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Sociodemographic Data and Work-Related Musculoskeletal Symptoms in the Metal Polishing Industry: A Case Study in Central Portugal

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Abstract: The prevalence of work-related musculoskeletal disorders is a red flag in industries and is considered an occupational health issue that affects the operator's well-being, safety, and health. This study contributes to understanding the impact of Industry 5.0 on the workforce and emphasizes the importance of promoting a safe and healthy working environment. Thus, it focuses on the assessment of anthropometric characteristics and work-related musculoskeletal symptoms in a real industrial environment, specifically in the metal polishing sector of a metallurgical industry in Portugal. The research collected data on physical attributes, health status, and musculoskeletal symptoms using the Portuguese version of the Nordic Musculoskeletal Questionnaire, and incorporated sociodemographic data, including age, gender, and professional status, to provide a comprehensive understanding of the active workforce. The results were analyzed by gender and age clusters and revealed a prevalence of musculoskeletal symptoms, particularly in the spinal column and upper limbs, with a significant impact on the ability to perform work tasks. The need for preventive measures and ergonomic interventions to minimize the high predominance of musculoskeletal symptoms in Portuguese industries is also highlighted to improve the working conditions and enhance the well-being and health of operators.

Keywords: Industry 5.0; aging workforce; metallurgical industry; polishing industry; anthropometry; Nordic musculoskeletal questionnaire; work-related musculoskeletal disorders

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1. Introduction

Industry 5.0, the evolution beyond Industry 4.0, is set to transform industrial settings by prioritizing the well-being and safety of the workforce [1]. With an aging population impacting modern production systems, there is a pressing need to integrate older employees effectively [2,3]. This involves evaluating age-critical tasks and adapting technologies to suit the cognitive and sensorial capacities of aging workers [4]. In Industry 5.0, improving working conditions and task performance for older workers through innovative technologies is crucial. Human centricity lies at the core of Industry 5.0, empowering workers through collaboration with digital technologies [1,5]. This shift underscores the synchronization of human capabilities with machine or equipment functionalities to bolster production efficiency [6]. Despite this, a notable gap exists in safety and human-centric design within this framework [7]. By fostering ergonomic workspaces and human–robot partnerships, Industry 5.0 can mitigate musculoskeletal issues and enhance worker well-being [2,3].

Workers' well-being and ergonomics play vital roles in various industries, including computer users and manufacturing workers, with numerous studies underscoring the prevalence of musculoskeletal disorders (MSDs) among these workers [8–10].

In addition, there is an increasing diversity in the workforce in terms of both age and gender, that is, the rise of an aging workforce and the increase and balance of the female gender in the workplace. Despite this, the prevalence of musculoskeletal symptoms is higher in older workers than in younger workers [11]. Studies reveal that older workers have a higher prevalence of more severe or fatal injuries when compared to younger operators, where less severe injuries predominate [12]. Aging workers with a high prevalence of WRMSDs incur significant costs for companies and contribute to job losses and early retirements [11]. Therefore, equipment and work systems must adapt to workers to reduce musculoskeletal risks and promote health, well-being, and job satisfaction, especially for those who have extended their active working life [11].

The Nordic Musculoskeletal Questionnaire (NMQ) serves as a crucial tool for evaluating MSDs and ergonomic factors, pinpointing high-risk areas like the lower back, neck, and shoulders [13]. Emphasizing the significance of proper training, ergonomic workshops, and proactive measures, industries intend to foster health-conscious work postures and healthy routines and alleviate musculoskeletal discomfort. The NMQ's widespread use in diverse studies across various occupational settings underscores its reliability and validity in identifying musculoskeletal risks, especially in tasks involving repetitive movements. Its applicability spans different worker populations, showcasing high specificity and reliability [14]. Consequently, the NMQ emerges as a valuable instrument for evaluating and addressing musculoskeletal concerns within work environments.

Thus, by administering questionnaires to workers, their participation and involvement in the appropriate application of participatory ergonomic interventions can be enhanced, thereby promoting and raising awareness among the groups involved, which is often neglected [15]. Studies show that through worker participation, effective and sustainable transformations of workplace interventions have been achieved. Notably, this includes prioritizing workers' needs, engaging management in occupational safety and health, and fostering a positive and motivating work environment that builds trust among workers [16].

This study focuses on the sociodemographic assessment and symptomatology of work-related musculoskeletal injuries in a Portuguese polishing industry using a questionnaire in a real industrial environment. This analysis and evaluation were performed by gender and age clusters.

2. Materials and Methods

A case study was conducted in a real industrial environment in a metallurgical industry specializing in high quality and precision crafting of metal items, including luxury leather accessories, jewelry, watches, and writing instruments. The company is part of a multinational corporation, with one of its facilities, where this study took place, situated in central Portugal. This industry focuses on machining, polishing, galvanizing, and final assembly, employing over 500 individuals across more than 20 jobs. Moreover, the company holds ISO 9001:2015 [17] and ISO 14001:2015 [18] certifications to ensure compliance with customer expectations regarding quality and delivery schedules.

Initially, the investigation targeted a specific operational area, with emphasis on the polishing division, chosen due to its predominantly manual procedures, mostly performed by humans, with the aim of creating or reactivating the shine of metal surfaces. This sector was selected because tasks are typically performed while seated, involving repetitive actions, and requiring the application of different forces throughout the working period, thereby increasing the risk of work-related musculoskeletal disorders. The operators involved in this study are exclusively dedicated to manually polishing pieces' work tasks, without any leadership responsibilities or labor ascendancy over other workers. So, the operators' work activities during their working hours are to polish small pieces of luxury jewelry by hand using polishing equipment, successively.

This research was approved by the Ethics Committee of the University of Beira Interior, ensuring the operator's confidentiality during their voluntary involvement in this study, including the completion of the questionnaire, as per the Free, Informed, and Informed

Consent Protocol. Only the researchers involved in this study had access to the gathered personal data, which, in any event, were not disclosed due to encryption protocols. Furthermore, the questionnaires were distributed and retrieved by the researcher, assuring total confidentiality.

The "Ergonomics, Wellbeing, and Health in the Industrial Context" questionnaire enhances a preliminary ergonomic evaluation and its impact on the occurrence of musculoskeletal injuries in industrial settings. This questionnaire aimed to conduct an initial symptomatic assessment of musculoskeletal injuries linked to industrial work. Designed to be user friendly within an industrial environment, the questionnaire comprises brief, clear, and direct questions for the operator. Its development drew upon two validated and tested questionnaires from various research studies [19–22], resulting in the questionnaire being divided into two sections: the first focusing on sociodemographic information and the second on health, ergonomics, and anthropometry.

The initial segment captures sociodemographic details, gathering personal and professional data to characterize the study sample. This section includes details such as date of birth, gender, marital status, cohabitation status, academic qualifications, and professional status. The subsequent part delves into health, ergonomics, and anthropometry, obtaining data on health status and work-related musculoskeletal symptoms. Information collected encompasses physical attributes like weight, height, dominant hand, physical activity, and sleep patterns. Additionally, it addresses the perceptual evaluation of musculoskeletal injuries according to the Portuguese version of the Nordic Musculoskeletal Questionnaire [19,20,23].

The Portuguese version of the NMQ comprises 27 binary choice questions, i.e., the response is yes or no. The questionnaire is grouped into three questions that correlate to nine anatomic regions that complete the entire human body, from the neck, shoulders, wrists/hands, upper back, lower back, hips/thighs, and knees to ankles/feet [14]. The first question is the existence and prevalence of fatigue, discomfort, pain, and/or musculoskeletal injuries related to work in the last 12 months; the second one is the existence and prevalence of fatigue, discomfort, pain, and/or musculoskeletal injuries related to work in the last 7 days; and the last one is the hindrance in performing normal work tasks in the last 12 months [13].

Regarding the initial segment, namely, the sociodemographic data, a set of questions from the Ergo@Office model questionnaire [20] was chosen with some adjustments and/or modifications to ensure a broader, more inclusive, and contextually relevant alignment with the industrial environment under investigation. The age question was refined to birthdate to facilitate proportional age calculation. Additionally, a new gender option, "Other/Undefined", was introduced for enhanced inclusivity. Similarly, concerning educational qualifications, three more choices were incorporated to account for potential lower academic qualifications within the study sample: "Primary Education (4th grade)", "Basic Education (5th to 9th grade)", and "Other/No Academic Qualifications". Moreover, within the professional context, two additional questions were integrated, specifically addressing work status, regular hours or shift work, and the equipment utilized by the operator.

3. Results

Data collection took place in March 2024, focusing on operators in the metal polishing sector. The initial sample included 144 workers, with two operators excluded for refusing to participate voluntarily, resulting in a response rate of 98.6%. Subsequently, during the analysis phase, two operators were eliminated: one due to having a BMI below 18.5 kg/m^2 and the other due to having a BMI above 40 kg/m^2. This exclusion factor was applied due to the significant impact of body mass index (BMI) on work-related musculoskeletal disorders. Low [24] and high [25] BMI levels have a direct influence on the development of discomfort or pain among workers. Therefore, the total number of respondents included in this study amounts to 140 workers, that is, 97.2% of the operators under study.

3.1. Sociodemographic Data

3.1.1. Sociodemographic Characterization

The sociodemographic characterization of the sample includes age, gender, marital status, living situation with children under 16 years old, educational qualifications, and professional status, which encompasses seniority in the company, hours worked per week, work schedules, and the equipment used. The sample consists of 55% (n = 77) male individuals and 45% (n = 63) female individuals, with the average age being 39 years (σ = 11.239) for males and 37 years (σ = 10.107) for females, respectively. Across the entire sample, the average age is 38 years (σ = 10.724), with a minimum age of 20 years and a maximum of 63 years.

In the study sample, 44.3% (n = 62) of individuals are single, and 36.4% (n = 51) are married. These values are consistent and reinforced in the male gender, with a higher percentage of single individuals (54.5%, n = 42) and a lower percentage of married individuals (28.5%, n = 22). On the other hand, the female gender shows contrasting values, with a higher percentage of married individuals (46%, n = 29) and a lower percentage of single individuals (31.7%, n = 20). Similarly, regarding the living situation with children under 16 years old, in the overall sample, 60% (n = 84) do not have children under 16 years old living with them. However, these values are more prevalent in the male gender, with 67.5% of individuals not having children under 16 years old, while in the female gender, these values decrease and approach a balance, in which only 50.8% of the female gender do not have children under 16 years old living with them.

Regarding educational qualifications, 43.6% (n = 61) of individuals have completed Secondary Education (10th to 12th grade), followed by Technical–Professional Education at 19.3% (n = 27), and then, very closely, Basic Education (5th to 9th grade) at 17.9% (n = 25). Table 1 summarizes the values obtained for the sociodemographic data collected for the entire sample and by gender.

Table 1. Sociodemographic data (n: frequency; %: percentage; NR: No Response).

	Total Sample		Female Gender		Male Gender	
	n	**%**	**n**	**%**	**n**	**%**
Age Clusters						
18–34	55	39.3	27	42.9	28	36.4
35–44	38	27.1	16	25.4	22	28.6
45–54	35	25	17	27	18	23.4
55–64	7	5	1	1.6	6	7.8
NR	5	3.6	2	3.2	3	3.9
Marital Status						
Single	62	44.3	20	31.7	42	54.5
Married	51	36.4	29	46	22	28.6
Divorced	9	6.4	6	9.5	3	3.9
Common Law	17	12.1	8	12.7	9	11.7
NR	1	0.7	0	0	1	1.3
Children < 16 Years Old						
No	84	60	32	50.8	52	67.5
Yes	55	39.3	30	47.6	25	32.5
NR	1	0.7	1	1.6	0	0
Educational Qualifications						
Primary Education	2	1.4	1	1.6	1	1.3
Basic Education	25	17.9	8	12.7	17	22.1
Secondary Education	61	43.6	30	47.6	31	40.3
Technical–Professional Education	27	19.3	10	15.9	17	22.1
Higher Education	21	15	12	19	9	11.7
Postgraduate Higher Education	3	2.1	1	1.6	2	2.6
NR	1	0.7	1	1.6	0	0

3.1.2. Professional Status

In terms of professional status, most individuals, that is, 71.4% (n = 100), have been with the company for less than 5 years, with an average seniority in the company of 3.6 years (σ = 3.792). In this scenario, the average seniority in the company for males, standing at 4.2 years (σ = 4.422), exceeds that of females, which is 2.7 years (σ = 2.624). The average weekly working hours are 40.1 h (σ = 2.642), which is slightly higher in males at 40.3 h (σ = 1.384) compared to 39.8 h (σ = 3.621) in females. Regarding work schedules, the majority work regular hours, with 85.7% (n = 120) working from 8 am to 5 pm, while the remaining 14.3% (n = 20) work shifts. Concerning the equipment used, 82.1% (n = 115) use the Vitax/polishing equipment, followed by 15.7% (n = 22) who use the lapidary machine. Data regarding professional status can be found in Table 2 and are analyzed for the entire sample and by gender.

Table 2. Professional status (n: frequency; %: percentage; NR: No Response).

	Total Sample		Female Gender		Male Gender	
	n	**%**	**n**	**%**	**n**	**%**
Seniority in the Company						
<5 years	100	71.4	50	79.4	50	64.9
5 to 10 years	23	16.4	9	14.3	14	18.2
>10 years	14	10	2	3.2	12	15.6
NR	3	2.1	2	3.2	1	1.3
Working Hours/Week						
<40	7	4.9	6	9.6	1	1.3
40	120	85.7	50	79.5	70	90.9
>40	10	7	6	9.3	4	5.2
NR	3	2.1	1	1.6	2	2.6
Work Schedules						
Regular	120	85.7	49	77.8	71	92.2
Shifts	20	14.3	14	22.2	6	7.8
Work Equipment						
Vitax/Polishing	115	82.1	54	85.7	61	79.2
Lapidary Machine	22	15.7	7	11.1	15	19.5
Other	3	2.1	2	3.2	1	1.3

3.2. Health, Ergonomics, and Anthropometry

3.2.1. Health Habits and Lifestyle

In the study sample, 62.9% (n = 88) of individuals identify their right hand as dominant, followed by 35% (n = 49) reporting both hands as dominant. This could suggest that with increased experience of the workers, i.e., higher seniority in the company, there could be an influence on hand dominance. However, such conclusions cannot be drawn since for both cases of hand dominance, the workers' seniority in the company is similar. Concerning weekly physical exercise, 57.9% (n = 81) engage in physical activity at least once a week, with a higher prevalence among males (61%) compared to females (46%). Sleep habits are primarily divided into two categories, with 53.6% (n = 75) sleeping between 7 and 8 h, while 44.3% (n = 62) sleep between 4 and 6 h, showing a balanced distribution across genders.

Regarding their overall health perception within the total sample, 47.1% (n = 66) report it as good, 25.7% (n = 36) rate it as very good, and 17.1% (n = 24) describe it as reasonable.

According to the Nordic Musculoskeletal Questionnaire, weight and height values are requested to calculate the body mass index (BMI) and classify it accordingly. In the total sample, the average weight is 73 kg (σ = 13.212), with the average weight for females at 66 kg (σ = 11.070) and for males at 78 kg (σ = 12.515). The average height in the sample is 1.69 m (σ = 0.093), with females averaging 1.64 m (σ = 0.078) and males 1.74 m (σ = 0.077). Consequently, the mean BMI for the entire sample is 25.3 (σ = 3.620), indicating overweight,

with an average BMI of 24.8 (σ = 3.705) for females and 25.7 (σ = 3.519) for males, classifying as normal weight and overweight, respectively.

Table 3 displays the obtained values concerning health habits and lifestyle.

Table 3. Health habits and lifestyle (n: frequency; %: percentage).

	Total Sample		Female Gender		Male Gender	
	n	%	n	%	n	%
Dominant Hand						
Right	88	62.9	38	60.3	50	64.9
Left	3	2.1	0	0	3	3.9
Both	49	35	25	39.7	24	31.2
BMI Situation						
Normal Weight	73	52.1	36	57.1	37	48.1
Overweight	53	37.9	23	36.5	30	39
Obesity Class I	11	7.9	2	3.2	9	11.7
Obesity Class II	3	2.1	2	3.2	1	1.3
Physical Exercise						
Yes	81	57.9	29	46	47	61
No	59	42.1	34	54	30	39
Sleep Habits						
Between 4 and 6 h	62	44.3	27	42.9	35	45.5
Between 7 and 8 h	75	53.6	34	54	41	53.2
More than 8 h	3	2.1	2	3.2	1	1.3
Health Perception						
Excellent	11	7.9	6	9.5	5	6.5
Very Good	36	25.7	11	17.5	25	32.5
Good	66	47.1	33	52.4	33	42.9
Reasonable	24	17.1	13	20.6	11	14.3
Deficit	3	2.1	0	0	3	3.9

3.2.2. Work-Related Musculoskeletal Disorders Symptomatology Perception

Through the application of the Portuguese version of the NMQ, it was possible to gather information regarding the existence and prevalence of fatigue, discomfort, pain, and/or musculoskeletal injuries related to work. This analysis is performed for various body areas, specifically the spinal column (neck, dorsal, and lumbar), upper limbs (shoulders, wrists/hands, and elbows), and lower limbs (hips/thighs, legs/knees, and ankles/feet) for different time frames, namely, in the last 12 months and the last 7 days, as well as the hindrance in performing normal work tasks (Figure 1).

By analyzing the graphical representation in Figure 1, it can be stated that the percentage of reported issues of fatigue, discomfort, or pain in the past 12 months is more pronounced for the anatomical areas of the spinal column, mainly the neck and lumbar region, as well as in the upper limbs, particularly the wrists/hands and shoulders. The neck was identified as the area with the highest reported complaints at 73.6%, followed by the wrists/hands at 72.8% and the lumbar spine at 69.3%.

Regarding the percentage of reported issues of fatigue, discomfort, or pain in the last 7 days, the anatomical area of the spinal column shows the highest prevalence, with 45.7% reporting complaints for the neck and 42.1% for the lumbar spine. Following this, the body area most affected by complaints of fatigue, discomfort, or pain in the upper limbs, with 32.1% reporting complaints for the wrists/hands and 31.1% for the shoulders.

Regarding the hindrance in performing normal work tasks in the previous 12 months, the highest incidence is in the anatomical area of the spinal column, which is particularly noticeable in the lumbar region at 7.1%, followed by the neck at 5.7%. It is also worth noting that only the anatomical areas of the spinal column and upper limbs, except for the elbows, showed hindrances in performing work. Comparing the percentages of reported

complaints of fatigue, discomfort, or pain for the different body areas studied with those prevented from carrying out normal work tasks, it can be said that there is a positive correlation between them. In other words, being prevented from doing work may be related to the high percentages of complaints of fatigue, discomfort, or pain in the same anatomical areas, i.e., due to problems and/or musculoskeletal injuries resulting from these complaints.

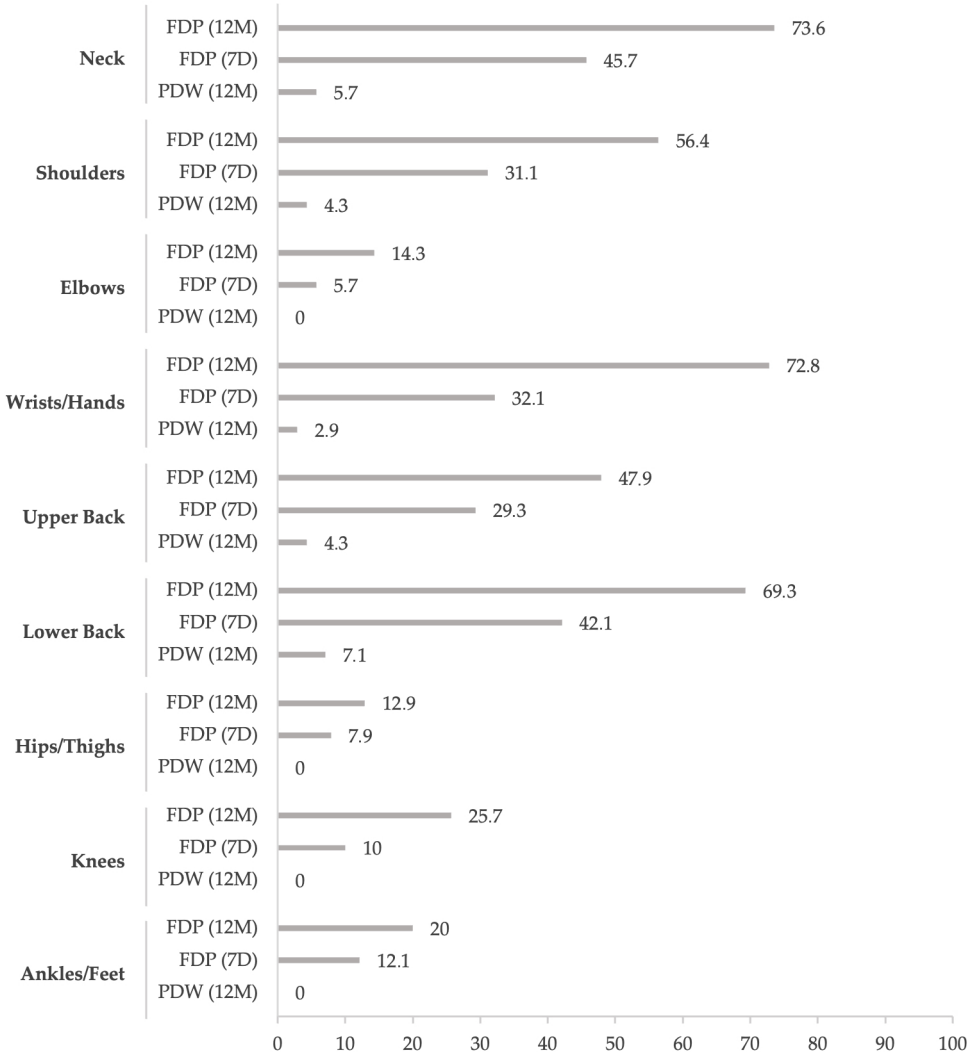

Figure 1. Graphical representation of reported issues percentage by anatomical area, time, and work hindrance for the total sample of individuals (FDP (12 M): fatigue, discomfort, or pain (12 months); FDP (7 D): fatigue, discomfort, or pain (7 Days); PDW (12 M): prevented from doing work (12 months)).

The intensity of discomfort, fatigue, or pain experienced by individuals in the same anatomical areas was also analyzed, ranging from mild, moderate, and intense to unbearable (Figure 2).

According to the graphical representation in Figure 2, it is observed that the intensity classification with the highest percentage of selection by individuals is moderate for all anatomical areas, but there are more pronounced percentages for the entire spinal column (47.9% in the neck, 32.1% in the lower back, and 25.7% in the upper back) and all upper limbs except the elbows (29.3% in the shoulders, 28.6% in the wrists/hands). It is important to highlight that for the anatomical areas mentioned, the second most prevalent classification chosen by individuals is intense, indicating a higher nature of intensity of discomfort,

fatigue, or pain. The wrists/hands stand out with an equal percentage between moderate and intense intensity (28.6%).

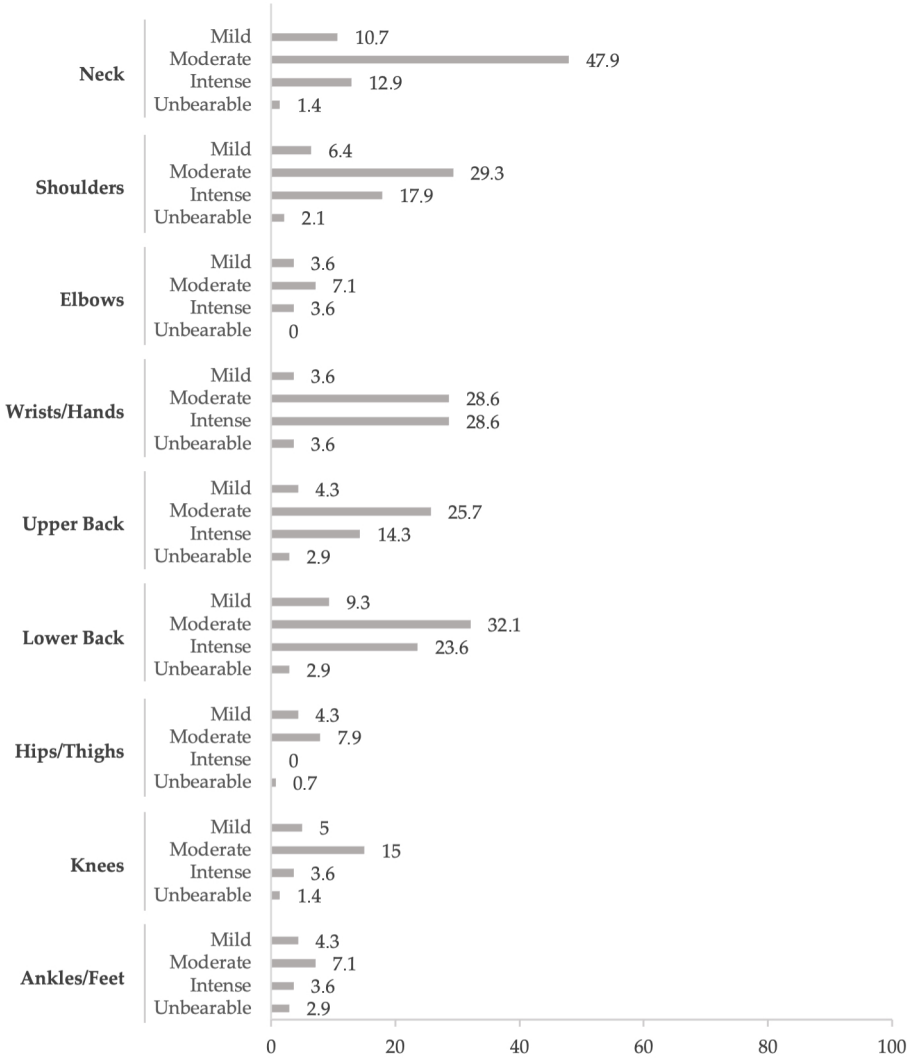

Figure 2. Graphical representation of fatigue, discomfort, or pain intensity percentage by anatomical area in the last 12 months for the total sample of individuals.

4. Discussion

This study was conducted in an industrial environment, specifically in the polishing section, as it encompasses a set of monotonous and repetitive tasks. This approach ensures, as far as possible, that operators are exposed to the same working conditions and similar tasks, thus forming a homogeneous work group [26]. This can be seen from the high percentage of Vitax equipment used, with most operators using this polishing equipment to carry out their work tasks, and, from another perspective, the high prevalence of people who use both hands as the dominant hand.

Regarding the age groups under analysis, various studies, in line with the Organization for Economic Co-operation and Development (OECD) data, divide ages into two main groups: younger workers, ranging from 20 to 54 years old, and aging workers, from 55 to 64 years old [2,3,27]. However, to provide a more detailed segmentation of both the younger and aging worker groups, this study focused on age clusters as per other research [28–30]. The age clusters were as follows: 18 to 34 years old, which includes younger workers who are not fully specialized or skilled and may, therefore, take longer to perform their work tasks correctly; 35 to 44 years old, corresponding to the group of

workers already specialized and skilled in their functions and who perform them more or less within the stipulated times; 45 to 54 years old, which includes older workers, highly specialized and qualified due to their professional experience; and, finally, 55 to 64 years old, corresponding to senior workers whose specialization and qualification have already been proven but who, for some reason, may no longer be able to perform all types of work tasks or activities. These age clusters were in line with the categories formalized in the study by Berti and colleagues, where workers were grouped by average ages and study groups in a generational mix [31]. Similarly, the aging age group was explained based on different studies that explore age diversities and define aging humans and/or operators as older operators from 45 to 54 years old and senior operators from 55 to 64 years old [26,31–33].

For the average age, it is found to be 38 years, with an average difference of 2 years between genders. This difference is smaller than that in the study by Filho et al., 2023, where the gender age difference is approximately 6 years, with males being of higher age. However, like the study by Filho and colleagues, the age distribution falls within the active workforce age range [34]. It is also important to mention the low number of senior operators in this work context, which may be associated with the high work demands that force them to take early retirement [35].

The gender proportion in the present study indicates a relatively balanced representation of men and women in the sample population, which is essential for understanding the anthropometric characteristics, health, and LMERT symptomatology between genders in the Portuguese active population. This gender balance agrees with a recent study in a similar industrial environment in Northern Portugal [34]. This gender equity can be seen as an integral part of Industry 4.0, where technological development promotes gender equality and female empowerment [36], despite women evaluating their job performance lower than men and generally being described as at higher risk of losing their jobs when work processes are automated [37,38].

In comparison with the recent study on anthropometry of Portuguese workers [34], the BMI indicates a significant difference in the average female BMI, while the average male BMI remains similar. Filho and colleagues highlight the prevalence of overweight and obesity in the Portuguese active population, with men being more prone to being overweight and women more prone to obesity [34]. In this case study, the trend of being overweight for men is maintained, but the opposite is true for women, i.e., they are more likely to have a normal weight. When stratified by age clusters, Filho and colleagues observed that the incidence of overweight and obesity increased with age [34], but this trend was not consistent with the results obtained in this report, as shown in Figure 3. In this context, the age group with the highest prevalence for overweight is 35 to 44 years old, and for obesity, it is 55 to 64 years old. The age clusters of 18–34 years old and 45–54 years old presented very similar results.

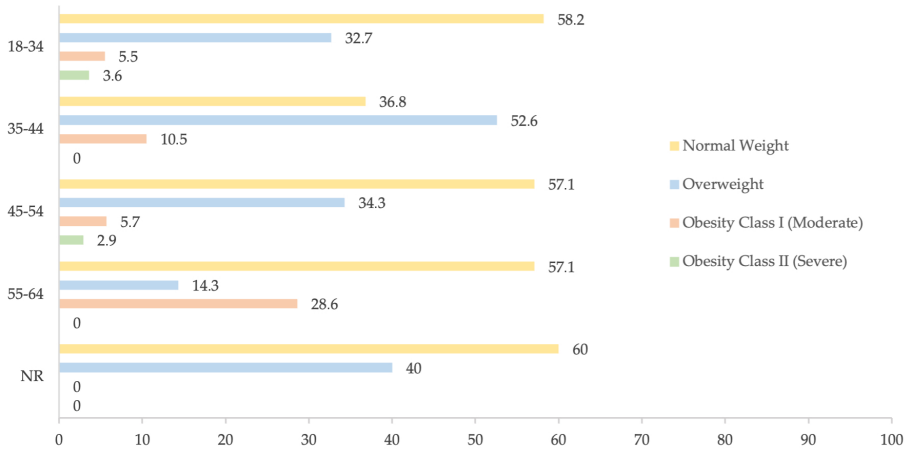

Figure 3. Graphical representation of BMI classification percentage by age clusters (NR: No Response (age)).

Finally, the symptomatic perception of work-related musculoskeletal disorders (WRMSDs) can be associated with working conditions that are constantly changing due to economic, technological, and demographic factors. Furthermore, WRMSDs can develop from changes in exposure to different occupational risk factors, such as repetitive work, physical overload with varying degrees of manual force, handling heavy loads, high work rates, and inadequate postures during task performance [39]. In Portugal, the prevalence of work-related musculoskeletal injuries in industries is a significant concern, defined as an occupational health problem that affects the well-being and health of workers and has an impact on industrial productivity [40–43].

In this metallurgical industry, there is a notable symptomatic prevalence of fatigue, discomfort, or pain in the body areas of the spinal column and upper limbs, which can subsequently result in work-related musculoskeletal disorders. This is evident for the last 12 months of work but is also proven in the last 7 days of work, which may indicate that the adverse conditions and exposures for performing work have persisted and there has been no prevention or action to reduce these symptoms. It can, therefore, be claimed that the symptomatic perception by the operators is quite burdensome, as they classify their intensity of fatigue, discomfort, or pain as moderate or intense.

As the operators work consecutively polishing small metal pieces by hand, using the polishing equipment, the rest time between job tasks is reduced and, as a result, it is difficult to relieve the operators' symptoms. Only at the end of the working day can workers fully recover.

Regarding reports of musculoskeletal symptomatology by gender (Figure 4), the percentage of fatigue, discomfort, or pain is quite similar for both genders, with a slight tendency for males to report their symptoms more, both for the last 12 months of work and the last 7 days. It is important to note that the inability to work is more evident for females.

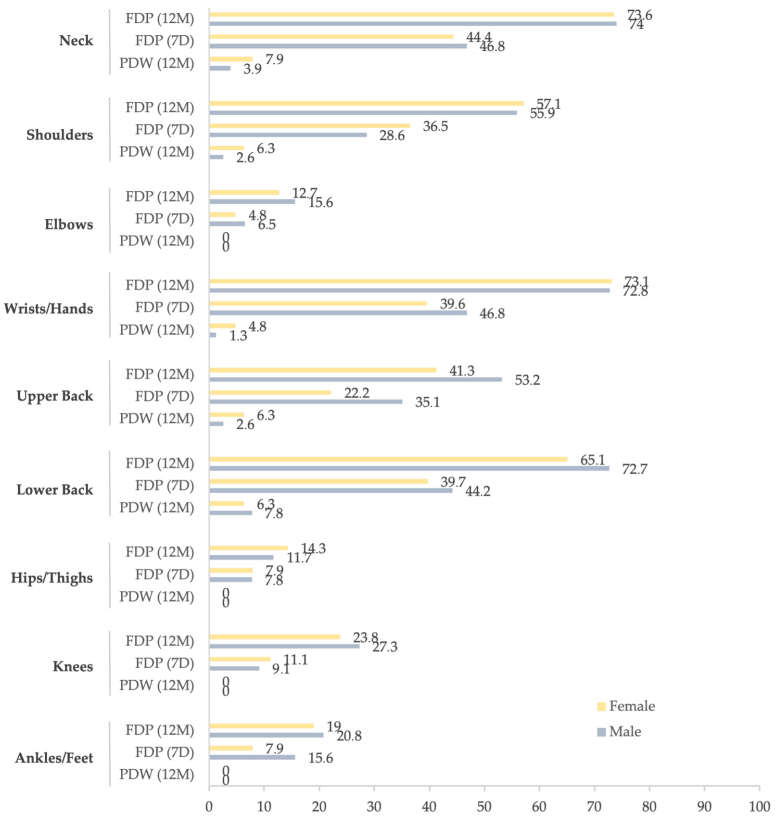

Figure 4. Graphical representation of reported issues percentage by anatomical area, time, and work hindrance for the total sample of individuals by gender (FDP (12 M): fatigue, discomfort, or pain (12 months); FDP (7 D): fatigue, discomfort, or pain (7 Days); PDW (12 M): prevented from doing work (12 months)).

On the other hand, regarding reports of musculoskeletal symptomatology by age clusters (Figure 5), there is a slight tendency for an increase in fatigue, discomfort, or pain with age, that is, with advancing age (progression through age clusters), there is a slight propensity for the prevalence of symptoms in the last 12 months and the last 7 days, but with greater prominence for body areas with higher musculoskeletal symptomatology prevalence. There is no tendency for an inability to work according to age clusters, indicating that these may be isolated cases and not related to the operators' age.

However, the prevalence of musculoskeletal symptoms is widespread across many other industrial sectors, from the textile industry with the lumbar region most affected [43] to the meat processing industry with high symptomatology in the cervical and lumbar regions of the spine [42]. Thus, Portuguese industries reveal the need for preventive measures and ergonomic interventions to minimize the high predominance of musculoskeletal symptoms [42,43]. In this specific case, in addition to the spinal area, symptoms are reported in the upper limb areas, with relevance in the wrists/hands, as work tasks are performed manually by the operators and cannot be automated due to the specificity of the work, often considered an "artisan's" art.

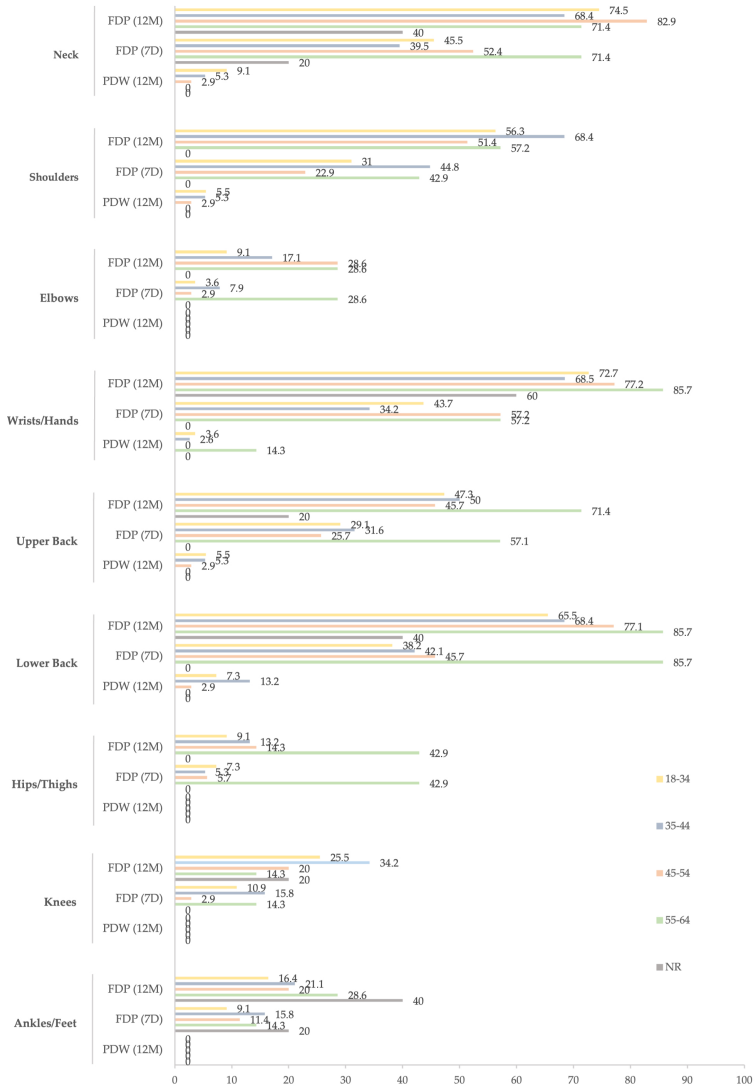

Figure 5. Graphical representation of reported issues percentage by anatomical area, time, and work hindrance for the total sample of individuals by age clusters (FDP (12 M): fatigue, discomfort, or pain (12 months); FDP (7 D): fatigue, discomfort, or pain (7 Days); PDW (12 M): prevented from doing work (12 months); NR: No Response (age)).

5. Limitations and Future Research Agenda

This research, carried out in a real industrial environment, analyzes work patterns and their implications for the health of operators carrying out repetitive manual tasks in a particular sector of work, bringing some limitations.

In this specific case study, most operators work during the daytime, without shift work, and their seniority in the company is less than 5 years. This became a limitation of this study, as it was not possible to carry out correlation studies of these variables with the perception of musculoskeletal symptoms reported by the workers. However, with the intention of industrial growth and possible expansion of shift work, it is necessary to investigate the implications of work schedules and shift work on personal life and health, considering factors such as age, gender, and children [44,45]. Similarly, the elevated BMI of the operators may also be related to their work hours, shift work, and seniority in the company, as studies indicate that more precarious jobs in terms of work schedules and fixed-term or permanent employment contracts lead to higher health risks, notably, a higher BMI and increased stress levels [46,47]. With the results obtained through this questionnaire, it was not possible to establish positive or negative correlations between musculoskeletal symptoms and physical exercise or sleep habits, and more detailed studies need to be carried out. Furthermore, specific analysis and evaluation of sleep habits and physical exercise practices on the health of operators must be performed, especially regarding anthropometric variations, such as BMI, and the possible consequences on the prevalence of musculoskeletal injuries. For example, it has been reported that working night shifts is associated with fewer hours of sleep and a higher BMI [34].

Moreover, the results obtained can, in the first instance, be used and applied directly in the polishing sector, i.e., the site under study. At this stage, easy-to-implement measures can be taken and small changes made to improve the working conditions, well-being, and health of the operators, as well as optimizing productivity. Furthermore, in the second instance, these data can and should be distributed to the occupational health and safety department to carry out more detailed monitoring of the measures taken and, mostly, when implementing measures that require legislative, regulatory, or financial approval.

That said, to improve the accuracy of the results, anthropometric measurements will be taken in the workplace using various measuring materials, such as a stationary and/or dynamic anthropometer and a height and weight measuring station [34], thus enabling the BMI to be calculated more accurately and obtain workers' posture measurements. Also, as future research, we intend to carry out correlation analyses between these variables to define some of the possible causes of musculoskeletal injury symptoms and propose measures to improve working conditions and increase the well-being and health of operators. To perform that, it is important to incorporate and support healthy aging practices by implementing Older Worker-oriented Human Resource Practices (OW-HRPs) to reduce ageism, work–life conflict, and psychological stress [48], including workplace physical activity interventions to foster health [49] and promoting good work environments, social support, and knowledge development, including intrinsic motivation for sustainable working life [50].

On the other hand, a more detailed ergonomic assessment will be necessary to prove and/or determine the reasons for the high prevalence of musculoskeletal symptoms more precisely. For the assessment of physical ergonomics and to evaluate the sequences of actions and postures during work tasks, several ergonomic risk assessment methods can be used, such as the RULA (Rapid Upper Limb Assessment), OCRA (Occupational Repetitive Action), REBA (Rapid Entire Body Assessment, and OWAS (Ovako Working Posture Analysis System) [3]. However, it will have to be assessed in the workplace if the best option is to conduct a complete assessment of the entire human body or if it would be better to choose an assessment of the upper body since this is where the highest prevalence of symptoms was detected, and the work is mostly performed sitting down. Following this analysis, and as mentioned above, since this is "artisan-style" work, the possibility of automating processes is extremely limited. Therefore, the strategy will involve human

approaches, for example, the use of exoskeletons to improve the health and quality of life of operators and reduce musculoskeletal discomfort by incorporating better equipment, such as padded insoles and/or adjustable chairs [3]. This will encourage more age-friendly working environments and boost well-being at work.

6. Conclusions

Industry 5.0 and its influence on the safety and well-being of workers, with a particular focus on the aging workforce, is a hot topic point of industries and companies. This strategy emphasizes the importance of adapting technologies and tasks to the cognitive and sensory capabilities of older workers, aiming to improve working conditions and industrial performance. Additionally, it stresses the need for human–machine partnerships and ergonomic workspaces to reduce work-related musculoskeletal disorders. This study conducted a sociodemographic assessment and evaluation of the symptomatology of work-related musculoskeletal injuries in a polishing industry in Portugal, focusing on the use of the Portuguese version of the Nordic Musculoskeletal Questionnaire.

The results revealed that in this industrial context, there is a good balance of genders and age clusters, except for the age group of senior operators (55–64). The trend towards overweight and obesity among active industrial workers was also shown. A significant prevalence of musculoskeletal symptoms was revealed, particularly in the spinal column and upper limbs, with moderate to intense classifications. Therefore, this reveals the need for urgent intervention in this work environment through a detailed ergonomic assessment and organizational management measures with the aim of improving the health and well-being of these operators, thus reducing work-related musculoskeletal symptoms. Limitations and future research also suggest the need to investigate the impact of working hours, work shifts, physical exercise, and sleep habits on workers' health, as well as the correlation between these factors and the symptomatology of musculoskeletal injuries.

In summary, by applying the Portuguese version of the Nordic Musculoskeletal Questionnaire, an insight into the symptomatology of work-related musculoskeletal complaints reported by operators was obtained. This enhances their involvement and participation in the development of future industrial environments so that workplaces can be adjusted and/or adapted to them, with the aim of improving their working conditions, well-being, and health, highlighting the importance of adapting working conditions to ensure the health and well-being of workers, especially for the aging workforce in the context of transitioning to Industry 5.0.

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