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Navigating Occupational Hazards: Musculoskeletal Disorders Among Slaughterhouse Workers in Brazil

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Abstract: (1) Background: The meatpacking industry in Brazil is vital for economic growth. It poses significant occupational health risks, particularly Work-Related Musculoskeletal Disorders (WMSDs). The present study analyzes the profile of slaughterhouse workers based on the governmental notification database. (2) Methods: The socio-demographic dataset (n = 820) was filled with worker data, and health profiles reported Repetitive Strain Injuries (RSI) and WMSDs from 2007 to 2019, available online by the Brazilian Health Service. The dataset was analyzed to identify patterns of injuries and contributing factors. Descriptive statistics outlined worker characteristics, while Analysis of Variance (ANOVA) explored associations between variables. (3) Results: The results revealed that 51.34% of workers were male, with most aged 30–45. Repetitive movements were reported by 89.63% of respondents, while 78.90% worked shifts exceeding six hours. Soft tissue disorders were the most prevalent diagnosis (40.97%). The majority (53.17%) experienced temporary disabilities, and 5.73% had permanent impairments. Key risk factors included inadequate breaks, stressful environments, and limited ergonomic adaptations. This study highlights the critical need for preventative measures, such as ergonomic interventions, adequate rest breaks, and employee education, to mitigate WMSDs. Future research should include ergonomic evaluations and consider broader organizational variables to enhance slaughterhouse occupational health and safety. Addressing these challenges is essential for improving worker welfare and maintaining industry productivity.

Keywords: agribusiness; musculoskeletal pain; occupational health; worker's welfare

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1. Introduction

Work-Related Musculoskeletal Disorders (WMSDs) represent a significant global occupational health issue characterized by injuries or disorders of muscles, nerves, tendons, joints, cartilage, and spinal disks resulting from workplace conditions. Common types include tendonitis, tenosynovitis, carpal tunnel syndrome, and soft tissue disorders. These conditions are often associated with repetitive motions, awkward postures, prolonged exertion, and exposure to vibrations or forceful tasks. WMSDs significantly impair worker productivity, well-being, and quality of life, leading to considerable economic and healthcare burdens [1–3].

Findings from the Global Burden of Disease (GBD) study reveal a significant global health challenge posed by musculoskeletal conditions, affecting approximately 1.70 billion people worldwide [4]. High-income countries bear the highest absolute burden, with nearly 450 million cases, followed closely by the Western Pacific Region (nearly 420 million) and Southeast Asia Region (approximately 360 million).

The advancement of agribusiness in Brazil has been primarily driven by global demand for agricultural commodities, including soybeans, corn, cotton, and meat. This production model has been characterized by the intensive use of technology and chemical inputs and the exploitation of cheap labor, especially in agricultural frontier regions [5]. Brazil is one of the leading producers and exporters of meat globally; according to data from the Brazilian Association of Meat Packers, the country exported around 2.53 million tons of beef, representing revenue of more than USD 10 billion [6]. The country is also a major player in poultry and pork production [7]. The importance of meat production for the Brazilian economy is indisputable, as the sector generates employment and income in several regions. Additionally, meat exports represent a significant component of the nation's foreign exchange earnings, strengthening its trade balance [8].

Furthermore, labor in the meatpacking sector has also been criticized due to precarious working conditions and worker health risks. Therefore, there must be public policies that aim to guarantee sustainable and fair production, that respect both the environment and workers' rights, and that there is transparency and responsibility in the dissemination of statistics about the sector to reflect not only its economic importance but also its social and environmental impacts [9].

As noted by Johnson and Lee [10], the intensification of labor has been linked to increased rates of occupational accidents and illnesses. Monotonous and repetitive tasks, even within modern facilities, are recognized as substantial factors contributing to worker accidents and burnout [11]. Such demanding and potentially limitless working conditions represent a form of worker exploitation and may reflect broader structural contradictions inherent in work organization. Cook et al. [12] suggest that as the meatpacking industry grows, the number of work-related accidents and illnesses increases due to the intensification of working conditions. Repetitive tasks, poor hygiene, and lack of protective equipment are major contributors to worker burnout and musculoskeletal injuries.

Reports of WMSD (Work-Related Musculoskeletal Disorders) in meatpacking workers are relatively common [13–16]. WMSDs are prevalent among slaughterhouse workers, primarily due to factors such as repetitive movements, awkward postures, and the lack of personal protective equipment [12]. These disorders affect the musculoskeletal system, including muscles, tendons, ligaments, joints, and nerves [17]. The nature of slaughterhouse tasks—such as cutting and boning meat, packaging products, and cleaning equipment—often involves monotonous and repetitive motions, contributing to the high incidence of WMSDs [18,19]. Additionally, slaughterhouse environmental conditions, including exposure to cold temperatures, humidity, and chemicals, further exacerbate the risk of these occupational injuries [20].

According to Sundstrup et al. [21], the working environment in slaughterhouses can be unfavorable to workers' health due to poor working conditions, which include repetitive and monotonous work, pressure for productivity, and unfavorable ergonomic conditions. These factors contribute significantly to the emergence of occupational diseases, including WMSDs.

A characteristic factor of this industry is the production process, which requires workers to stand for long hours, alternating repetitive movements, and follow the rhythm and speed imposed by the production line, as determined by the company. This can lead to illness [22]. Although it features new and modern configurations, it is observed that work

intensifies due to the increased speed of machines, as monitored by production supervisors [23]. During their task on the production line, workers perform consistent, strong, and repetitive movements to debone a piece of meat, for example, while also working with sharp equipment, such as saws, knives, and other sharp tools [24]. The intensive use of slaughterhouse machinery significantly contributes to work intensification [25]. This increase in intensity is characteristic of the capitalist mode of production, where the increased speed at which workers perform their tasks intensifies the production volume. Roughly, slaughterhouse workers perform up to 90 movements per minute, with around 30 being the most acceptable, and are exposed to cold, noise, inadequate postures, humidity, excessive load displacement, exposure to ammonia, pressure vessels, and exhausting journeys [18].

Modern conditions in meat processing plants frequently fail to meet standards of health and human dignity [26]. Constant exhaustion, injuries, fractures, and contusions, which can even lead to the loss of limbs due to the use of work equipment and tools, are the day-to-day experience for those who work in the meatpacking sector in Brazil. Marra [22] reports that by using sharp instruments, such as saws, knives, and straighteners to sharpen knives, workers operate in a workplace where the risk of cuts is a reality. Long working hours, without the necessary rest, and the series of repetitive movements that are performed during the working day favor the appearance of cases of WMSDs, as well as psychological illnesses, in addition to many other cases of diseases [27].

Bonetti et al. [28] suggest that challenges in collecting reliable data on occupational morbidity and mortality persist across industries, particularly in high-risk sectors such as meat processing. Continuous efforts are necessary to improve reporting accuracy and address underreporting. Additionally, working conditions in slaughterhouses often pose significant health risks to workers, including exposure to cold temperatures, humidity, and chemicals used for cleaning and food preservation [11,29]. It is essential to adopt ergonomic and safety measures at work, such as training in proper postures, rotating tasks, regular rest breaks, and personal protective equipment, to prevent the occurrence of WMSD in meatpacking workers. Ensuring appropriate working conditions, including optimal thermal environments, proper lighting, and access to medical and psychological support, is essential for maintaining worker well-being and productivity [29].

The growth of WMSD throughout the intense industrialization process helps debunk the myth that the world is jobless due to the automation of factories and services, as people are becoming ill from overwork [30]. Today, compared to the end of the 19th century, much fewer working hours are spent producing the same type and quantity of products. Numerous products were made over a century ago with higher expenses and less labor and workload [31]. The ILO (International Labor Organization) conducted a detailed analysis of the profiles of workers in slaughterhouses in Brazil [32] based on field research in seven Brazilian states and interviews with workers and employers in the sector. The results of this report indicate that workers in meat processing plants in Brazil are predominantly men (approximately 70% of the workforce), aged between 18 and 39, and many are migrants from impoverished regions. The report also found that most workers in meatpacking plants have little education and receive low wages. The report also highlighted the poor working conditions faced by workers in meatpacking plants, including exposure to chemicals and the risks of injuries associated with repetitive work.

The present study aimed to describe the socio-demographic, work, and health profile of workers who reported complaints of Repetitive Strain Injuries (RSI)/Work-Related Musculoskeletal Disorders (WMSDs) through the Notifiable Diseases Information System (SINAN) from 2007 to 2019.

2. Materials and Methods

The present study is an exploratory investigation utilizing quantitative data. This study analyzed data from a Brazilian public health notification system (2007–2019) regarding slaughterhouse workers (beef, swine, and poultry) who were on sick leave due to work-related musculoskeletal disorders (WMSDs). The database was obtained from confirmed records of work-related musculoskeletal disorders, an open-source database available on the Notifiable Diseases Information System (SINAN) platform [33] in digital form (Supplementary Materials). The confidentiality of patient data is guaranteed, as it is impossible to identify the patient in this database using the criteria outlined in the General Law for the Protection of Personal Data [34].

The analyzed database included all regions of Brazil, some of which have vulnerabilities concerning housing and education.

Inclusion criteria included employment in high-risk occupations classified under the Brazilian Classification of Occupations (BCO) #8485 (e.g., slaughterers, butchers, and deboners) and a confirmed work-related musculoskeletal disorder (WMSD) diagnosis, as documented in the International Classification of Diseases (ICD-10) codes and supported by symptoms available in the SINAN database. According to the Brazilian Classification of Occupations (CBO), the chosen professions were from the slaughtering and meat processing industry. The sample size (N = 820) spans the period from 2007 to 2019, and 10 independent variables were considered (Table 1).

Table 1. Independent variables are considered for statistical associations.

Independent Variable	Description
Sex	Male, female.
Age	Less than or equal to 40 years old and over 40 years old.
Level of education	Incomplete primary education and lower, complete primary education, and over.
The job is outsourced.	Yes or No.
Signs and symptoms, and other clinical reports.	Changes in sensitivity, decreased muscle strength, movement limitations, the presence of pain, and inability to perform everyday tasks.
Company organizational measures	Awards for production, repetitive movements, stressful environment, breaks, and working hours longer than six.
Diagnosis.	Disease (according to the International Classification of Diseases—ICD-10).
Sick leave.	Less than or equal to 15 days, over 15 days, no sick leave time.
Evolution of the case.	Cured; non-confirmed cure; any disability (temporary, partial, or total permanent disability).
Issuance of Work Accident Report (CAT).	Yes or No.

The Consolidation of Brazilian Labor Laws (CLT) is the contractual agreement between the worker and the company, legally supported by Brazilian law. Work Accident Communication (CAT) is the primary source of data collection on work accidents. However, it is precarious in Brazil due to its dependence on company notification. Furthermore, the absence of CAT in legal processes that grant benefits proves the existence of underreporting. It highlights the fragility of the data collection system, which may underestimate the actual incidence of work-related accidents in the country [34].

A descriptive statistical analysis was performed on the data using MATLAB (2021; version R2021b), followed by an Analysis of Variance (ANOVA) to evaluate the

impact of the different variables studied on the observed WMSD. The null hypothesis assumed that there were no significant differences among the group means. In contrast, the alternative hypothesis posited that at least one group's mean differed significantly from the others (p-value ≤ 0.05). ANOVA is well-suited for identifying significant group-level differences, as presented in our current analysis, which explores associations. We also calculated the ηp^2, a measure of effect size used in ANOVA. This metric represents the proportion of variance in the dependent variable explained by the independent variable. It ranges from 0 to 1, where 0 represents no effect, and 1 represents a high effect. The in-between values range from the variance in the dataset.

This statistical approach enhances the validity of our findings and contributes to a more comprehensive understanding of the nuances involved in identifying WMSD in slaughterhouse workers. For the statistical analyses, some data were grouped, as shown in Table 1.

3. Results

Table 2 presents the social–demographic results and the working characteristics of the subjects without the grouped data. The sample presents 48.66% (399) female records and 51.34% (421) male records. The basic descriptive statistics for age are presented in Table 2. The table shows an age range of 18 to 64 years, characterizing an activity involving professionals of different ages. By analyzing the data distribution described in the table, it is estimated that 75% of patients are between 30 and 45 years old (third quartile). The data present a mean of 37.73 and a median of 38 years.

Table 2. Social–demographic and working data from subject records.

General Variables	Specific Variables	N	%
Sex	Male	421	51.34
	Female	399	48.60
Age (years)	Less than or equal to 40	395	60.96
	More than 40	253	39.04
Level of education	Illiterate	6	0.73
	Slightly literate	69	8.41
	Incomplete or complete primary education	50	6.10
	Complete primary education	138	16.7
	Incomplete or complete secondary education	86	10.49
	Complete secondary education	86	10.49
	Incomplete or complete higher education	174	21.22
	Complete higher education	10	1.22
	Unknown	3	0.36
The situation in the labor market	Registered employee	736	89.76
	Unregistered employee or temporary worker	6	0.73
	Self-employed/own account	6	0.73
	Registered employee	3	0.36
	Retired	2	0.73
	Unemployed/Temporary worker	8	0.97
	Cooperative-affiliated worker	2	0.73
	Unknown	43	5.26

Table 2. *Cont.*

General Variables	Specific Variables	N	%
Working time in the last company	Between 1 and 7 months	66	8.04
	Between 8 and 15 months	11	1.35
	Between 16 and 30 months	208	25.36
	Between 31 and 45 months	167	20.37
	Between 46 and 60 months	253	30.85
	Over 50 months	104	12.68
	Unknown	11	1.35
Working characteristics (according to the company's organizational measures)	Awards for production	136	16.58
	Repetitive movements	735	89.63
	Stressful environment	460	56.09
	Existence of breaks	310	37.80
	Working hours longer than six hours.	647	78.90
Days away from work (sick leave)	From 1 to 15 days	361	44.02
	More than 15 days	459	55.97
CAT release	Yes	270	32.93
	No	335	40.85
	It does not apply	42	5.12
	Unknown (or uninformed)	173	21.10

Regarding the education parameter, it was noted that the majority of the analyzed sample (174 people (21.22%)) had only completed secondary education, with only 10 (1.22%) completing higher education, and only 3 (0.36%) individuals were able to complete higher education. Considering that 137 people (16.72%) ignored this issue, it can be inferred that 496 people did not complete their education. From this population, the data in Table 2 show that six individuals were illiterate, 69 had incomplete basic education (first to fourth primary school year), and 50 completed basic education but did not enter elementary school. Another large portion of the sample, approximately 138 people, reported having incomplete secondary education (fifth to sixth year), accounting for 16.7% of the total. Furthermore, regarding individuals who completed primary education and those who entered secondary education but did not finish it, 86 people (10.49%) were reported in both cases (Table 2).

Regarding the work status of these individuals, the data collected (Table 2) indicate that the majority, approximately 89.76% (736), held a working contract, while only 0.73% (6) performed functions without being registered in the professional service. Furthermore, other situations were found during the analysis, with 0.73% (6) of all those analyzed performing their functions autonomously; 0.24% (2) were statutory public servants; 0.12% (1) were civil servants with a contract under CLT; 0.73% (2) were retired; 0.12% (1) were unemployed; 0.85% (7) were in temporary jobs; 0.73% (2) were cooperative members, and another 0.73% (2) were independent workers. None was detected as the employer, and 5.26% (43) were reported as unknown.

The working time in the last company of the subjects (Table 2) showed that 8.04% (66 workers) had worked between one and seven months, while 1.35% (11 workers) had worked their duties for eight to fifteen months. A portion of 25.36% (208 workers) reported having between 16 and 30 months of service, while 20.37% (167 workers) reported having between 31 and 45 months of service. It was also possible to identify that 30.85% of the sample (253 workers) had worked between 46 and 60 months. A rate of 12.68% (104 workers) had been working for more than 50 months. It is essential to highlight that 1.35% of the investigated sample (11 workers) chose not to report this question.

It was possible to identify that 361 workers (44.02%) had a period of sick leave only between 1 and 15 days. For absences lasting more than 15 days, the sample was 459 individuals, representing a percentage of 55.97%. Regarding policies to encourage production and breaks during the working day, 136 workers (16.58%) reported receiving bonuses for production, and 310 (37.80%) reported having breaks during the working day (Table 2). Regarding the company's organizational measures, 735 workers (89.63%) stated that their activities require repetitive movements. Furthermore, 460 workers (56.09%) reported stressful work environments, and 647 (78.90%) reported working more than six hours daily.

Table 3 presents the diagnostic assessments, treatments, and documented symptoms among those on sick leave, aligned with the International Classification of Diseases (ICD-10).

Table 3. Clinical diagnosis according to the International Classification of Diseases (ICD-10), treatments performed, and symptoms.

International Classification of Diseases (ICD)	*n*	%
Soft tissue disorders related to the use, excessive work, and pressure (M70 through M79).	336	40.97
Synovitis and tenosynovitis (M65)	124	15.12
Dorsalgya (M54)	95	11.58
Mononeuropathies of the upper limbs (G56)	66	8.05
Other disorders affecting the intervertebral disks (M51).	28	3.41
Other classifications of less than five occurrences (M25, M53, X50, S83, M17, M18)	87	10.63
Occupational exposure to risk factors (Z57)	84	10.24

Considering 820 workers, 336 (40.97%) presented soft tissue disorders (M70 through M79) (Table 3). A total of 124 individuals presented with this pathology, specifically synovitis and tenosynovitis, corresponding to 15.12% of the sample. A total of 95 workers (11.58%) were affected by back pain. It was also possible to identify that 10.24% of workers (95) suffered occupational exposure to risk factors without clear identification. Some 66 workers (8.05%) had mononeuropathy of the upper limbs. Concerning other enthesopathies, 46 workers were represented (5.61%). We identified 87 workers (10.63%) who were classified in different categories with fewer than five occurrences.

Regarding the treatment regimen, 720 patients (87.80%) received outpatient treatment, and only 34 (4.27%) received hospital treatment. Approximately 65 individuals disregarded this parameter, accounting for 7.93% of the sample. The evolution of the clinical condition of the workers is shown in Table 4. It was found that only 32 of them (3.96%) claimed to have achieved a cure, while 89 (10.85%) had an unconfirmed cure. However, Table 4 reveals that the majority of workers, that is, 436 of them (53.17%), had temporary disabilities, while 47 (5.73%) had partial permanent disabilities, and four workers (0.49%) had total permanent disabilities. No information was available for 212 workers (25.80%).

Table 4. Evolution of the disease during the activities without the grouped data.

Evolution of the Disease	N	%
Cure	32	3.96
Non-confirmed cure	89	10.85
Temporary disability	436	53.17
Partial permanent disability	47	5.73
Total permanent disability	4	0.49
Unknown	212	25.80

The statistical analysis investigated associations between socio-demographic, occupational, and other factors and specific outcomes relevant to Work-Related Musculoskeletal

Disorders (WMSDs). Independent variables included Sex, Age, Education Level, Work Outsourcing, Presence of Pain, and Incapacity to perform everyday tasks. The factors were Organizational Measures (Work Pauses, Stressful Environment, Working Hours), Diagnosis (ICD classification), and Clinical Outcomes (Incapacity to Perform Everyday Tasks, Sick Leave Duration). Table 5 presents the ANOVA results, highlighting statistically significant associations (p-value ≤ 0.05) between selected variables and the outcomes. Effect size (ηp^2) was computed to evaluate the strength of these associations, with interpretations as small ($\eta p^2 \approx 0.01$), moderate ($\eta p^2 \approx 0.50$), or large ($\eta p^2 \geq 0.51$). The results showed significant associations between sick leave, age, working time, and ICD (p-value ≤ 0.05). The remaining variables did not show an association (p-value > 0.05). The ηp^2 value indicates the proportion of variance in the outcome attributable to the tested factor. For instance, only 1% of the variance in pauses during work is explained by whether the worker is male or female. The remaining (99%) is due to other factors or randomness.

Table 5. The associations found between the studied variables, with the corresponding p-value, ηp^2 value, and the effect size.

Independent Variables	Factor	p-Value	ηp^2 Value	Effect Size
Sex (F)	Pauses during work	>0.05	0.01	small
	Stressful environment	>0.05	0.02	small
	Working more than 6 h/day	0.009	0.01	small
	Inability to perform everyday tasks	0.002	0.50	moderate
Age (>40)	Inability to perform everyday tasks	0.002	0.50	moderate
	Sick leave (time)	0.023	0.60	large
Education (complete primary education)	Outsourced work	>0.05	0.47	moderate
	Pauses during work	>0.05	0.06	small
	Repetitive movements	>0.05	0.03	small
	Stressful environment	>0.05	0.04	small
Presence of pain	Movements limitations	>0.05	0.30	moderate
	Inability to perform everyday tasks	>0.05	0.06	small
	Pauses during work	>0.05	0.05	small
	Stressful environment	>0.05	0.02	small
Inability to perform everyday tasks	Presence of pain	>0.05	0.05	small
	Stressful environment	>0.05	0.03	small
	ICD for soft tissue disorders	0.002	0.40	moderate

The analysis indicated several critical associations relevant to slaughterhouse workers. Female workers exhibited a moderate association with increased incapacity in everyday tasks, while workers over 40 showed a moderate association with increased incapacity and a high effect from longer sick leave durations. Additionally, lower education levels (primary education) were moderately associated with outsourced employment. The presence of pain showed a moderate correlation with movement limitations. Finally, the inability to perform everyday tasks was significantly correlated with diagnoses of soft tissue disorders, highlighting their considerable impact on worker functionality and underscoring the need for targeted ergonomic interventions and workplace policy enhancements.

4. Discussion

Managing and exploiting labor power is a fundamental contradiction inherent to the capitalist production system [35]. In pursuing mass production, businesses often employ workers at low wages to maximize profitability. While most cattle slaughter products cater to domestic consumption, government statistics on the meat industry primarily focus on export data. Such a scenario reflects Brazil's significant role in the global meat market

as one of the top producers and exporters [36]. Studies highlight the high prevalence of musculoskeletal injuries among slaughterhouse workers [29].

To carry out work, employees use the movements of their upper and lower limbs in most production process activities, which increases the incidence of occupational diseases [37]. It is worth emphasizing that most tasks carried out in slaughterhouses are classified as monotonous, repetitive, and physically demanding, which can lead to problems related to worker safety, comfort, and health [38]. Some studies used the Occupational Repetitive Actions (OCRA) checklist and found that the majority of tasks in slaughterhouses represented high ergonomic risk (56%) [28] and moderate risk (77% and 63%, respectively) [39,40].

We analyzed data from 820 slaughterhouse workers. We found that 51.34% of workers were male and 48.60% female. Both men and women are at risk of developing WMSD in slaughterhouses. In a study of slaughterhouses in Brazil [41], it was found that women predominantly worked in meatpacking plants. Moreover, a study recognized that in slaughterhouses, the OR of women feeling bodily discomfort was higher than that of men [42]. According to Overstreet et al. [43], musculoskeletal conditions are highly prevalent and impact females more frequently and more severely than males.

In the associations, we found that females were more vulnerable to breaks during work, experiencing stress, working more than six hours per day, and feeling incapable of completing everyday tasks. Long working hours without adequate pauses can become a risk factor for musculoskeletal disease [44]. Occupational stress can cause changes in nerves, hormones, and blood pressure, leading to increased musculoskeletal co-activation, thereby increasing the load on the musculoskeletal system and potentially inducing or aggravating musculoskeletal disorders (MSDs) [45]. In a systematic review study by Biswas et al. [46], women were at a higher risk of injury due to physical demands and repetitive tasks, and the relationship between repetitive tasks and absence was stronger among women.

Most of the workers in the present study were 40 years old or younger (60.96%). In another study [35], 44.00% of the analyzed population was between 18 and 25 years old, and less than 40.00% were over 40. The research included 925 workers from three poultry slaughterhouses, 575 women, and 350 men. A previous study found associations between age, inability to perform everyday tasks, and sick leave. A review study by Okunribido et al. [47] suggests that older workers are more susceptible to MSDs than young workers. However, for the authors, the propensity for injury among older workers depends more on the difference between work demands and their physical capacity to perform their jobs relative to their age. On the same path, Ducas et al. [48] suggest that efforts to reduce physical strain through work optimization should focus on matching task requirements to workers' physical abilities and addressing environmental factors rather than targeting interventions based on age categories. MSDs are typically associated with pain, limited mobility, and reduced dexterity, leading to early retirement from work and a reduced ability to participate fully in society [49].

The workers most affected in slaughterhouses are those who perform activities that require repetitive movements, inadequate postures, and intense physical effort, such as meat cutters, boners, packers, and machine operators. Damages to workers' health have developed historically and socially in response to economic growth and the diversification of production processes. The intensification of activities in the meatpacking sector led to the installation of new production units, the incorporation of units of all sizes to form large economic groups, an increase in formal employment, and, in addition, an increase in related accidents and work-related illnesses [50]. Another critical fact about slaughterhouses is that around 80% of the work activities carried out are in the standing position and performing manual activities, following the speed imposed by the production lines, which leads to

muscle fatigue and postural discomfort, resulting in the development of WMSD, one of the primary diseases that worsen the health of employees [51]. Tirloni et al. [42] concluded that workers were vulnerable to ergonomic risks due to repetitive movements and were more likely to develop upper limb work-related musculoskeletal disorders (WMSDs).

We found that a low level of education is associated with outsourced work, work-related stress, pauses during work, and repetitive movements. Previous research has emphasized that better education and training improve hygiene and preventive practices [52–54]. Slade and Alleyne [55] suggest that schooling enhances psychosocial well-being by equipping workers with coping mechanisms for the stresses of slaughterhouse work.

Pain is usually the first complaint of workers and a symptom of WMSD, followed by functional incapacity in the affected segment. We found strong associations between the presence of pain and movement limitations, the inability to perform everyday tasks, pauses during work, and stressful environments. Common symptoms of musculoskeletal disorders include pain, stiffness, swelling, and limited movement over the affected area [45]. Other symptoms related to WMSD may arise, such as lack of strength, cramps, tingling, loss of sleep, and limitation of daily life and household chores, so workers with these pathologies, in addition to muscle pain, feel the limitation of their health and suffer from being away from work [56]. Disability associated with musculoskeletal conditions has also been increasing worldwide and is projected to continue in the following decades [56].

Our results indicate a prevalence of soft tissue disorder (M70 through M79, Table 3). The majority of the workers had temporary disabilities (53.17%), while 5.73% had partial permanent disabilities, and 25.8% could not answer this question. Shoulder injury (M75) had a prevalence of occurrence (28.66%), followed by synovitis and tenosynovitis (M65). According to Reis and Moro [13], slaughterhouse workers feel body discomfort in their shoulders (45.00%), neck (29.00%), spine (26.00%), arms (23.00%), hands (20.00%), and fists (20.00%). After investigating meatpacking workers in Denmark, Sundstrup et al. [21] found a prevalence of pain in the neck, shoulder, elbow, and hand/wrist. Another study conducted by Busnello and Dewes [57] found that the most prevalent work-related musculoskeletal disorders (WMSDs) in slaughterhouse workers are those affecting the upper limbs and neck, including several conditions such as tenosynovitis, epicondylitis, carpal tunnel syndrome, synovial cysts, bursitis, and trigger finger.

Mechanical factors associated with prolonged stay in one position, repetitive movements, and trunk twisting trigger musculoskeletal pain, showing different symptoms varying in location, frequency, intensity, and cause [11]. Faoro et al. [58] also suggest a strong correlation between musculoskeletal pain and common mental disorders in workers, which was evaluated in a slaughterhouse with 1103 participants using the Nordic Musculoskeletal Symptom Questionnaire and the Self-Reporting Questionnaire (SRQ-20). The stressful work environment reveals a worrying scenario for companies and their employees [30].

Work-related musculoskeletal disorders (WRMSDs) frequently necessitate employees to take leave for medical treatment. A study conducted by Chamorra et al. [59] in Rio Grande do Sul, Brazil, slaughterhouses revealed that out of 1903 outpatient visits within a month, 366 (19.23%) were attributed to musculoskeletal complaints. Similarly, of 795 instances of work absenteeism, 195 (24.53%) were due to musculoskeletal issues, highlighting a significant concern. According to Dias et al. [55], absence from work is recognized as a therapeutic measure for employees who require rest, treatment, or to be removed from exposure to occupational risk factors associated with their condition. Such a move underscores the impact of inadequate working conditions on employee health and productivity. Tirloni et al. [60] theorize that work absenteeism due to illness arises when an individual's capacity to work is compromised, necessitating a cessation or interruption of

their duties. In the context of musculoskeletal disorders, this incapacity extends beyond the physical limitations imposed by the condition, affecting the individual's psychological and social well-being and ultimately leading to a multidimensional decline in overall health. This suggests a strong correlation between the deterioration of physical and psychological states in such cases.

When seeking to offer better working conditions for meatpacking workers, it is also essential to identify possible illnesses that affect these individuals. Bonetti et al. [61] indicate that work-related accidents are evident due to the injuries they cause and their causal relationship with the work activity. However, occupational diseases can be more challenging to identify and associate with the employee's profession. Merely meeting essential obligations may not ensure employee motivation or job satisfaction, potentially leading to diminished performance. Importantly, productivity is closely linked to employee motivation. Therefore, effective human resource management is crucial in mitigating occupational risks [62].

The work environment's influence on productivity is undeniable; the healthier and more favorable it is for employee well-being, the more productive the company will be [42]. Therefore, the company must prioritize processes and actions that promote a healthy and effective work environment. Safety laws and standards focus on the physical environment, as damage to a worker's health and even death can occur due to inadequate conditions. When there is harmony between the mind and body, an individual's well-being and motivation increase, enabling them to manage their emotions and relationships at work better [63].

It is possible to mitigate the risks associated with working in slaughterhouses through a structured, planned, and comprehensive approach to prevention, in which the employer invests in organizational, technical, and administrative measures to ensure the well-being of workers [64]. Bonetti et al. [29] emphasize that attention to workers' health is crucial in this profession, as a stressful work environment can profoundly adversely impact the employee's life. Therefore, the company must provide all necessary protective equipment, offer regular rest periods, and create a pleasant working environment, which can increase employee productivity while simultaneously reducing the number of accidents and negative health impacts.

Ferreira et al. [65] investigated solutions to enhance storage and shipping operations in a slaughterhouse, recognizing that this stage is characterized by high rates of absenteeism and illness among workers, which poses a significant health risk. Among the main threats to the industry's development, the team identified high turnover and labor shortages, which can be attributed to the freezing working environment, which leads to muscle stiffness, circulatory problems, reduced agility, and increased accident risks. Furthermore, the study showed a high rate of repetitive strain injuries in this production stage.

Matias and Moreira [63] highlight a concerning trend of inadequate occupational health and safety practices within businesses, indicating a failure to adhere to established legislation. Such a trend is evidenced by deficient medical records that impede accurate diagnosis of work-related illnesses, underutilization of mandatory Accident Reports (CATs), insufficient implementation of preventative measures against occupational disease progression, untimely medical examinations, and inadequate documentation within occupational health medical certificates. Such deficiencies have significant implications for worker well-being and labor standards enforcement.

However, despite the importance of communication, many companies fail to notify, aiming to conceal the incident and its effects. However, it is essential to highlight that the lack of declaration leads to significant problems, as without registration, the work accident is not included in the statistics, which can lead to underreporting and distortion of the

data necessary to manage this issue in the country [66]. As stated by Cusciano [27], it is the responsibility of the legal entity employer to communicate work accidents to the INSS (Brazilian Social Health Care System) through the issuance of the Work Accident Report (CAT), even in cases where the employee does not need to leave work. Its activities. Sá et al. [66] observed that reporting an accident at work is essential, as its consequences can affect various aspects, including social security, labor, the company's finances, and criminal matters.

In previous research, Chamorra et al. [59] noted that the lack of registration is evident in the absence of CAT for musculoskeletal disorders and in the discrepancy between cases of musculoskeletal complaints treated in the work environment. This discrepancy is strong evidence that these injuries are related to working conditions, as their etiology is associated with biomechanical overload resulting from biomechanical and psychosocial factors common in slaughterhouses. Complete reporting of WMSDs requires supportive public policies that guarantee workers can notify authorities or employers about their condition, free from fear of retaliation. Furthermore, corporations must actively address occupational illness risks, develop and institute preventative measures, and adhere to established protocols for reporting WMSD cases. Although the issue of underreporting of occupational injuries, particularly WMSDs, is acknowledged in Brazil's slaughterhouse industry, there is a lack of adequate regulatory enforcement to ensure accurate data collection and reporting. This deficiency hampers the development of responsive public health policies and preventive occupational safety programs. A more robust regulatory framework, including reforms to existing legislation such as the Consolidation of Labor Laws (CLT), is required to mandate independent auditing of injury reports and penalize non-compliance with mandatory Work Accident Reports (CATs).

International experiences indicate that enforcement mechanisms—such as surprise inspections, electronic injury logs, and publicly accessible safety records—improve transparency and employer accountability. For instance, OSHA in the United States mandates electronic submission of injury and illness records, allowing public scrutiny and targeted inspections [67]. Denmark complements mandatory reporting with participatory safety committees that regularly assess and address workplace risks [21]. Brazil could adopt similar measures by strengthening coordination among labor inspection agencies, public health institutions, and the Social Security System (INSS), ensuring more consistent and credible injury surveillance. In parallel, educational campaigns are necessary to empower workers to recognize WMSDs and report them without fear of retaliation.

The present study findings indicate the urgent need for preventative measures and actionable recommendations for policymakers and employers. These include (i) enforcing mandatory ergonomic risk assessments in slaughterhouses; (ii) implementing structured rest breaks and task rotation based on ergonomic principles; (iii) developing compulsory training programs for safe practices and appropriate use of personal protective equipment; (iv) strengthening mandatory reporting through the systematic issuance of Work Accident Reports (CATs); (v) creating incentive-based programs to reward compliance with health and safety standards; and (vi) integrating occupational health surveillance into national public health policies.

A comparative perspective reinforces the importance of these recommendations. The Occupational Safety and Health Administration (OSHA) has issued specific ergonomic guidelines for the meatpacking industry in the United States, emphasizing engineering controls, job redesign, and worker training to reduce repetitive strain injuries [67]. Denmark, known for its proactive occupational health system, mandates comprehensive ergonomic assessments and encourages worker participation in safety management through institutionalized committees [21,26]. These international practices demonstrate the value of

regulatory enforcement and participatory governance in reducing WMSDs. Aligning Brazil's regulatory framework with such standards could improve worker well-being and operational sustainability. Future research should assess the feasibility and impact of implementing these international benchmarks within the Brazilian context.

The current study has limitations. One limitation was the forms used to analyze the data; some were not completed, even though we analyzed only those containing all the necessary information. Additionally, the forms pertain to workers already with WMSD and on sick leave, as the data form collects information on notifiable diseases. However, we did not have information about today's clinical condition; therefore, the analysis refers to the time of registration. Also, the study selected some professions that may not be generalized to all professions in the field, so further studies are necessary to explore other professions related to slaughterhouses.

Injuries depend on tasks and working conditions, including organizational and psychosocial aspects. For example, intense, repetitive work in a stressful environment may overload musculoskeletal demands. An in-depth ergonomic analysis of working conditions and risks of musculoskeletal disorders is necessary for prevention, an aspect not addressed in the present study. Therefore, an in-depth ergonomic analysis of tasks and working conditions in each location is recommended for a better analysis.

The analysis was constrained by the available data source (official notification forms), which lacked information categorizing workers by specific slaughterhouse tasks such as cutting, packaging, or machine operation. Therefore, assessing the differential risk associated with distinct work activities was beyond the scope of this study and represents a limitation. A further limitation is the participants' absence of data regarding potential pre-existing health conditions. Although the study cohort consisted exclusively of workers diagnosed with WMSD, the utilized dataset did not contain information allowing for the analysis or control of pre-existing conditions that might influence WMSD development or presentation. Another limitation concerns the scope of the sex-based analysis. Although initial associations involving sex were identified, the study did not conduct a deeper exploration of potential differences in WMSD risk factors or outcomes between male and female participants using the available data. Further research explicitly investigating these sex-specific aspects is warranted.

Some other organizational aspects that may influence the WRMSD, such as rhythm and overtime work, were not investigated. Future studies should measure organizational variables in detail and analyze their association with body discomfort, in addition to the ergonomic analyses of tasks in actual working activities. Thus, the sample is related to a specific period (2007 to 2019); consequently, it limits the generalization of the data to all slaughterhouse workers in Brazil today. Conversely, this research was exploratory and contributed to the analysis of WRMSD risks in slaughterhouses in Brazil, as well as providing evidence of the need to promote deeper analyses and better working conditions.

5. Conclusions

The findings of this study reveal a high prevalence of Work-Related Musculoskeletal Disorders (WMSDs) from the professions of slaughterers, butchers, and deboners among slaughterhouse workers in Brazil in the studied period (2007 to 2019), emphasizing the urgent need for preventive strategies. However, beyond recognizing the problem, proposing specific and actionable recommendations for policymakers and employers is essential. We suggest enforcing ergonomic standards through mandatory risk assessments and compliance audits, implementing structured rest breaks and task rotation guided by ergonomic principles, and developing targeted training programs focusing on safe work practices and the adequate use of protective equipment. Additionally, we recommend strength-

ening mandatory reporting mechanisms for work-related injuries, introducing incentive programs for companies that invest in occupational health, and integrating occupational risk surveillance into broader public health policies.

The present study supports the database's follow-up and the development of evidence-based policies and interventions that can significantly reduce the incidence of WMSDs in the meat processing industry. These measures will improve worker health and safety and enhance productivity and sustainability in this critical economic sector. Further studies should investigate other profiles of slaughterhouse workers, considering other variables as well.

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