aimed at encouraging physical activity and good nutrition.

Table 1. General socio-demographic characteristics of operators in an automotive industry

Variables	Total group (*n* = 30)
Shift work, *n* (%)	
Daytime	11 (36.7)
Evening	8 (26.7)
Nocturnal	11 (36.7)
Work regime, *n* (%)	
Salaried	30 (100)
Sex, *n* (%)	
Masculine	30 (100)
Age (years)	30.13 ± 8.57
Weight (kg)	78.27 ± 11.77
Height (m)	1.75 ± 0.05
BMI (kg/m^2)	25.69 ± 3.84
Education, *n* (%)	
Complete first degree	1 (3.3)
Incomplete second degree	4 (13.3)
Second degree completed	23 (76.7)
Graduated	2 (6.7)
Working time at the company (months)	21.93 ± 12
Working time in the Sector (months)	18.73 ± 11.09

Quantitative data expressed as mean ± standard deviation and categorical data as absolute count and percentages between parenthesis

A correlation between overweight operators and work shifts was identified, predominantly at night, justified by changes in the circadian rhythm that can modify the body, including eating rhythms, which often leads to excess weight and obesity. In a systematic review and meta-analysis carried out by Sun et al. [18], it was found that night work increases the risk of obesity/overweight by 23%, and the excess risk of visceral obesity was even greater, equal to 35%, and it was recommended to modify the working hours, particularly for that permanently extended period.

The main failures in the sector reported by operators were the lack of material (20%), and, above all, problems with equipment (53%; Table 2). One of the operator's technical requirements is to know each piece of equipment in their area, in terms of working autonomously at the workstation, understanding the

automation concepts used in welding lines, and how the standard established to detect faults works. Furthermore, maintenance is carried out by maintenance specialists, which requires more time to restore equipment and production.

Table 2. Occupational health and work capacity characteristics reported by operators in an automotive industry

Variables	Total group (*n* = 30)
Failures due to lack of material, *n* (%)	6 (20)
Failures regarding equipment problems, *n* (%)	16 (53.3)
Failures and problems with the team, *n* (%)	0 (0)
Failures when depending on other sectors, *n* (%)	2 (6.7)
Failures and other factors, *n* (%)	1 (3.3)
Difficulties due to little work space	3.45 ± 4.33
Demand for speed, even within a schedule	6.38 ± 5.18
Enough time to finish work	7.72 ± 5.32
Performs other work that is not your role	2.56 ± 3.09
Insufficient number of operators for the function	1.54 ± 1.89
Managers are safe and effective	10.02 ± 4.2
Sufficient lighting for activities in the sector	8.4 ± 4.9
Uncomfortable temperature for work	9.05 ± 3.62
Workplace is noisy	7.39 ± 3.55
Noise interferes with activities	2.88 ± 2.89
Pain/discomfort during activities	3.86 ± 3.7
Work capacity	
Current work capacity	9.37 ± 1.67
Work capacity in relation to physical demands	9.11 ± 1.68
Work capacity in relation to mental demands	9.28 ± 1.62

Quantitative data expressed as mean ± standard deviation and categorical data as absolute count and percentages between parenthesis

Regarding questions related to their activity, the highest scores with positive aspects were regarding sufficient time and lighting to carry out activities, in addition to safe and effective management. Hong et al. [19], valued in their study that adequate planning of light in the work environment could reduce accidents resulting from visual fatigue, in addition to establishing a pleasant environment, exerting a positive psychological influence on the performance of the task.

The relationship with management is perceived as cordial and cooperative, this perception is identified during a verbal interview and ratified in a questionnaire administered. This successful relationship may not only be due to the management's "dealing" with subordinates, but also through the practice of techniques that involve operators in continuous improvement projects, participating in risk analysis with the director and management, both present. On the factory floor so that operators feel important and safe in their work environment.

The main negative aspects reported by the operators were the uncomfortable temperature, as well as the noise in the work area (Table 2). The two environmental risk factors reported, heat and noise, are objects of study regarding worker health.

Noise was identified in a study by Assunação and Silva Abreu [20], when describing the prevalence of work-related musculoskeletal disorders and analyzing the factors associated with this outcome in the Brazilian population, it was found that 32.1% of those affected were exposed to noise in the work environment, the same author, when citing a study by Basner et al. [21], reports the possibility of a correlation between noise and the musculoskeletal system, causing irritation and discomfort that provoke reactions at the level of muscle fibers. These reactions provoke inflammatory processes that cause symptoms of muscle fatigue and pain.

Several authors describe that exposure to cold and/or excessive heat are risk factors for work-related musculoskeletal injuries [22]. The Ergonomic Workplace Analysis (EWA) method establishes that the combination of environmental factors—temperature, humidity and air speed, thermal radiation, type of activity, workload and type of clothing—are essential for evaluating thermal effects in the work environment. In this environment under study, the uniform is light, however, in some positions, it is necessary to use an apron to minimize the risk of cuts, as the metal piece has areas that expose the worker to the risk of cuts; the average IBUTG (Wet Bulb Index-Globe Thermometer) is 28.3. The company has air blowers and exhaust fans, and operators have reported discomfort from the heat. The acquisition of fans was a request from operators.

Still in Table 2, in relation to work capacity scores, where score 10 refers to "I am at my best capacity", the group of operators, in general, reported being in excellent work capacity.

To assess the prevalence of musculoskeletal symptoms among operators in the workplace, within an ergonomic approach, the Nordic questionnaire was applied (Table 3). A significant frequency of musculoskeletal symptoms was observed in the following regions: shoulders, in the last 7 days (17%), right wrist, in the last 12 months (17%), wrists, in the last 7 days (20%), lower back, in the last 12 months (27%) and in the last 7 days (27%).

Table 3. Prevalence of musculoskeletal symptoms in operators in an automotive industry using the Nordic questionnaire (*n* = 30)

Region of pain	Last 7 days		Last 12 months	
	n (%)	Missing work *n* (%)	*n* (%)	Missing work *n* (%)
Neck	2 (6.7)	0 (0)	3 (10)	1 (3.3)
Right shoulder	0 (0)	0 (0)	3 (10)	0 (0)
Left shoulder	0 (0)	0 (0)	2 (6.7)	0 (0)
Shoulders	5 (16.7)	0 (0)	1 (3.3)	1 (3.3)
Right elbow	0 (0)	0 (0)	0 (0)	0 (0)
Left elbow	0 (0)	0 (0)	0 (0)	0 (0)
Elbows	0 (0)	0 (0)	0 (0)	0 (0)
Right fist	0 (0)	0 (0)	5 (16.7)	0 (0)
Left fist	0 (0)	0 (0)	2 (6.7)	0 (0)
Fists	6 (20)	0 (0)	1 (3.3)	0 (0)
Upper back	3 (10)	0 (0)	3 (10)	2 (6.7)
Lower back	8 (26.7)	0 (0)	8 (26.7)	2 (6.7)
Hip/Thigh	3 (10)	0 (0)	3 (10)	2 (6.7)
Knees	1 (3.3)	0 (0)	1 (3.3)	0 (0)
Ankle/Foot	4 (13.3)	0 (0)	4 (13.3)	2 (6.7)

Categorical data as absolute count and percentages between parenthesis

Regarding work situations that the operator considered to be responsible for his pain and/or discomfort, the final inspection tasks were listed: removing burrs from parts; make the practicalities of the pieces; deposit on the rack and remain standing for a long time. Within the categories of risk situations, they can be considered physical when microlesions occur, whether of mechanical origin, which may occur direct trauma, or of ergonomic origin, when they generate erroneous postures and exaggerated efforts of the upper, lower limbs and trunk [23].

This study demonstrated a lower frequency of musculoskeletal symptoms in operators compared to a study by Pereira da Silva et al. [24], which, through the analysis of the results obtained by the Nordic questionnaire in the automotive industry, found that 95% of workers in the production sector presented some musculoskeletal discomfort. Among workers, 65% of those interviewed reported pain in the dorsal and lumbar spine region in the last 12 months, followed by the lower limb region (50%), the neck region—cervical and shoulders, both (35%) and the wrist and hand (30%).

This reality can be influenced due to the practice of administrative conduct such as job rotation (rotation between operations) carried out by the company under research, as no conduct was reported in the aforementioned study. Studies show the benefits of rotating activities through changes in the variability of muscular activity [25, 26]. Furthermore, psychosocial factors, such as job satisfaction and engagement, also favor the reduction of muscle complaints [27, 28].

Among the symptoms that caused some days of absence from work among the operators in this research, the neck (3.3%), shoulders (3.3%), upper back (6.7%) and lower back (6.7%) were affected, and hips/thighs (6.7%), ankle/foot (6.7%) were reported (Table 3). It is observed that the majority of operators were not absent from their work activities. "It may be influenced by the company's conduct in identifying complaints, it is a form where the sector leader, when identifying a complaint reported by the operator, informs the EHS sector through the Panorama Complaints Form".

In this form, the leader identifies which part of the body the complaint occurs and the probable cause of the involvement, whether it was related to any domestic activity (e.g., painting the house, handling a sofa), sporting activity (e.g., football game, running), activity labor (e.g., some operation) or other causes. This form is delivered to the EHS sector, which assesses the need to schedule an appointment with a specialist, recommend physiotherapeutic treatment, relocate to a compatible activity or other protective measure so that the complaint does not progress. It is worth considering that there is no confidentiality when filling out the form and this may represent a measurement bias due to the possibility of the operator omitting their complaints, in order to minimize the negative impact of their image with the employer.

Regarding pain intensity, operators indicated the amount of pain felt using a visual analogue pain scale. Only 2 operators reported severe pain, one in the dorsal spine and the other in the lumbar spine. Moderate pain in the right wrist was the most frequent report in this category, with almost (30%) frequency, followed by moderate pain in the right and left ankles/feet (25% and 28.6%, respectively). However, more than (70%) of the operators reported at least mild pain in some region of the body (Table 4).

Table 4. Pain assessment through complaints reported by operators in an automotive industry

Variables	**Total group (*n* = 30)**		
	Pain intensity		
	Light, *n* (%)	**Moderate, *n* (%)**	**Intense, *n* (%)**
Neck	25 (83.3)	5 (16.7)	0 (0)
Right shoulder	25 (89.3)	3 (10.7)	0 (0)
Left shoulder	25 (89.3)	3 (10.7)	0 (0)
Right elbow	27 (96.4)	1 (3.6)	0 (0)
Left elbow	27 (96.4)	1 (3.6)	0 (0)
Right fist-hand	20 (71.4)	8 (28.6)	0 (0)
Left hand fist	24 (85.7)	4 (14.3)	0 (0)
Back column	23 (82.1)	4 (14.3)	1 (3.6)
Lumbar spine	22 (78.6)	5 (17.9)	1 (3.6)
Hip/Thigh	26 (92.9)	2 (7.1)	0 (0)
Right knee	25 (89.3)	3 (10.7)	0 (0)
Left knee	25 (89.3)	3 (10.7)	0 (0)
Right ankle/foot	21 (75)	7 (25)	0 (0)
Left ankle/foot	20 (71.4)	8 (28.6)	0 (0)

Categorical data as absolute count and percentages between parenthesis

Impact of musculoskeletal symptoms on the occupational health of operators

By evaluating the prevalence of musculoskeletal symptoms using the Nordic questionnaire, the most frequently asked questions were selected: Pain in the shoulders in the last 7 days, right wrist in the last 12 months, in the wrists in the last 7 days, in the lower back in the last 12 months and lower back in the last

7 days. From then on, groups with and without musculoskeletal symptoms were created in these regions and scores related to occupational health were compared.

Operators who presented musculoskeletal shoulder symptoms in the last 7 days had worked longer in the company (33.6 ± 8.79 vs. 19.6 ± 11.27 months, $P = 0.014$) and in the sector (33.6 ± 8.79 vs. 15.76 ± 8.97, $P < 0.001$). Furthermore, this group significantly reported that noise interferes with work activities [5.2 (4.8–6.7) vs. 1 (0.7–3.1), $P = 0.022$], and complained more about pain or discomfort somewhere on the body during work activities [9.3 (6.9–10.5) vs. 2 (1–3.4), $P = 0.001$; Table 5].

Table 5. Assessment of occupational parameters according to shoulder musculoskeletal symptoms in the last 7 days

Variables	Musculoskeletal symptoms: Shoulders (last 7 days)		*P*
	Yes (*n* = 5)	No (*n* = 25)	
Age (years)	31.6 ± 9.61	29.84 ± 8.54	0.683
Weight (kg)	77.8 ± 16.08	78.36 ± 11.15	0.925
Height (m)	1.74 ± 0.04	1.75 ± 0.06	0.662
BMI (kg/m^2)	25.74 ± 4.74	25.68 ± 3.75	0.977
Working time at the company (months)	33.6 ± 8.79	19.6 ± 11.27	0.014
Working time in the sector (months)	33.6 ± 8.79	15.76 ± 8.97	< 0.001
Difficulties due to little work space (points)	6.7 (2.9–8.9)	1 (0.5–3)	0.042
Demand for speed, even within a schedule (points)	11.4 (6–13)	3.4 (1–11.8)	0.122
Enough time to finish work (points)	11.2 (10.5–11.7)	10 (1.3–12.5)	0.516
Performs other work that is not your role (points)	4.3 (1.2–4.5)	0.9 (0.5–2.4)	0.355
Insufficient number of operators for the function (points)	2.4 (1–2.7)	0.9 (0.6–1.4)	0.085
Managers are safe and effective (points)	11 (10.4–12)	12.3 (8.7–12.7)	0.385
Sufficient lighting for activities in the sector (points)	12.5 (10.8–12.9)	9.7 (1.6–12)	0.096
Uncomfortable temperature for work (points)	11.5 (10.5–13)	9.5 (6.8–11.2)	0.208
Workplace is noisy (points)	9 (7.5–9.5)	6.8 (4.5–10.4)	0.108
Noise interferes with activities	5.2 (4.8–6.7)	1 (0.7–3.1)	0.022
Pain/discomfort during activities (points)	9.3 (6.9–10.5)	2 (1–3.4)	0.001
Work capacity (points)			
Current work capacity	10 (8–10)	10 (10–10)	0.448
Work capacity in relation to physical demands	7.5 (7.4–10)	10 (10–10)	0.188
Work capacity in relation to mental demands	10 (9.7–10)	10 (9.3–10)	0.957

Quantitative data expressed as mean ± standard deviation or median and interquartile range between parenthesis

Operators who had musculoskeletal symptoms in their right hand wrists in the last 12 months had significantly lower weight and height than operators without right hand symptoms (Table 6). Furthermore, operators who presented musculoskeletal symptoms in the right hand reported statistically significantly less time to complete activities [3.7 (1.3–8.5) vs. 11.3 (9.4–12.5), $P = 0.029$]. However, the current work capacity, and in relation to physical and mental demands, did not differ statistically (Table 6).

Table 6. Assessment of occupational parameters according to musculoskeletal problems of the right hand wrists in the last 12 months

Variables	Musculoskeletal symptoms: right hand wrists (last 12 months)		*P*
	Yes (*n* = 5)	No (*n* = 25)	
Age (years)	34 ± 13.11	29.36 ± 7.51	0.324
Weight (kg)	66.8 ± 9.31	80.56 ± 10.96	0.028
Height (meters)	1.71 ± 0.03	1.75 ± 0.06	0.012
BMI (kg/m^2)	23.02 ± 3.75	26.23 ± 3.69	0.161
Working time at the company (months)	25.8 ± 9.65	21.16 ± 12.44	0.446
Working time in the sector (months)	23.6 ± 11.76	17.76 ± 10.94	0.628
Difficulties due to little work space (points)	3.5 (3–3.6)	1 (0.7–2.9)	0.300

Table 6. Assessment of occupational parameters according to musculoskeletal problems of the right hand wrists in the last 12 months (*continued*)

Variables	Musculoskeletal symptoms: right hand wrists (last 12 months)		*P*
	Yes (*n* = 5)	No (*n* = 25)	
Demand for speed, even within a schedule (points)	3.8 (1–11.4)	6 (1.4–12.4)	0.448
Enough time to finish work (points)	3.7 (1.3–8.5)	11.3 (9.4–12.5)	0.029
Performs other work that is not your role (points)	2.3 (0.7–4.3)	0.9 (0.6–4.5)	0.666
Insufficient number of operators for the function (points)	0.8 (0.6–1)	1 (0.7–1.7)	0.706
Managers are safe and effective (points)	12.4 (3.8–13.2)	11.7 (9.5–12.6)	0.829
Sufficient lighting for activities in the sector (points)	3.5 (1.6–10)	11.5 (6.5–12.7)	0.122
Uncomfortable temperature for work (points)	11.5 (9.5–13)	10 (6.5–11.2)	0.208
Workplace is noisy (points)	6.8 (6.5–7)	7.3 (4.5–10.4)	0.666
Noise interferes with activities	3.1 (1.4–5.2)	1.3 (0.7–4.1)	0.385
Pain/discomfort during activities (points)	6.5 (3.4–6.8)	2 (1–6)	0.275
Work capacity (points)			
Current work capacity	10 (10–10)	10 (10–10)	0.872
Work capacity in relation to physical demands	8.7 (7.3–9)	10 (10–10)	0.065
Work capacity in relation to mental demands	9.7 (7.5–10)	10 (10–10)	0.208

Quantitative data expressed as mean ± standard deviation or median and interquartile range between parenthesis

Another location with an important prevalence of musculoskeletal symptoms in the Nordic questionnaire was the wrists in the last 7 days. However, there were no important statistical differences in relation to socio-demographic and occupational health parameters.

Regarding musculoskeletal symptoms in the lower back in the last 7 days, more symptoms were observed in operators who reported difficulties due to limited space in the workplace, the requirement to work faster, that the workplace is noisy and that the noise interferes with activities (Table 7).

Table 7. Assessment of occupational parameters according to musculoskeletal symptoms of the lower back in the last 7 days

Variables	Musculoskeletal symptoms: Lower back (last 7 days)		*P*
	Yes (*n* = 8)	No (*n* = 22)	
Age (years)	29.75 ± 8.38	30.27 ± 8.83	0.909
Weight (kg)	78.88 ± 16.41	78.05 ± 10.07	0.945
Height (meters)	1.76 ± 0.05	1.74 ± 0.06	0.344
BMI (kg/m^2)	25.43 ± 4.95	25.79 ± 3.48	0.696
Working time at the company (months)	25.75 ± 12.24	20.55 ± 11.89	0.500
Working time in the sector (months)	24.75 ± 13.76	16.55 ± 9.38	0.156
Difficulties due to little work space (points)	5.15 (2.3–12.35)	0.9 (0.4–2.5)	0.004
Demand for speed, even within a schedule (points)	12 (10.2–13.15)	2.45 (1–7.6)	0.003
Enough time to finish work (points)	10.85 (9.25–12.7)	6.85 (1.2–12.4)	0.202
Performs other work that is not your role (points)	1.05 (0.55–4.4)	1 (0.7–5)	> 0.999
Insufficient number of operators for the function (points)	0.95 (0.6–4.85)	1 (0.7–1.6)	0.629
Managers are safe and effective (points)	11.5 (8.25–12.65)	12 (9.5–12.6)	0.836
Sufficient lighting for activities in the sector (points)	11.85 (10.35–13)	8.35 (1–12)	0.035
Uncomfortable temperature for work (points)	11 (8.15–13.25)	9.5 (6.2–11.2)	0.142
Workplace is noisy (points)	10.1 (7.5–12.1)	6 (4.4–8.6)	0.008
Noise interferes with activities	3.65 (1.85–6.1)	1 (0.7–4)	0.027
Pain/discomfort during activities	8.2 (6.4–11)	1.75 (0.7–3)	0.001
Work capacity (points)			
Current work capacity	10 (9–10)	10 (10–10)	0.872
Work capacity in relation to physical demands	9.35 (7.45–10)	10 (10–10)	0.298
Work capacity in relation to mental demands	10 (9.85–10)	10 (8–10)	0.597

Quantitative data expressed as mean±standard deviation or median and interquartile range between parenthesis

The need to accelerate the pace of work, increasing the speed of actions that must complete them and the concern about not reaching the requested goal can cause tension in operators. Occupational tensions can be expressed in less satisfaction with work, experiencing a stressful environment, which interact with the individual's physical and mental health, worsening musculoskeletal symptoms.

Lower back in the last 12 months and in the last 7 days were the two issues with the highest prevalence of musculoskeletal symptoms in operators, using the Nordic questionnaire. Operators with lower back symptoms in the last 12 months had a higher discomfort and pain score during work and in relation to the limited space in the workplace (Figure 1).

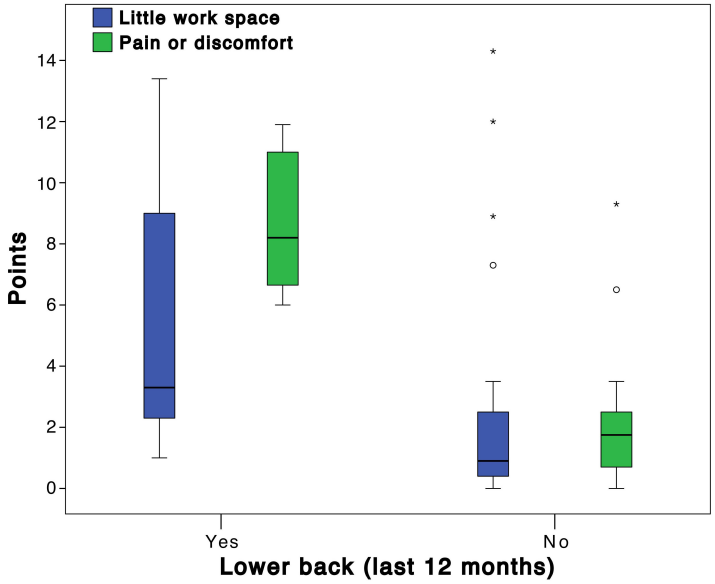

Figure 1. Relationship between pain and discomfort during work and little work space with musculoskeletal symptoms in the lower back in the last 12 months. $P < 0.05$ between groups for both variables

The sizing and spacing of the machinery must be well evaluated, avoiding ergonomic losses [29], considering that the layout has repercussions on the transport of a load and the space implies supporting a certain weight for a prolonged period of time, influencing the level of risk for developing musculoskeletal diseases.

Impact on the occupational health of operators due to pain

By evaluating the prevalence of pain using the Pain Scale in operators, complaints of pain in the right wrist/hand, pain in the lumbar spine, pain in the right ankle/foot were selected. From then on, groups with and without reported pain in these regions were created and scores related to occupational health were compared.

Moderate pain in the wrist of the right hand was related to a feeling of discomfort due to the temperature of the workplace, noise, and pain or discomfort during activities (Figure 2).

Furthermore, operators who reported moderate pain in the lumbar spine had higher pain or discomfort scores during work, had a greater demand for speed in completing activities and also reported that the workplace was noisy (Figure 3).

Operators who complained of moderate pain in both the right and left ankle/foot were those who required greater speed to complete activities (Figure 4).

Assessment of the dimension of the psychological demand of operators

The evaluation of the Karazek questionnaires applied to operators provided information regarding psychological aspects of the work environment. Contradictory requirements were observed, the majority reported that they almost never occur (66.7%). Furthermore, the majority reported that they often have

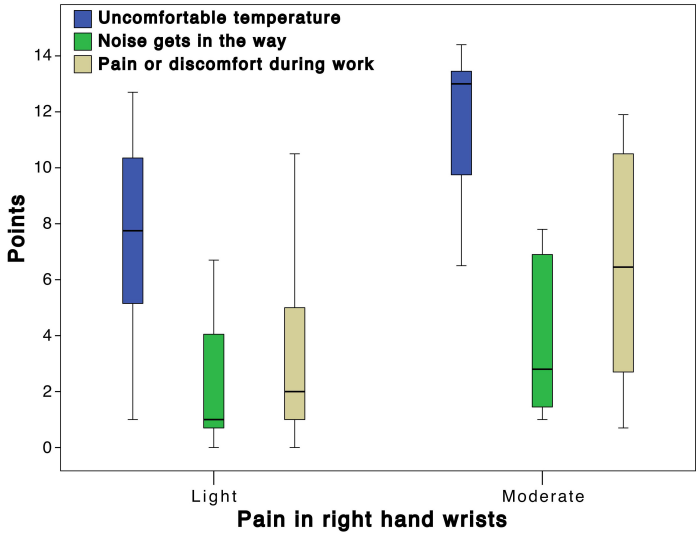

Figure 2. Relationship between complaints of pain in the lumbar spine and the speed required at work and complaints of pain and discomfort during work. *P* < 0.05 between groups with all variables

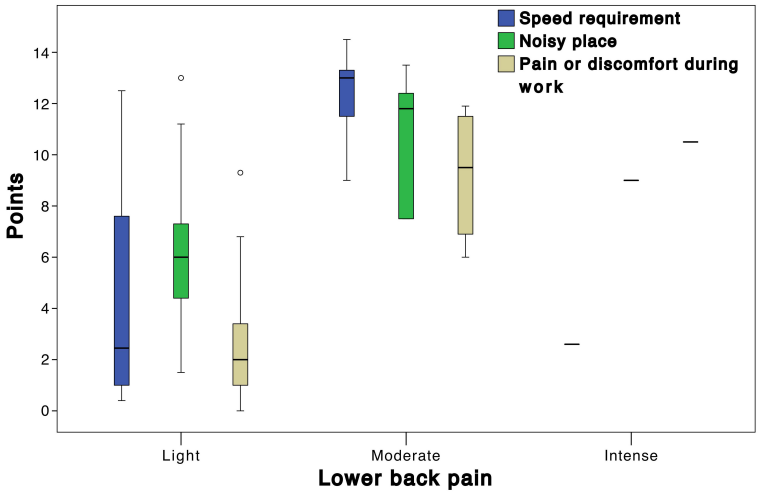

Figure 3. Relationship between complaints of pain in the lumbar spine and the speed required at work, the noisy place and complaints of pain and discomfort during work. *P* < 0.05 between the mild and moderate groups, considering all variables

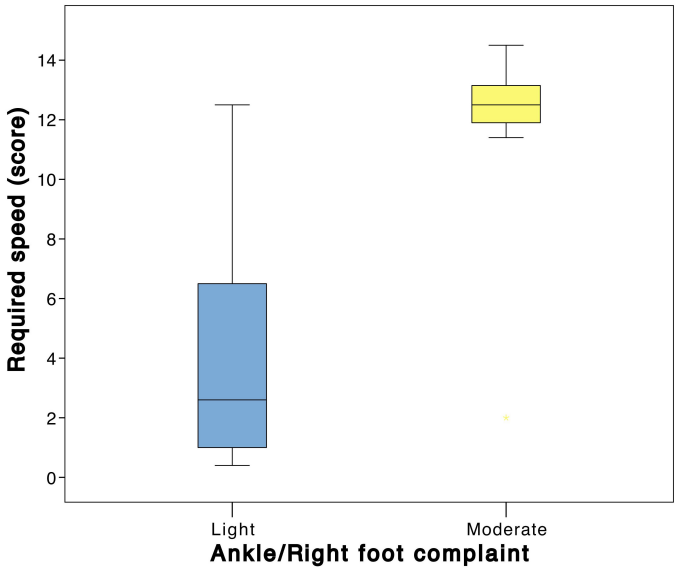

Figure 4. Relationship between complaints of pain in the right and left ankle/foot and greater speed required at work. *P* < 0.05 between groups

enough time at work to perform activities (76.7%), to learn new things (66.7%). On the other hand, most operators reported that the work often requires speed (63%), intensity (47%), requires initiative (66.7%) and is repetitive (80%; Table 8).

Table 8. Karazek questionnaire applied to operators in an automotive industry

Aspects—Karazek questionnaire	Total group (*n* = 30)			
	Never or almost never	Rarely	Sometimes	Often
Need to do tasks quickly	2 (6.7)	3 (10)	6 (20)	19 (63.3)
Need to work intensely	3 (10)	6 (20)	7 (23.3)	14 (46.7)
Work demands a lot	2 (6.7)	5 (16.7)	15 (50)	8 (26.7)
Enough time for tasks	0 (0)	0 (0)	7 (23.3)	23 (76.7)
Working with contradictory demands	20 (66.7)	4 (13.3)	4 (13.3)	2 (6.7)
Possibility to learn new things	1 (3.3)	1 (3.3)	8 (26.7)	20 (66.7)
Work requires specialized knowledge	3 (10)	3 (10)	10 (33.3)	14 (46.7)
Work requires initiatives	2 (6.7)	1 (3.3)	7 (23.3)	20 (66.7)
Work is repetitive	4 (13.3)	0 (0)	2 (6.7)	24 (80)
Choose how to do your work	8 (26.7)	3 (10)	13 (43.3)	6 (20)
Choose what to do at work	17 (56.7)	5 (16.7)	6 (20)	2 (6.7)
Aspects—Karazek questionnaire	**Totally disagree**	**I disagree more than I agree**	**I agree more than I disagree**	**I totally agree**
Calm environment at work	0 (0)	3 (10)	10 (33.3)	17 (56.7)
Good relations between other operators	0 (0)	0 (0)	2 (6.7)	28 (93.3)
Coworkers support each other	0 (0)	0 (0)	2 (6.7)	28 (93.3)
Understanding from colleagues	1 (3.3)	0 (0)	6 (20)	23 (76.7)
Good relationship with the head of service	0 (0)	1 (3.3)	1 (3.3)	28 (93.3)
I like working with my colleagues	0 (0)	0 (0)	1 (3.3)	29 (96.7)

Categorical data as absolute count and percentages between parenthesis

The occurrence of a change in production demand, machine breakdown or lack of material requires greater speed from the operator to meet the target. The supply policy established in the company called Just In Time (JIT) is a consequence of the methodology of working with the lean production system, as this reduces inventories, both at customers and suppliers. Reducing inventories between suppliers and customers, as well as reducing deadlines in production processes between two plants, can significantly contribute to increased tension in the production environment.

Regarding relationships with co-workers, it was observed that the sector has excellent relationships during activities, both with colleagues and management. However, there were differences in reports regarding the calm work environment, (16.7%) did not agree that the work environment was calm.

Impact of psychological aspects of the work environment on the occupational health of operators

The assessment of the physiological imbalance of the human organism, both in the musculoskeletal system and in the cognitive system, has been evaluated by tools that use a questionnaire with personal evaluation criteria demonstrated by the perception of the workers themselves or observations. Regarding psychological aspects of the work environment assessed through the application of the Karazek questionnaire, it was observed that younger operators recognized that there was enough time for tasks. Operators who had been with the company longer reported that there was rarely work with contradictory demands (Figure 5).

Unlike this result, Silva [30], in his study revealed that the presence of stress was mentioned by 96% of workers, pressure supervision by 74%, intense work pace by 70% and fear of losing the job due to 72% of respondents. According to the author of the aforementioned research, the results allow us to affirm that the

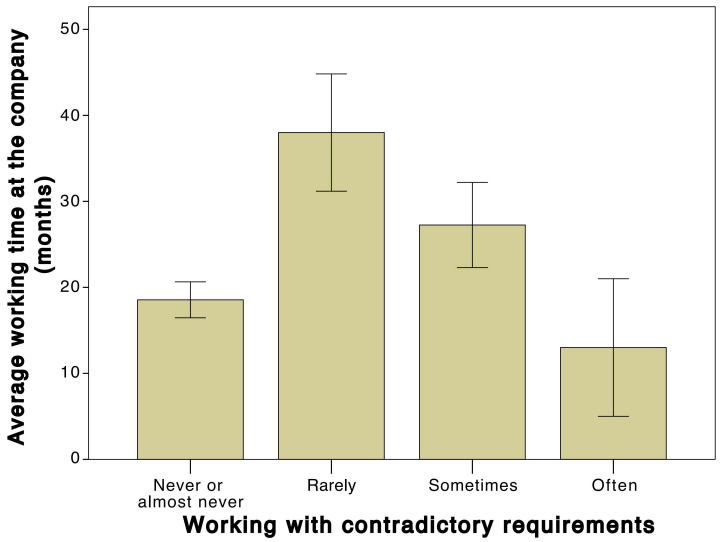

Figure 5. Relationship with recognition of work with contradictory demands and time working in the company. $P < 0.005$, between the rarely vs. other groups

work process studied presents risks that interfere with the health and illness of workers, concluding that in the automobile industry sector, the work and social reality is complex and contradictory.

In relation to how to do the work, a disagreement was observed in relation to age, where the average age was higher both in recognizing rarely and frequently in relation to choosing how to do the work (Figure 6). Other Karazek questions focused on positive aspects regarding the relationship between professionals in the workplace, did not have statistical comparisons, because as previously shown, the vast majority (from 83%) considered they had good relationships and understanding among co-workers and managers.

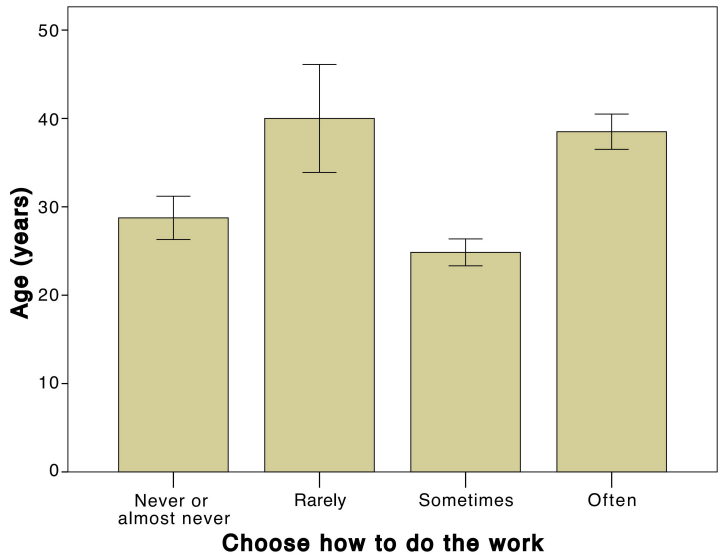

Figure 6. Relationship between choosing how to do the work and the age of the operators. $P < 0.005$, between rarely vs. Never or almost never and vs. Sometimes; between Often vs. Sometimes and vs. Never or almost never

It has been pointed out by previous researchers that factors that influenced the performance of a group of workers were participation in work-related decisions, self-regulation and worker autonomy. Job satisfaction is greatest when a person feels they have control over the way a particular task is accomplished. Marqueze and Moreno [31], states that the process of job satisfaction results from the complex and dynamic interaction of general living conditions, work relationships, the work process and the control that workers themselves have over their living and working conditions.

This indicator, in terms of worker satisfaction, is one of the areas intensely studied in human resources and management. However, there was little information available about how ergonomics and the production environment affect job satisfaction. Still, according to a recent study, it was found that ergonomics plays the most important role in worker satisfaction [32]. Combined with worker satisfaction with the ergonomic aspects of the work environment, an improvement in the level of performance indicators is jointly expected. Job satisfaction can therefore be a source of health, and dissatisfaction can cause harm to physical, mental and social health, causing problems for the organization and the work environment.

It was observed that the lower the work capacity due to mental demands, the more related to the issue of choosing how to do the work. Furthermore, a greater demand for speed and less ability to work under mental demands were observed in operators who reported that they frequently choose what to do at work (Figure 7).

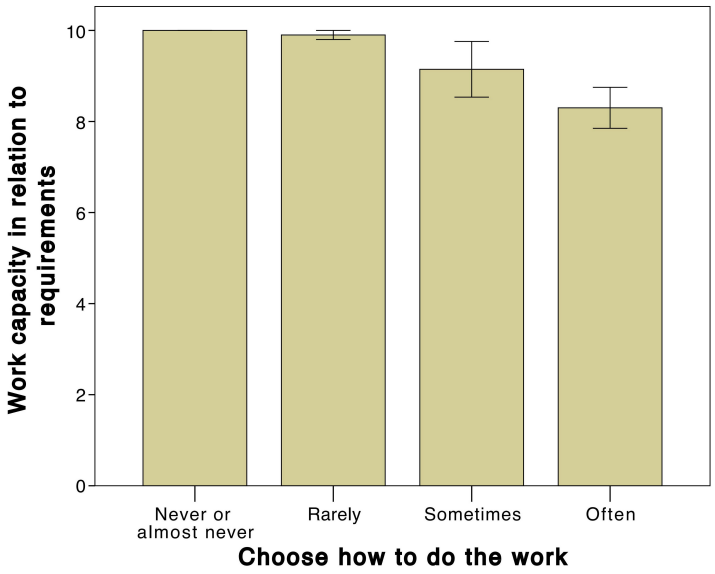

Figure 7. Relationship between choosing how to do work and work capacity in relation to mental demands. $P < 0.005$, between frequently and the other groups

Finally, in the open interview, the most cited EDIs are represented in Table 9. The sum of the weights relative to each item gives rise to the importance ranking of the items, which served as a guide for the preparation of a questionnaire filled out by the entire population. The EDIs were listed in order of priorities pointed out by the interviewees themselves, as shown in Table 9, with the weight of importance of the elements mentioned with the greatest weight of importance being the heat of the work environment and the difficulty of positioning the part on the rack (packaging).

Table 9. EDIs mentioned in the open interview by the operators

EDIs cited by operators	OM	Weight	Intensity
Heat in the work environment	1	1	4.2
Difficulties in placing parts on racks	2	0.5	5.1
The GP 12 RM DX SX stays away from the treadmill	3	0.33	11.2
Space to carry out work	4	0.25	12.5

OM: order of mention

The intensity varies on a scale from 0 to 15, that is, 0—dissatisfied to 15—satisfied. Degree of satisfaction was used for the constructs environment and operating mode. In the environment construct, the temperature and noise of the environment present a low level of satisfaction among interviewees. Although the company has an air conditioning system, it was designed for a layout from another company that had given

up on installing itself in the Polo. There is a difference between what was designed and what was installed, which makes the system inefficient.

Discussion

From the literature review, it was found that the automotive sector is essential for the country's economic development, with modern industries that invest in technological innovations and control of the activities of the production process. Despite all the investment in improvement processes, some studies on absenteeism in automotive companies emphasized that its main reasons came from reports of musculoskeletal symptoms. Given this scenario, the present work proposed to evaluate the work activity of operators in this industrial segment, based on the ergonomic analysis of the workplace on an assembly line.

From the operators' point of view, the heat in the work environment and the difficulties encountered in the part inspection operation and in placing parts on the racks are the main aspects of increasing the workload. In this research, the main musculoskeletal symptoms that caused absence from work were: neck (3.3%), shoulders (3.3%), upper (6.7%), lower back (6.7%), hips/thighs (6.7%), and ankle/foot (6.7%). In this sense, the importance of business follow-up in monitoring and monitoring the health of workers is highlighted, as symptoms could be an indicator that allows preventive action before the disease develops.

Without, however, neglecting the importance of engineering measures and robotization of operations, which certainly contribute to the reduction/elimination of ergonomic risks and increased productivity, this work identified the need to carry out improvement measures in machines and robots with the aim of eliminating quality problems that require technical actions involving biomechanical risk due to the lack of adequate parameterization of the robot, a situation which had an impact on the symptoms reported by the operators.

It was identified that the analyzed work environment generates satisfaction on the part of all employees, including management, which is of great value from the organizational point of view of the task. It is believed that the inclusion and listening of operators in the process of continuous improvement of the production process adds to this achievement of the work environment.

In addition to the good organizational climate, there are constant executions of improvements related to the workplace—positioning of components in the worker's Golden zone, health educational campaigns, Kaizen project campaigns related to Ergonomics—with the company adopting behaviors based on decisions made by an Ergonomics committee formed by the Board, Management, Security Sector and Ergonomics Specialist.

Furthermore, the company uses alternative strategies to reduce exposure to biomechanical risk factors, such as job rotation, which was, at least from the researcher's perspective, the organizational decision adopted with the greatest positive impact, as it could in the absence of this conduct, the level of complaints could be greater given the classification of risks detected in two main activities of the line. However, this organizational strategy must be monitored, standardized and followed appropriately to be more efficient.

Finally, it is concluded that ergonomic action must involve all levels of employees: management, management and operators to have adequate process and/or project development, improving working conditions. As management defines operations strategies, processes are planned, organized, led and controlled, aiming at the company's functioning, mediating material and financial resources for the development of actions.

By implementing a comfortable and healthy environment, there is the possibility of minimizing risks and improving health conditions. This topic must be positioned among the company's operations strategies in order to carry out actions to resolve symptoms and balance the relationship between health and productivity.

For future work, it is suggested to delve deeper into musculoskeletal complaints since the development of such disorders can be multicausal, and it is important to analyze the risk factors involved directly or indirectly. Identify local physiological dysfunctions through infrared thermography in order to prove the

real impact on the development of activities on the worker. Authors have already identified in some studies that point to thermography as an important complementary method in the evaluation of musculoskeletal disorders and guarantee that it is possible to use thermography in analyzes of work activities with the aim of preventing disorders. Thus, infrared digital thermography is an efficient method that has broad potential for ergonomics and usability, and can be used for physical and cognitive assessment.

It is also suggested to demonstrate the gains, with the intervention of ergonomists, in the project, ensuring the participation of operators in simulations of future activity. According to Pinto et al. [33], the role of the ergonomist in the design must go beyond predicting in detail the activity that will be carried out in the future, but also evaluating the extent to which the choices will allow the elaboration of operating modes compatible with the chosen criteria, in terms of health, productive effectiveness, personal development and collective work.

This present study had limitations, including small sample size. However, we believe the data collected provides valuable insights despite the smaller sample size. Further research with a larger sample size would be beneficial to confirm these findings.

Abbreviations

EDIs: ergonomic demand items

Declarations

Author contributions

RFAdC: Investigation, Data analysis, Writing—original draft, Writing—review & editing. MAM: Conceptualization, Investigation, Writing—review & editing. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

The research began, exclusively, after its approval by the Research Ethics Committee of the Federal University of Pernambuco, following the guidelines of Resolution No. 466/2012, being approved on 09/05/2019, by opinion no. 3,555,847. All research participants were guaranteed anonymity, with the signing of a Free and Informed Consent Form, explaining in detail the objective of the research.

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Not applicable.

Availability of data and materials

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

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