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Strength and Perceived Effort in Repetitive Upper-Limb Tasks: An OCRA Method Analysis of 900 Workers

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Keywords: Musculoskeletal Disorders; Ergonomics; Risk Assessment; OCRA; Handgrip

Abstract

Background: *Work-related musculoskeletal disorders pose a significant burden on the population. The OCRA method plays a key role in assessing the risk associated with repetitive actions of the upper limbs. In this method, muscular force is evaluated based on the rate of perceived effort (RPE) reported by the worker, which can introduce subjective bias into the assessment. This study aims to determine whether testing the worker's handgrip strength can improve the accuracy of the force assessment in the OCRA method.* **Methods:** *Handgrip strength was measured during the risk assessment process following the OCRA method. Data were divided into specific percentile ranks based on age, gender, height, and handedness.* **Results:** *903 workers from 43 different Italian companies were surveyed. There was a significant difference in handgrip strength percentiles stratified by report of an RPE > 2 and those without ($p = 0.047$). Additionally, significant differences were found in perceived effort rates (based on the OCRA method) among workers with different levels of stratified handgrip strength (dominant hand: $p = 0.04$, non-dominant hand: $p = 0.02$).* **Conclusions:** *Workers performing repetitive upper limb actions at various strength levels experience different perceived effort rates during tasks. These findings suggest that measuring handgrip strength is a crucial component of risk assessments using the OCRA method. To date, this study's sample size is among the largest for this evaluation method; we believe these results could be a significant step forward in improving the risk assessment process for biomechanical overload.*

1. Introduction

The incidence and prevalence of musculoskeletal disorders (MSDs) have been steadily increasing over the years. Data provided by the 2021 Global Burden Disease study [1] revealed that MSDs were responsible for 162 million DALYs (Disability-Adjusted Life-Years), accounting for 6.6% of the total DALYs in 2021 [2]. Numerous reports, such as the one presented by EU-OSHA in 2021 [3], acknowledge the strong link between biomechanical factors and MSDs in workers. Another significant

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risk factor for developing MSDs appears related to the decline in muscle strength [4, 5]; or, from a different perspective, muscle strength seems to be a protective factor against MSDs. Therefore, it is essential to identify and refine suitable assessment tools that accurately measure both movement (technical actions) and muscle strength, including the expected decline associated with worker aging.

To reduce the risk of developing MSDs as a negative consequence of work-related factors (Work-related Musculoskeletal Disorders, WR-MSDs), several risk assessment procedures have been developed. These aim to evaluate the level of biomechanical overload caused by repetitive actions, manual handling of loads, pushing, pulling, and other factors. This overload may serve as a pathomechanism due to the overuse of certain muscle groups and the underuse of others [6], leading to imbalances and repetitive strain injuries [7]. One assessment tool for repetitive actions is the OCRA (Occupational Repetitive Actions) method, which is detailed in the OCRA checklist and OCRA index. It is recognized as the reference methodology by the technical standards of the International Organization for Standardization (ISO) 11228-3 “handling of low loads at high frequency,” alongside other methods such as the strain index and Hal/ACGIH TLV. The OCRA method incorporates time-based risk factors like recovery periods and action frequency, allowing risk evaluation based on exposure duration across multiple tasks through multitask analysis. The final risk score generated by OCRA, used to predict the likelihood of developing upper limb WR-MSDs, is derived from six multipliers or factors: frequency, force, posture, complementary factors, recovery, and duration. For the force multiplier, the Borg CR-10 scale [8] is recommended to evaluate the amount of force needed for specific tasks. Notably, the OCRA method does not consider age or gender differences, despite their significant impact on muscle strength. Conversely, the NIOSH equation for manual material handling explicitly accounts for age and gender differences, providing different lifting indexes for men and women of various ages (under 20 or over 45 years old), whether healthy or affected by MSDs.

A key benefit of the OCRA approach using the Borg CR-10 is that workers independently assess their perceived exertion during repetitive tasks. This micro-procedure takes only a short time and requires no special equipment. According to the instructions for applying the OCRA methodology [9], authors recommend this approach because it helps reduce bias. However, using the Borg CR-10 remains a subjective method that measures the relative internal load [10], which can also be influenced by temporary fatigue and familiarity with the task. This may lead to over- or under-estimation of effort, which could inevitably affect the force factor in the OCRA calculation. Additionally, previous reports indicate that psychosocial factors can also influence workers’ perception of effort during heavy physical work [11]. To mitigate this risk, authors recommend interviewing more than one worker per task, averaging the results, and excluding operators with disabilities or “anthropometric extremes.” However, this is rarely practical, and there are no specific guidelines on how to adjust (or if adjustment is necessary at all) the methodology in less-than-ideal situations.

One of the simplest tests to assess overall strength and physical efficiency is the handgrip strength test [12, 13], which has also been shown to serve as a prognostic marker for all-cause mortality [14] and disability [15]; notably, the handgrip strength test is recommended as a diagnostic tool capable of predicting the development of musculoskeletal disorders of the upper extremities [16, 17]. This test is quick to perform, requires minimal setup and explanation, and the device can be easily transported for field use. Therefore, this study aimed to explore the potential role of the handgrip strength test in a real work environment. Objectively measuring handgrip strength could serve as a helpful addition to interpreting biomechanical overload risk from repetitive actions using the OCRA method. A secondary goal was to examine whether workers with different strength levels report varying rates of perceived exertion during tasks, which could affect risk assessment.

2. Methods

Data were collected by trained ergonomists with at least five years of experience during risk evaluation procedures. They conducted interviews with workers at each company, gathering general health data such as stature, age, gender, dominant hand side, and handgrip strength. They also collected data for the formulation of the OCRA checklist, including working time, non-repetitive work time, rest time, video recordings of repetitive tasks, number of items processed per day, and the rate of perceived effort (RPE). The RPE was measured on a standard Borg CR-10 scale and related to technical actions that were subjectively identified as requiring muscular force. These actions, observed during recorded repetitive tasks, could involve either handling a significant load (e.g., lifting a heavy component for assembly) or performing forceful upper limb actions (e.g., tightening a bolt, sanding operations).

Handgrip strength was measured using a hydraulic dynamometer (Baseline Hydraulic hand dynamometer, Fabrication Enterprises Inc., White Plains, NY 1062, USA). The test involved the participant standing upright, with the arm at their side and the elbow flexed at 90°. Each participant completed three trials, with three minutes of rest between each attempt, and the highest result was recorded.

Handgrip strength percentiles stratified by gender, age, stature, and handedness were calculated for each participant for their dominant and non-dominant hands using the normative values presented by Spruit and colleagues [18], based on the UK Biobank database. The distribution of participants with below (<1st quartile), within (1st-3rd quartiles), or above (>3rd quartile) average handgrip percentile strength was then determined.

Participants were workers whose tasks included at least one hour of repetitive upper limb actions (but did not meet all of the quick assessment acceptability criteria), and their risk was assessed using the OCRA checklist. Participants had to be free of any current acute health condition that would be an absolute contraindication to work and were excluded if they were currently in training or had less than 6 months of experience at the tested workstation. Participants were considered outliers and excluded if their dominant handgrip strength was ≤ 5 kg.

Age groups were identified based on the age when muscle strength generally begins to decline, estimated to occur in the third decade of life, and the age after which the decline becomes more pronounced, after the fifth decade of life [19] as cut-off points. Descriptive statistics are shown as mean, standard deviation, or median and IQR range when appropriate. Normality of handgrip data was evaluated using the one-sample Kolmogorov-Smirnov test and through visual inspection of QQ-plots and histograms.

The Wilcoxon rank-sum test for unpaired samples was performed to compare the distributions of stratified percentiles between the group that reported a "moderate" or greater effort during work tasks and the group that did not. The Kruskal-Wallis rank sum test was used to compare handgrip percentiles across three age groups. The Jonckheere-Terpstra one-sided test for ordered alternatives assessed differences in perceived exertion rates—based on the OCRA categorization (ordered as: "No exertion" < "Moderate" < "Intense" < "Near maximum")—across grouped handgrip stratified percentiles (ordered as: "Below average" < "Average" < "Above average"). A permutation method was chosen to handle the large sample size and ties in the data, with 10000 permutations performed for each test. A significance level of $p < 0.05$ was set for all statistical tests. Percentages for age groups and perceived exertion categories were used solely for visualization purposes.

All statistical analyses were conducted using R version 4.4.2 [20] within the RStudio environment, version 2024.09.1+394 [21], utilizing packages such as tidyverse version 2.0.0 [22], dgof version 1.4 [23], pspearman version 0.3-1 [24], sjPlot version 2.8.15 [25], and DescTools version 0.99.58 [26]. Plots were generated using R with the packages ggplot2 version 3.5.1, ggpubr version 0.6.0 [27], and qqplotr version 0.0.6 [28].

3. Results

3.1. Participants' Characteristics

Data were collected from October 2020 to October 2024 for 903 workers (899 after removing outliers; 486 Women, 413 Men)), representing 41 companies across various sectors including manufacturing (such as furniture, eyewear, medical supplies, and electrical appliances; see Table S3,

Table 1. Description of the sample.

	Stature (m)	Age (y)	D Handgrip (kg)	ND Handgrip (kg)
Min	1.45	18	9.00	4.00
Max	1.97	66	71.00	69.00
Mean (SD)	1.70 (0.09)	43.59 (11.05)	33.94 (11.86)	30.19 (11.86)

D Handgrip: dominant side handgrip, ND Handgrip: non dominant side handgrip.

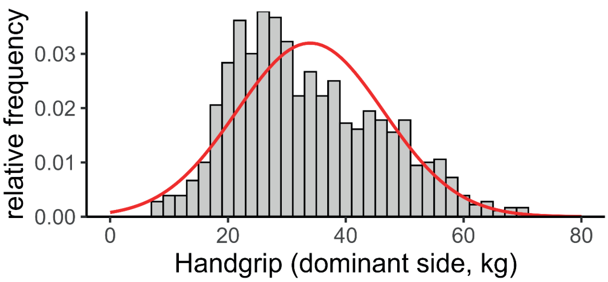

Figure 1. Dominant side handgrip strength (Kg) compared to a normal distribution using the same mean and SD.

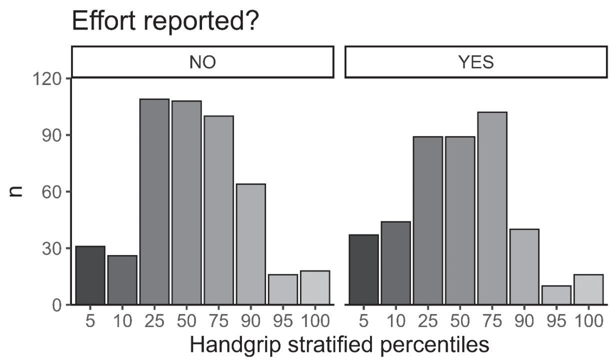

Figure 2. distribution of participants' handgrip percentiles according to their reporting of effort during working tasks.

available in the supplementary material), logistics, and waste management. Sample characteristics are reported in Table 1.

The Kolmogorov-Smirnov test for normality was significant for both the dominant and non-dominant sides' handgrip strength tests (N = 899, both p-values < 0.0001), indicating a non-normal distribution, consistent with visual inspection of histograms (see Figure 1 for the dominant side) and QQ-plots (Figures S1 and S2, available in Supplementary material, for the dominant and non-dominant sides, respectively), which show a right skewness of the data. A relative scale on the y-axis was used for Figure 1 to facilitate visual comparison with the normal curve.

3.2. Handgrip Strength Percentiles Distributions

After calculating handgrip strength percentiles, the sample was divided based on whether the participants reported any significant use of force, as defined in the OCRA methodology (RPE > 2), regardless of the type of task (Figure 2 and Table S4, available in the supplementary material). The groups showed significant differences in stature (No effort declared: 1.69 ± 0.09 m, effort declared: 1.71 ± 0.09 m, p = 0.0004) and handgrip strength on the dominant side (No effort declared: 33.06 ± 12.40 kg, effort declared: 34.93 ± 12.49 kg, p = 0.03). For a full description of the two groups, see table S1 in the supplementary material. Wilcoxon rank-sum test between the two groups indicated a significant difference in the distribution of handgrip stratified percentiles (W = 108375, p-value = 0.047).

3.3. Age Groups Analysis

Handgrip strength stratified percentiles showed a variable distribution across age groups (Figure 3), which are also described in Table S2 of the Supplementary material.

According to a Kolmogorov-Smirnov test, only the distribution of handgrip data for the youngest group appears to follow a normal distribution ($D_{18\text{-}34} = 0.08$, p-value = 0.14; $D_{35\text{-}49} = 0.10$, p-value = 0.001; $D_{50\text{-}66} = 0.12$, p-value = 0.0001).

The Kruskal-Wallis test on the distribution of handgrip strength percentiles stratified by age

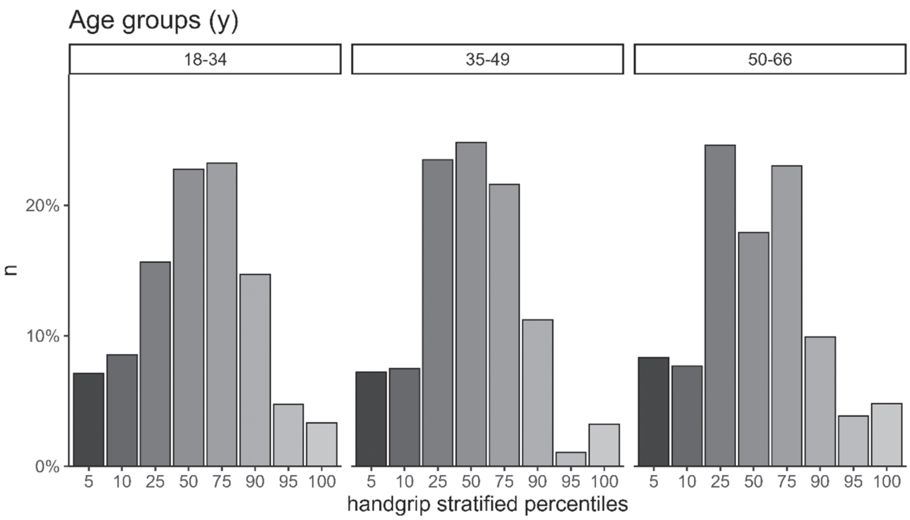

Figure 3. Percentage distribution of participants' percentiles between different age groups.

groups did not reach the significance threshold (H = 4.08, df = 2, p-value = 0.13).

3.4. Perceived Effort Values and OCRA Categories

The median RPE score was 0 with IQR = 4 for the dominant side and 0 with IQR = 3 for the non-dominant side.

The declared scores were aggregated into categories following the classification used in the OCRA method:

- RPE 0-2: no exertion.
- RPE 3-4: moderate exertion.
- RPE 5-7: intense exertion.
- RPE 8-10: near maximum exertion.

These are represented in Figure S3 and available in supplementary material. The participants were then grouped according to their respective handgrip strength percentiles (Figure 4a and 4b, dominant and non-dominant sides, respectively). Given the different sizes of the three groups, relative distributions were plotted as percentages (below average: 336, 37.4%; average: 399, 44.4%; above average: 164, 18.2%).

The Jonckheere-Terpstra test for ordered alternatives showed a statistically significant trend of lower Borg CR-10 scores, ranging from "No exertion" to "Near maximum," across higher handgrip strength percentile groups, from "Below average" to "Above average," for both the dominant side (JT = 120856, p-value = 0.04) and the non-dominant side (JT = 120098, p-value = 0.02).

4. Discussion

This study aimed to examine in a real-world setting whether using the handgrip strength test could serve as a useful and objective adjunct in interpreting biomechanical overload risk from repetitive upper limb actions with the OCRA checklist. The main finding was that the distribution of handgrip stratified percentiles was significantly affected (p-value = 0.047) by dividing participants into those who reported an RPE > 2 and those who did not. Among workers who reported significant effort during their tasks, 40% fell below the 1st quartile of the reference table, compared to 35% in the group that did not report significant effort. This difference is also reflected in the upper quartile distribution: 20% versus 15% in the groups that did and did not report effort, respectively.

Another interesting observation emerging from this analysis concerns data distribution. Handgrip strength values in workers performing upper-limb

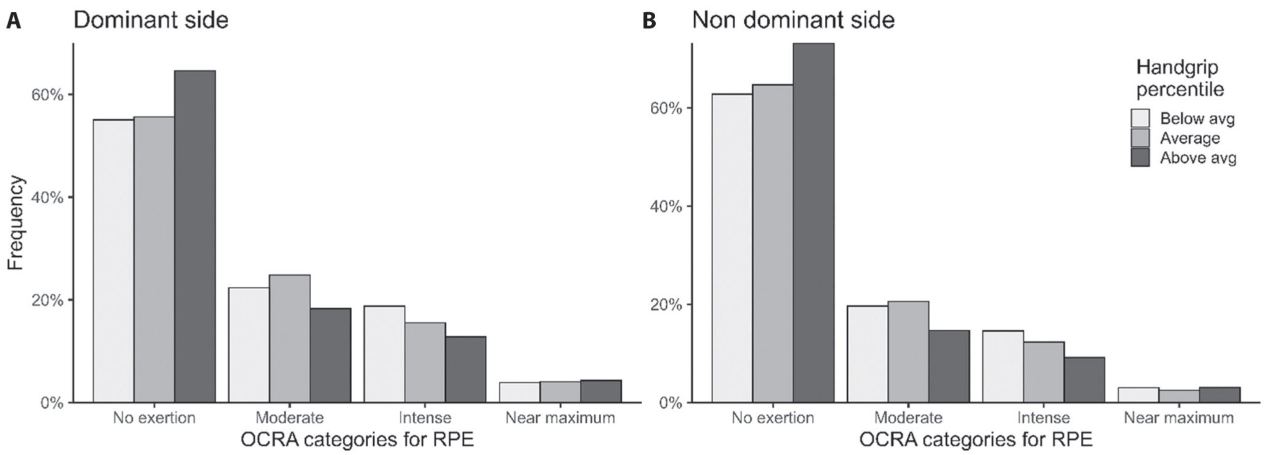

Figure 4. Percentage of rate of perceived effort declared grouped by OCRA categories and split between handgrip strength percentiles groups, **(a)** dominant side; **(b)** non-dominant side.

repetitive actions appear to deviate from a normal distribution with a right skew and show a distribution that is significantly below the expected percentiles, even after accounting for gender, age, stature, and handedness. Several possible explanations could account for the observed discrepancy: this subgroup (workers engaged in repetitive upper-limb actions) may not be representative of the general population. Additionally, the sample was not randomly selected but instead obtained during risk evaluation procedures, which could introduce selection bias despite the large sample size. One could argue that companies with higher work demands and a greater prevalence of musculoskeletal disorders are more likely to request a risk assessment; however, this process is mandatory in Italy under Legislative Decree No. 81 of 2008 (and subsequent changes) [29] and must be updated whenever there are changes in working conditions, production processes, or organization, reducing this potential bias. We instead hypothesize that the high prevalence of musculoskeletal disorders among workers, as extensively reported for both the EU and USA [30, 31], may partially explain their reduced performance in the handgrip test. Previous studies have shown significant associations between lower handgrip strength and low back pain [32], as well as a higher risk of work limitations [33]. Furthermore, an observational study by Walker-Bone et al. [34] found that lifetime exposure to physically demanding work was inversely associated with handgrip strength (although this effect was not statistically significant after adjusting for socioeconomic confounders).

It is worth emphasizing that the data we refer to throughout this paper are not raw percentiles of handgrip strength, but already adjusted to account for age, gender, handedness, and stature, producing stratified rankings. When we divided the data into three age groups, only the youngest group followed a normal distribution, while the older groups showed a right skew, suggesting that the decline in handgrip strength with age may be more pronounced in manual workers. Although the distributions were not significantly different ($p = 0.13$), manual workers tend to have lower handgrip strength compared to individuals of the same age, gender, handedness, and stature. These points raise an important question: if workers with below-average handgrip strength are more likely to report significant effort in their tasks (RPE > 2), could the risk assessment process be improved by incorporating an objective measure of handgrip strength? Particularly in the OCRA checklist, the force evaluation can greatly influence the risk assessment for repetitive actions, with scores reaching over 32 points (a score of ≥ 22.5 indicates high risk) for near-maximum efforts sustained over more than 10% of the work cycle. Therefore, it is crucial that this component of the risk assessment accurately reflects the true demands of the task.

The same trend appears when examining the distribution of RPE across different handgrip strength percentile groups, for both the dominant and non-dominant sides. From fig 4 a and b, it is evident that (for both sides) the above-average group reported no exertion more often and moderate or intense exertion less frequently compared to other groups. Conversely, the below-average group reported no exertion the least and more often reported intense exertion. These trends are statistically significant ($p = 0.04$ and $p = 0.02$ for the dominant and non-dominant sides, respectively), further supporting the idea that handgrip strength influences effort perception measured with the Borg CR-10 scale during work tasks. Therefore, including a strength assessment such as the handgrip test in the risk evaluation process may help reduce subjectivity related to the interviewed worker and enhance the focus on an objective evaluation of the task itself. The differences among the three handgrip strength percentile groups diminish when considering the "near maximum" category. We hypothesize that, for very heavy lifts, the variation in handgrip strength scores becomes less relevant in determining perceived effort (e.g., for a 97 kg shaft spool and coil lifted by two workers). Additionally, since workers with lower handgrip strength scores may be more prone to WR-MSD, they might face work limitations when performing tasks that involve particularly heavy lifts.

In summary, adding handgrip strength evaluation during risk assessment is practically feasible since the test can be done with portable equipment, quickly, and with minimal risk to the person tested. A future perspective could involve applying these results to explore different methods of calibrating risk calculation related to force use, such as adjusting the declared Borg CR-10 scores for workers with very low or very high handgrip scores. Alternatively, the adjustment could be implemented further downstream, directly in the risk-score factors. Compared to the reported Borg CR-10 score, multipliers would offer greater precision, with a broader range (1-32), and the option to use decimal values for fine-tuning. Another approach might include applying different multiplying factors based on age and gender, similar to the NIOSH equation, or directly using handgrip percentile to develop a stratified risk index that accounts for individual muscular strength differences and the potential non-normal distribution of data.

On one side, we recognize some limitations in the present study: first, we lacked information on workers' seniority, which likely plays an important role in increasing the risk of developing a WR-MSD; similarly, we did not have access to medical details of the workers interviewed and could not distinguish between healthy workers and those who had a hidden WR-MSD that did not prevent them from fully attending work. Additionally, companies and workers were not selected at random. On the other hand, we also highlight some strengths in our investigation. We collected data from over 900 workers from a diverse group of companies located in different regions of Italy. To the best of our knowledge, this is the first study exploring this aspect of the OCRA methods, and we believe it could be a significant step toward improving the risk assessment process.

5. Conclusion

Handgrip strength appears to be distributed differently among workers exposed to repetitive upper limb actions, showing a non-normal, right-skewed distribution compared to the general population. We hypothesize that this difference may be caused by the high prevalence of WR-MSD in this subgroup. This difference is more noticeable in workers reporting the use of force (RPE > 2) during any task. Conversely, workers with lower handgrip strength values (considering age, gender, handedness, and stature) are more likely to report effort during their tasks, compared to those with higher handgrip scores. In this context, adding handgrip strength assessment could provide more objectivity to biomechanical load risk evaluation, especially when it is not feasible to interview multiple workers for the same task. The evaluation and integration of the handgrip test could help refine this part of the assessment.

Supplementary Materials: The following are available online: Figure S1. QQ-plot of dominant side handgrip strength; Figure S2. QQ-plot for nondominant side handgrip strength; Figure S3. Frequency of rate of perceived effort declared grouped by OCRA categories; Table S2. Descriptive statistics stratified in age groups; Table S3. Number of companies evaluated by sector; Table S4. Stratified percentiles distribution split by effort declaration.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Declaration of Interest: The authors declare no conflict of interest.

Author Contribution Statement: G.S. and B.M. conceived and planned the investigation; B.V., P.D., and B.A. contributed to the design of the research and collected the data; F.F. and G.S. wrote the first drafts of the paper; F.F., B.V., and D.B. designed and performed the analysis; D.P.G., S.E., M.S., and D.B.A. contributed to the writing and revision of the paper and provided key insights. All authors reviewed and approved the final draft of the paper.

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APPENDIX

SUPPLEMENTARY MATERIAL

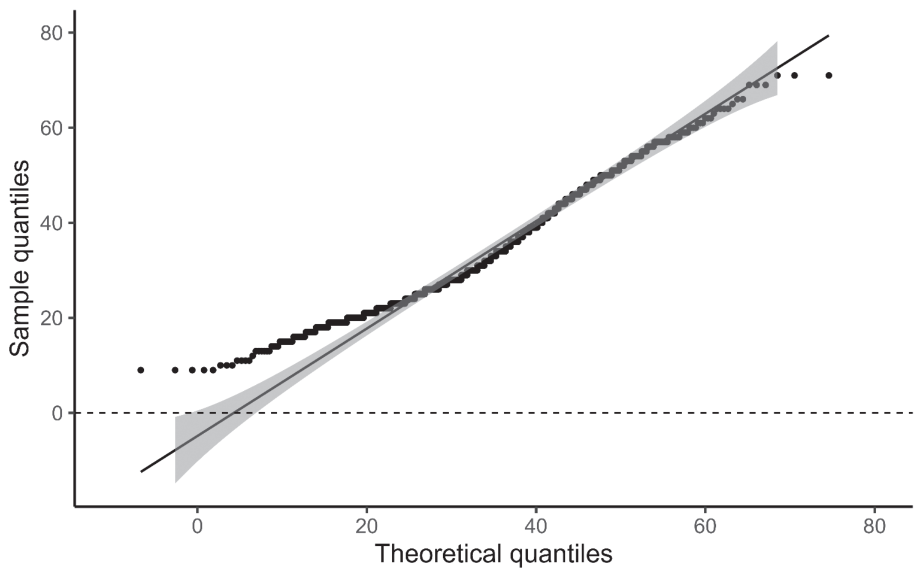

Figure S1. QQ-plot of dominant side handgrip strength.

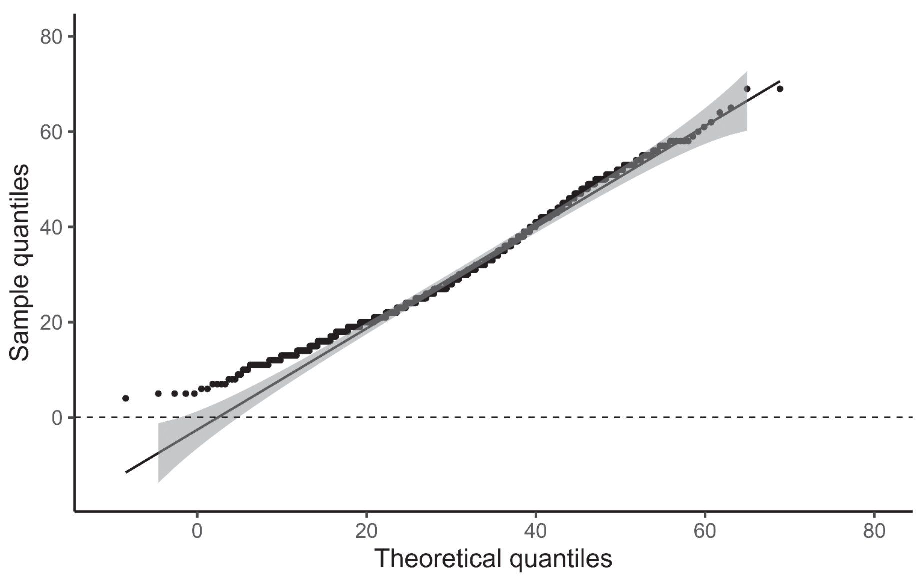

Figure S2. QQ-plot for nondominant side handgrip strength.

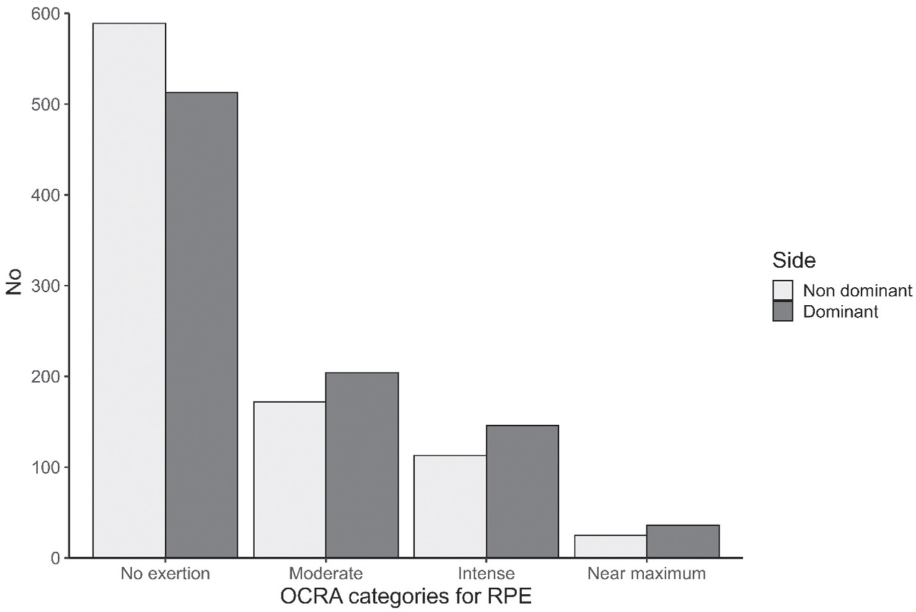

Figure S3. Frequency of rate of perceived effort declared grouped by OCRA categories.

Table S1. Descriptive statistics divided between persons that reported effort or not on the Borg CR-10 scale.

Effort declared	N	Stature (m)	Age	D Handgrip (kg)	ND Handgrip (kg)
No	472	1.69 (0.09)	43.74 (10.95)	33.06 (12.40)	29.50 (12.13)
Yes	427	1.71 (0.09)	43.43 (11.16)	34.93 (12.49)	30.95 (11.52)
p value[1]	-	**0.0004**	0.7	**0.03**	0.07

Descriptive data are presented as mean (SD); D: dominant side; ND: non-dominant side.
[1]*: two-sample Welch t-test, significant difference highlighted in bold.*

Table S2. Descriptive statistics stratified in age groups.

Age group	N	M/F	Stature (m)	D Handgrip (kg)	ND Handgrip (kg)
18-34	211	129/82	1.73 (0.09)	38.97 (12.70)	34.39 (11.85)
35-49	375	149/226	1.69 (0.09)	32.86 (11.73)	29.31 (11.05)
50-66	313	135/178	1.69 (0.09)	31.86 (12.70)	28.41 (12.15)

M/F: number of males and females in each group; D: dominant side; ND: non-dominant side.
Descriptive data are presented as mean (SD).

Table S3. Number of companies evaluated by sector.

Sector		N companies	N workers
Bookbinding		1	6
Logistics		2	23
Meat processing		1	13
Waste disposal		1	4
Manifacturing			
	Chemical products, paints, etc.	5	69
	Drugs and pharmaceutical preparations	1	19
	Electrical cables	2	28
	Electronic components	2	123
	Eyewear	3	165
	Furniture	5	186
	Medical instruments and supplies	2	26
	Metallic products	2	15
	Plastic materials and products	5	99
	Shoes	1	42
	Vehicle parts and components	3	38
	Other manifacturing	5	47

Other manufacturing comprises: electrical parts, lighting appliances, pumps and compressors, paper products, and prostheses.

Table S4. Stratified percentiles distribution split by effort declaration.

Stratified percentile	Effort: no (n = 472)	Effort: yes (n = 427)	Effort: no (%)	Effort: yes(%)
5	31	37	6.6%	8.7%
10	26	44	5.5%	10.3%
25	109	89	23.1%	20.8%
50	108	89	22.8%	20.8%
75	100	102	21.2%	23.9%
90	64	40	13.6%	9.4%
95	16	10	3.4%	2.3%
100	18	16	3.8%	3.8%

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A 21-Year Perspective on Occupational Skin and Respiratory Diseases Among Food Handlers

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Keywords: Cooks; Pastry-Makers; Bakers; Occupational Skin Diseases; Asthma; Rìhinitis

Abstract

Background: *Food handlers may have an increased risk of developing occupational skin and respiratory diseases.* **Methods:** *This retrospective study was based on examinations, skin prick testing, and patch testing performed at the Unit of Occupational Medicine at the University of Trieste (N-E Italy) between 2002 and 2022 in food-handler workers referred to the unit for suspected occupational allergic diseases.* **Results:** *More than half of the population (58.1%) experienced occupational skin diseases, with a higher prevalence among women (OR 3.3, 95% CI 1.5-7.6). Irritant contact dermatitis was the most prevalent skin condition (22.9%), followed by allergic contact dermatitis (20%) and protein contact dermatitis (15.1%). Pastry makers and bakers exhibited a high rate of protein contact dermatitis (20.6 and 17.7%, respectively), which was primarily attributed to wheat flour. Of the participants, 47.8% reported having rhinitis, and 17.6% reported having asthma. Positive SPT results were observed in 34.4% of workers with rhinitis and 58.3% of those with asthma, with bakers and pastry makers being more frequently sensitized to wheat flour (22.8% and 20.6%, respectively). Cooks reported rhinitis (43.2%) and asthma (12.3%) with sensitization to soy, scampi, peanuts, and other foods. Atopy determined by prick test was significantly linked to respiratory symptoms. Bakers and pastry makers showed significantly higher sensitivity to wheat flour (OR 3.3, 95% CI 1.3-7.8).* **Conclusions:** *Food handlers can experience occupational skin and respiratory diseases, and more efforts are needed to prevent such diseases by improving preventive habits and avoiding exposure to allergens.*

1. Introduction

Skin and respiratory diseases are common in food workers due to exposure to irritants and sensitizing agents. In terms of numbers, this occupational group ranked third after hairdressers and healthcare workers for occupational skin diseases [1] in patients who underwent patch testing. Considering epidemiological data on the incidence of occupational skin diseases (OSD), Dickel et al. reported in 2002 that there were 37.7 cases per 100,000 workers among bakers and pastry makers, and 8.5 cases per 100,000 workers among all food handlers in Germany [2].

The main cause of irritant contact dermatitis (ICD) in these workers is repeated water exposure, followed by the use of soaps and detergents during cleaning, as well as contact with food [3]. Besides wet work, these workers are also exposed to heat and thermal burns, which damage the skin's barrier

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and raise the risk of skin diseases [4]. Additionally, bakers, cooks, and pastry makers can develop allergic contact dermatitis (ACD) due to sensitization to rubber additives like thiuram mix [5]. A potential role of nickel sulfate in handled pans and pots has been suggested [6]. However, an extensive database of 1,297 food handlers with suspected ACD investigated in the North East of Italy did not find any increased risk of sensitization compared with clerks [5].

A specific type of contact dermatitis is Protein Contact Dermatitis (PCD), which is characterized by an allergic skin reaction mainly triggered by proteins of animal or plant origin. [7]. Bakers, pastry chefs, and cooks can all be affected. Nieto et al. [8] showed that common allergens causing dermatitis include peanuts, scampi fish, tomatoes, onions, garlic, milk, grains, and meat, with a positive prick test for the offending allergen.

Work-related allergic respiratory disorders are common in bakers, with approximately 15-20% of workers experiencing rhinitis and 5-10% developing asthma, making it a common occupational health concern [9]. Baker's asthma ranks as the second leading cause of occupational asthma in Norway and England and the primary cause in France, Germany, and Italy [10] with sensitization to flours or enzymes [11]. A study conducted among bakers in the Veneto region [12] reported a prevalence of occupational asthma of 7% and upper respiratory symptoms of 22%, with 37.1% of participants sensitized to occupational allergens. The age of symptom onset varies, but the highest risk occurs within the first two years of exposure [13].

Exposure to flour dust has been recognized as a trigger for allergic sensitization and respiratory diseases; however, other causative agents, such as different flours, enzymes (alpha-amylase), egg proteins, and organic contaminants, including storage mites, molds, and insects, have also been identified [14-16]. Cross-reactivity among different flours is common, with lupine proteins emerging as antigens. Fungal enzymes, such as *Aspergillus*-derived α-amylase, are significant triggers for OA, as are other enzymes [17]. Soya flour, used as a baking additive, can cause sensitization to components like lipoxygenase and soybean trypsin inhibitors, leading to asthma and rhinitis [18, 19]. Gluten-free and vegan baking ingredients, such as psyllium derived from Plantago ovata, have also been linked to occupational rhinitis and dermatitis [20]. Additionally, kitchen workers exposed to cooking fumes may develop rhinitis and asthma due to inhaling food allergens like seafood. A recent systematic review on occupational asthma analyzed only five studies dealing with occupational exposure to wheat flour, crabs, and spices [21], though more data are needed on these professional groups.

Despite major changes in food production methods, skin and respiratory symptoms related to work stay high, especially in the artisan sector, where work conditions are the worst and exposure to allergens can be greater. Our study aimed to investigate skin and respiratory symptoms in food handlers who underwent a medical examination for a suspected occupational disease at the Unit of Occupational Disease at Trieste University from 2002 to 2022.

2. Methods

This retrospective study analyzed 205 food workers examined at the Occupational Health Clinic (University of Trieste) for suspected allergic occupational diseases from 2002 to 2022. The group was composed of 81 kitchen workers (19 men and 62 women), 79 bakers (48 men and 31 women), 34 pastry workers (14 men and 20 women), and 11 food industry workers (six men and five women).

Each participant underwent a thorough medical assessment, including skin prick tests (SPTs) for common and occupational allergens, as well as patch tests if allergic contact dermatitis was suspected. Additionally, all subjects were required to complete a standardized questionnaire based on the Nordic Occupational Skin Questionnaire (NOSQ-2002) [22] to gather information on their symptoms, occupational exposure, smoking habits, atopy or familial allergies, and personal history of dermatitis and respiratory symptoms. ICD was defined in cases of local inflammatory reactions characterized by erythema, fissures, edema, vesicles, and blisters after exposure to irritant agents and water [3]. The patch test results were usually negative or irrelevant. ACD was defined as a local inflammatory reaction characterized by erythema, edema, vesicles, blisters, and itching, with positive and relevant patch tests.

PCD was defined as acute flares of symptoms, such as pruritus (itching), urticaria (hives), edema (swelling), or vesiculation, occurring within minutes of contact with the causative substance. Moreover, the patch test was typically negative, while the prick test with food was positive [7]. Contact urticaria (CU) was defined as a wheal-and-flare reaction that occurs immediately after external contact with a specific food, clearing completely within hours without residual signs of irritation or the presentation of eczema [23].

Diagnosis of asthma was supported by spirometry and, when needed, a methacholine challenge. In patients with asthma, work-related asthma was defined as recurrent cough, wheezing, and dyspnea that occurred exclusively during work or significantly worsened at the workplace. Allergic occupational asthma was diagnosed by a specialist in occupational medicine in patients with work-related asthma that occurred only during work, with a positive result for the suspected occupational allergen. Irritative occupational asthma was diagnosed by a specialist in occupational medicine in patients with work-related asthma that occurred only during work, with no positive result for any occupational allergen, but with exposure to irritants at work. Occupational rhinitis was described as symptoms such as sneezing or an itchy, runny nose that occurred solely during working hours and were attributed to workplace conditions.

Before conducting SPTs, a comprehensive interview with a trained physician was undertaken to identify and exclude individuals at risk for severe adverse reactions to SPTs. Individuals who had experienced a severe asthma attack within the past year or had a history of anaphylactic shock or severe reactions to allergens being tested were excluded. Workers taking antihistamine medications during testing were also exempted from SPTs. Skin prick tests were performed with a panel of common inhalant allergens, including perennial allergens such as *Dermatophagoides farinae, Dermatophagoides pteronyssinus*, dog and cat dander, pollens, foods like soy, yeast, white eggs, yolks, milk, peanut, scampi fish, and specific occupational allergens like latex, wheat, rye, barley, rice flours, green coffee bean, and α-amylase. Lofarma Allergeni (Milan, Italy) provided allergen extracts for testing, and SPT was performed using standardized lancets (Hollister Stier Laboratory, Spokane, Washington). After a 15-minute wait, all tests were read and recorded, with a wheal of at least 3 mm considered a positive result. A single positive response to an inhalant allergen was the defining criterion for atopy, as determined by the SPT. No adverse reactions to SPTs were reported in this study.

Patch testing was performed using the European baseline series, with Finn® Chambers applied on aluminum on Scampor® tape (Epitest Ltd, Tuusula, Finland). Additionally, specific allergens, including the flours they worked with, were tested by bakers and pastry makers. The substances used and the clinical protocols remained consistent throughout the study period. Substances were applied to the upper back and removed after 48 hours (day 2). Examination of the test sites was performed upon removal and again after either 24 h (day 3) or 48 h (day 4), following the guidelines established by the International Contact Dermatitis Research Group [24].

Data analysis was performed using STATA 13.0 (STATA Corp, College Station, Texas, USA). Continuous data are summarized as median and 25°-75° percentiles. Differences between the mean values were assessed using the Mann-Whitney test. Categorical data were analyzed using the appropriate likelihood chi-square test with Yates' correction. Univariate logistic regression analysis assessed factors associated with occupational skin diseases or respiratory symptoms (asthma and/or rhinitis). Factors that were significantly associated were included in the multivariate logistic regression analysis. Results are reported as odds ratios (ORs) and 95% confidence intervals (CIs). A sensitivity analysis was performed to verify factors associated to only skin or respiratory symptoms.

3. Results

Table 1 summarizes the general characteristics of the study population. There were 87 males and 118 females, with a median age of 34 and 25th-75th percentiles of 27-45 years. The median

Table 1. Characteristics and workers studied according to gender.

	Men **N (%)** **87 (42.4)**	**Women** **N (%)** **118 (57.6)**	**Total** **N (%)** **205 (100)**	**P**
Age, years, median (25°-75° percentiles)	32 (25-75)	37 (27-45)	34 (27-45)	0.264
Seniority of work, years, mean (CI 95%)	9 (1-23)	6 (2-12)	7 (2-15)	0.155
Job tasks, N (%)				
Food industry-workers	5 (5.7)	1 (0.85)	6 (2.9)	<0.001
Bakers	48 (55.2)	31 (26.3)	79 (38.5)	
Pastry-makers	14 (16.1)	20 (17.0)	34 (16.6)	
Cooks	19 (21.8)	62 (52.5)	81 (39.5)	
Trainees	1 (1.2)	4 (3.4)	5 (2.4)	
Smoke habits, N (%)				
Smokers	25 (28.74)	42 (35.6)	67 (32.7)	0.324
Ex smokers	18 (20.7)	16 (13.6)	34 (16.6)	
Familiar Allergy N (%)	33 (37.9)	51 (43.2)	84 (41.0)	0.447
Atopic eczema N (%)	23 (26.4)	32 (27.1)	55 (26.8)	0.913
Diseases N (%)				
Contact dermatitis	39 (44.8)	80 (67.8)	119 (58.1)	0.001
Urticaria	8 (9.2)	13 (11.0)	21 (10.2)	0.671
Oculorhinitis	49 (56.3)	49 (41.2)	98 (47.8)	0.053
Asthma	18 (20.7)	18 (15.3)	36 (17.6)	0.288
Symptoms duration, years (SD) CI 95%	1 (0.66-4)	1 (1-3)	1 (1-3)	0.753

latency period before symptom onset was 7 years (25th-75th percentiles: 2-15 years).

An analysis of smoking habits revealed that nearly 50% of the study population was either smokers or ex-smokers, with no statistically significant difference between the sexes (p=0.324). Furthermore, regarding individual allergic susceptibility, 84 (41%) workers reported having at least one family member with allergies. Additionally, 55 (26.8%) individuals had a history of atopic dermatitis, with no significant differences between the sexes.

Skin-related conditions were the most common work-related diseases, including ACD, ICD, PCD, and urticaria (Table 2). Women had a higher prevalence of skin disease than men (67.8% *vs.* 44.8%, respectively, p=0.001). ACD and PCD affected 72 (35.1%) workers (23 men and 49 women), with a statistically significant difference between the two groups (p=0.008). ICD was observed in 16 men and 31 women, with no significant difference between sexes (p=0.185).

Ninety-eight workers had oculorhinitis (47.8%) and 36 (17.6%) reported asthma during their work. The median duration of symptoms was 1 year (25°-75° percentiles 1-3 years), similar in both sexes. Cooks were the most represented professional group (n. 81, 39.5%), and 60.5% of them reported occupational contact dermatitis (29.6% ACD, 11.1% PCD, 19.8% ICD, 11.1% urticaria) with sensitization to various allergens (Table 3).

Patch tests were positive for nickel sulfate (30.6%), thiuram mix (2%), benzoyl peroxide

Table 2. Characteristic of workers and distribution of work-related diseases in 205 workers from the food industry.

	Food industry(%)	Bakers (%)	Pastry-makers (%)	Cooks (%)	Total (%)
Study subjects N (%)	11 (5.4)	79 (38.5)	34 (16.6)	81 (39.5)	205 (100)
Age median years (25th-75th percentile)	38 (32-43)	33 (28-47)	31 (24-42)	37 (28-45)	34 (27-45)
Seniority, years (25th-75th percentile)	2 (1-3)	10 (2-20)	7 (2-12)	6 (2-13)	7 (2-15)
Smoking habits N (%)					
Smokers	4 (36.4)	23 (29.0)	12 (35.3)	28 (34.6)	67 (32.7)
Ex smokers	1 (9.1)	16 (20.2)	7 (20.6)	10 (12.35)	34 (16.6)
Familiar Allergy N (%)	4 (36.4)	30 (38)	16 (47.0)	34 (42.0)	84 (41.0)
Atopic eczema N (%)	3 (27.3)	22 (27.9)	8 (23.5)	22 (27.2)	55 (26.8)
Work-related symptoms N (%)					
Contact dermatitis	7 (72.7)	38 (48.1)	25 (73.5)	49 (60.5)	119 (58.1)
ACD	1 (9.1)	10 (12.6)	8 (23.5)	24 (29.6)	41 (20.0)
PCD	1 (9.1)	14 (17.7)	7 (20.6)	9 (11.1)	31 (15.1)
ICD	5 (45.4)	14 (17.7)	10 (29.4)	16 (19.8)	47 (22.9)
Urticaria	0	7 (8.9)	5 (14.8)	9 (11.1)	21 (10.2)
Oculorhinitis	5 (45.4)	43 (54.4)	15 (44.1)	35 (43.2)	98 (47.8)
Asthma	4 (36.4)	18 (22.8)	4 (11.8)	10 (12.3)	36 (17.6)
• Occ. Allergic N (% on asthma)	2 (50)	8 (44.4)	4 (100)	4 (40)	19 (52.8)
• Occ. Irritative N (% on asthma)		6 (30)			6 (16.7)
• Work exacerbated asthma N (% on asthma)	2 (50)	4 (22.2)		6 (60)	12 (33.3)
Symptom duration, median y (25th-75th percentile)	1 (1-1)	1 (0.66-3)	1 (1-2)	1.25 (1-6)	1 (1-3)

ACD = allergic contact dermatitis. ICD=irritant contact dermatitis. PCD=protein contact dermatitis.

(4.1%), and diallyl disulfide (4.1%). Oculorhinitis and asthma were reported by 43.2% and 12.3% of cooks, respectively. Five of 54 tested (9.3%) were sensitized to wheat flour, 5 of 52 (9.6%) to soy, 4 of 81 (4.9%) to scampi with symptoms cooking them, 3 of 81 (3.7) to peanut, one of 81 to fish (1.2%), one to latex, and few of them were sensitized to other allergens (Table 3).

The number of bakers was 79 (38.5%); more than half reported work-related rhinitis (54.4%), 22.8% had asthma, 8.9% had urticaria, and 48.1% had skin symptoms. Allergy to wheat flour was demonstrated in 22.8% of workers, 8.9% were sensitized to soy, 7% to alpha-amylase from *Aspergillus oryzae,* and a few subjects were sensitized to other potential professional allergens such as yeast, eggs, and other flours. Two workers reported symptoms with latex gloves that were positive for the skin prick test. In bakers with skin diseases, 9 of the 34 patches tested (26.5%) were positive for standard allergens (nickel sulfate, palladium chloride, balsam of Peru, and potassium dichromate). Furthermore, 5.9% of the samples were positive for sodium metabisulfite, a common reducing agent used in dough preparation. Fourteen (17.7%) had PCD with sensitization to wheat, soy, yeast, rye, barley, and white eggs (Table 2 and Table 3).

Pastry makers reported work-related oculorhinitis, asthma, and urticaria in 44.1%, 11.8%, and 14.8%

Table 3. Results of skin prick test and patch test in different occupations. Patch test concentration is reported in percent.

Skin prick test	**Food industry N. 11 N/tested (%)**	**Bakers N. 79 N/tested (%)**	**Pastry- makers N. 34 N/tested (%)**	**Cooks N. 81 N/tested (%)**	**Total N. 205 N/tested (%)**
Wheat/whole wheat flours	0/2	18/79 (22.8)	7/34 (20.6)	5/54 (9.3)	30/169 (17.8)
α-amylase from *Aspergillus Oryzae* (IgE)	-	3/43 (7.0)	-	-	3/43 (7.0)
Rye flour	-	1/79 (1.3)	0/34	-	1/113 (0.9)
Barley flour	-	2/79 (2.6)	0/34	-	2/113 (1.8)
Rice flour	-	0/79	0/34	-	0/113
Soy	2/11 (18.2)	7/79 (8.9)	2/34 (5.9)	5/52 (9.6)	16/167 (9.6)
Yeast	-	2/79 (2.5)	1/34 (2.9)	0/50	3/163 (1.8)
White eggs	-	2/79 (2.5)	1/34 (2.9)	1/81 (1.2)	4/194 (2.1)
Yolks	-	2/79 (2.5)	2/34 (5.9)	1/81 (1.2)	4/194 (2.1)
Milk	-	0/79	0/34	2/81 (2.4)	2/194 (1.0)
Peanut	-	1/10 (1.3)	-	3/81 (3.7)	4/91 (4.4)
Scampi	-	1/10 (1.3)	1/34 (2.9)	4/81 (4.9)	6/125 (4.8)
Fish	-	1/10 (1.3)	-	1/81 (1.2)	2/91 (2.2)
Latex	-	2/2 (100)	1/1 (100)	1/1 (100)	4/4 (100)
Green coffee bean	1/1 (100)	-	-	-	1/1 (100)
Dermatophagoides farina	3/10 (30.0)	27/71 (38.0)	6/27(22.2)	18/53 (34.0)	54/161 (33.5)
Dermatophagoides pteronyssinus	2/10 (20.0)	24/71 (33.8)	5/27 (18.5)	19/53 (35.8)	50/161 (31.0)
Dog dander	1/10 (10.0)	8/71 (11.3)	4/27 (14.8)	11/53 (20.7)	24/161 (14.9)
Cat dander	1/10 (10.0)	7/71 (10.8)	4/27 (14.8)	7/53 (13.2)	19/161 (11.8)
Alternaria alternata	1/10 (10.0)	4/71 (5.6)	0/27	5/53 (9.4)	10/161 (6.2)
Graminae	4/10 (40.0)	21/71 (29.6)	5/27 (18.5)	16/53 (30.2)	46/161 (28.6)
Compositeae	1/10 (10.0)	7/71 (9.9)	1/27 (3.7)	5/54 (9.3)	15/162 (9.2)
Cupressaceae	1/10 (10.0)	11/71 (15.5)	3/27 (11.1)	6/53 (11.3)	21/161 (13.0)
Betulaceae	2/10 (20.0)	15/71 (21.1)	1/27 (3.7)	11/53 (20.7)	29/161 (18.0)
Oleaceae	2/10 (20.0)	13/71 (18.1)	2/27 (7.4)	10/53 (18.9)	27/161 (16.8)
Patch test (occupational)					
Nickel sulphate 5%	1/7 (14.3)	5/34 (14.7)	2/20 (10.0)	15/49 (30.6)	24/110 (21.8)
Thiurams mix 1%	0/7	0/34	0/20	1/49 (2.0)	1/110 (0.9)
Benzoyl peroxide 2%	0/7	0/34	1/20 (5.0)	2/49 (4.1)	3/110 (2.7)
Ammonium persulfate 1%	0/7	0/34	0/20	0/49	0/110
Sodium metabisulfite 5%	0/49	2/34 (5.9)	2/20 (10)	0/49	4/110 (3.6)
Sorbic acid 5%	0/7	0/34	0/20	0/49	0/110
Butylated hydroxyanisole 2%	0/7	0/34	0/20	0/49	0/110
Butylated hydroxytoluene 2%	0/7	0/34	0/20	0/49	0/110
Propylgallate 0.1%	0/7	0/34	0/20	0/49	0/110
Diallyl disulphide 1%	-	-	-	2/49 (4.1)	2/49 (4.1)
Patch test with flours in water	-	0/34	0/20	0/49	0/103

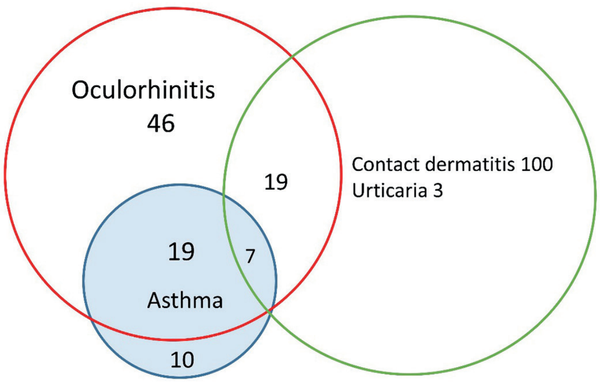

Figure 1. Symptoms and co-morbidities in workers involved in the study.

of the cases, respectively. The prevalence of skin symptoms was higher than that in bakers (73.5% vs. 48.1%, p<0.02). The prevalence of sensitization to wheat flour was over 20%, whereas sensitization to other flours was less relevant. Positive results were also observed for yeast, legumes, soy, and eggs. In patch tests, 2/20 (10%) individuals tested positive for nickel sulfate, 2/20 (10%) for sodium metabisulfite, and 1/20 (5%) for benzoyl peroxide, a possible oxidizer used in flour. Seven pastry makers had PCD (20.6%), with sensitization to wheat (n = 3), soy (n = 2), egg yolk (n = 1), yeast (n = 1), and white eggs (n = 1).

Among the 11 food industry workers investigated, most reported skin diseases (72.7%), primarily ICD (45.4%). One subject was sensitized to nickel sulfate. Four (36.4%) patients reported asthma with oculorhinitis. In two cases, we found sensitization to soy and, in one case, to green coffee beans in a worker occupied in a coffee roasting facility. In one case, we did not find any specific occupational allergens.

Figure 1 reports the relationship between symptoms: 26 subjects with skin diseases also had oculorhinitis (26/119=21.8%). Twenty-six subjects with asthma also had oculorhinitis (26/36=72.2%).

Factors associated with skin and respiratory diseases were investigated using univariate and multivariable logistic regression analyses. Results showed an increased risk of occupational skin diseases among women (OR 3.3; 95% CI 1.5-7.6) and an increased risk for bakers and pastry makers to be sensitized to wheat (OR 3.3; 95% CI 1.30-7.81) and common allergens. Differences were found between the different work tasks analyzed (Supplementary Table 1). When considering only subjects with respiratory diseases, women are underrepresented compared to men (OR 0.3; 95% CI 0.1-0.8).

4. Discussion

Our study reports occupational symptoms in a large group of food handlers in the Trieste Province from 2002 to 2022. Skin or respiratory work-related symptoms began at a median age of 34 years (25th-75th percentiles 27-45 years), a value higher than that reported in other studies [25-26], where the median age was lower and around the twenties. Symptoms appeared in the median after 7 years of work (25th-75th percentiles 2-15 years), which aligns with previous reports [25-26], and the median symptom duration was 1 year. Women had a higher prevalence of skin diseases than men (67.8% vs. 44.8%). It is well known that women are more exposed to detergents and irritants, and their skin is thinner, increasing their risk of being affected by irritants and allowing greater permeation of allergens [27]. About half of the workers were smokers or ex-smokers, a rate higher than that reported in similar workplace studies (24% of current smokers in a survey of bakers in Verona province, reported by Olivieri et al. 2021 [28]). Additionally, smoking raises the risk of skin and respiratory allergic diseases due to its effects on skin microcirculation and the irritant effects on airways [29, 30]. Familial allergy was reported by 41% of workers. In comparison, 26.8% had a personal history of atopic eczema, which is a well-known risk factor for respiratory allergic diseases [31].

4.1 Skin Diseases

Fifty-eight percent of workers presented with skin diseases involving the hands and fingers, with pastry makers having the highest prevalence (73.5%). This value was expected because of wet work, protective gloves, and contact with irritants and allergens. In a recent paper on subjects who underwent patch tests for suspected allergic contact dermatitis in the North East of Italy, food handlers ranked 3rd after healthcare workers and metal workers regarding the number of workers tested [5]. Compared to clerks, they presented a higher risk of hand dermatitis (odds ratio [OR] 2.15; 95% confidence interval [CI] 1.89–2.45) and occupational irritant or allergic contact dermatitis (OR: 7.7; 95% CI 6.37–9.54).

ICD prevalence was 22.9% of the workers tested, with vast differences between professional groups: 45.4% in food industry workers, 29.4% in pastry makers, 19.8% in cooks, and 17.7% in bakers. The variability in ICD prevalence can be attributed to work environment, hygiene practices, and individual susceptibility factors. Work in wet or humid environments, contact with irritant foods, exposure to various food additives, and thermal burns have been identified as the potential causes of ICD. Moreover, bakers, cooks, and pastry makers are at higher risk of developing allergic respiratory and skin diseases due to exposure to wheat flour and other allergens [11,29], which means that it is easier to find a sensitization to flour in these groups compared to food industry workers, for whom the diagnosis of ICD is sometimes derived from the lack of sensitization to common and occupational allergens.

ACD was diagnosed in 20% of workers, higher in cooks (29.6%) and pastry makers (23.5%). The relevant allergens were rubber additives in cooks (thiurams 2%), benzoyl-peroxide (potentially used in flours as oxidizer in the past) in cooks (4.1%) and pastry-makers (5%), sodium metabisulfite, used as preservatives in food, positive in pastry-makers (10%) and bakers (5.9%), diallyl disulfide found in garlic, and onions positive in cooks (4.1%). The prevalence of sensitization to nickel sulfate was 21.8%, which is within the expected range for the non-occupational population in our region [32]. Only one baker was sensitized to Balsam of Peru, a resin that can cross-react with some flavors used in foods and bakery goods [33].

PCD was demonstrated in 15.1% of the subjects studied with prick test sensitization mainly to wheat flour, soy, yeast, and other food allergens. There is limited data on the prevalence of PCD [34,35], and our results align with those obtained in a Danish study, which found a prevalence of 22% in patients with occupational food-related skin diseases [23]. This result highlights the need to perform a prick test for food in workers to verify this allergy. Moreover, patch tests performed with flours handled during work were negative in all tested subjects, confirming a role for IgE-mediated allergy.

Contact urticaria was more prevalent among pastry makers (14.8%), with wheat flour being the primary allergen. Legumes and soy are the main allergens responsible for cooking. The prevalence of contact urticaria was higher than that reported in a similar study [23]; however, data in the literature are limited [36].

4.2 Respiratory Diseases

Bakers had the higher prevalence of occupational oculorhinitis (54.4%) while asthma was diagnosed in 4/11 (36.4%) of the food processing workers. In bakers and pastry makers, sensitization to wheat flour was found in 22.8% and 20.8%, respectively. In our study, wheat flour was identified as the primary occupational allergen in both occupational groups, which aligns with the literature. A survey conducted in Verona province on bakers [28] found a higher prevalence of wheat sensitization (44.6%) among 174 bakers tested. However, considering wheat sensitization only in subjects with asthma, wheat sensitization was confirmed in 30% of the workers. Wheat sensitization was significantly increased in bakers and pastry makers, as well as in workers with respiratory symptoms, in multivariable logistic regression analysis. This finding aligns with the extensive literature on baker's asthma, which is strongly related to wheat sensitization (9-17, 37-39). Olivieri et al. noted the potential for cross-reactivity between cereals [28]. Still, in our case, sensitization to other flours was zero for pastry makers and very low for bakers (2.6% for barley flour and 1.3% for rye flour), likely due to the higher use of wheat flour compared to other flours. More importantly, sensitization to alpha-amylase from *Aspergillus Oryzae* resulted in 7% positivity, whereas Olivieri et al. (2021) [28] reported a higher prevalence of sensitization (20.7%). Possible risk factors for oculorhinitis and asthma include personal atopy to common inhaled allergens. Due to their similarities, grass allergens and wheat sensitization are strongly associated [28].

Among the cooks, 43.2% had oculorhinitis, and 12.3% had asthma with sensitization mainly to common inhalant allergens and, in some cases, foods, with symptoms occurring when cooking them (one case with fish, four cases with scampi, and one case with eggs). Five patients were sensitized to wheat flour. One patient was sensitized to latex with respiratory symptoms that disappeared using alternative gloves. Overall, occupational asthma and oculorhinitis in cooks were observed in 8 cases. The literature on cook respiratory allergy data is limited to a few case reports; however, it is a well-known asthma among food-processing workers [40]. In our study, only 11 patients were included from the food industry, as there are few such industries in our region. In four cases, the workers had asthma and oculorhinits: one was exposed and sensitized to green coffee beans and two to soy. In one case, we failed to identify the causative occupational allergen.

4.3 Strengths and Limitations of the Study

This study presents data on various skin and respiratory diseases among food handlers, spanning a prolonged timeframe in our region and utilizing a consistent protocol, which includes a skin prick test for subjects with contact dermatitis. All workers underwent a comprehensive allergic evaluation to identify the allergen responsible, which should be avoided in the workplace. Additionally, our study has limitations, including its cross-sectional design, which does not provide follow-up information or data on symptom persistence after diagnosis and the implementation of preventive measures. Another limitation is the lack of data on some prick and patch tests for workers who refused to undergo additional testing. There is also a shortage of data on critical diagnostic tools for occupational asthma, according to the most recent reviews on this topic [41], such as serial PEF measurements and specific inhalation challenge.

5. Conclusion

This study offers valuable insights into the prevalence of work-related diseases, risk factors, and allergen sensitization among various occupational groups within the food industry. The findings underscore the importance of understanding these factors to enhance the occupational health and safety of food handlers.

Moreover, there is a need to improve the diagnosis of occupational allergic diseases in food handlers using skin-prick tests to diagnose protein contact dermatitis and to identify culprit allergens that sensitized workers must avoid. Most workers who came to our attention had mild symptoms (oculorhinits, mild asthma, and mild contact dermatitis), meaning that therapy and prevention of new symptoms were easier if the culprit allergen could be identified.

Supplementary Materials: The following are available online: Supplemental material table S1 includes the univariate and multivariate logistic regression analysis examining factors associated with occupational skin and respiratory symptoms. Data are reported as OR (Odds Ratios) and 95% CI (Confidence Intervals).

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Institutional Review Board Statement: The study was conducted following the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee (CEUR) of the Friuli Venezia Giulia Region (protocol number: 709/2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Appendix

Supplementary Material

Table S1. The univariate and multivariate logistic regression analysis investigated factors associated with occupational skin and respiratory symptoms. Data are reported as OR (Odds ratios) and 95% CI (Confidence Intervals).

Factors associated with skin symptoms	**Univariate analysis**	**Multivariable analysis symptoms**	**OR (95%CI) Skin Only skin symptoms**
Women	**2.55 (1.5-4.6)**	**3.3 (1.5-7.6)**	**1.2** (0.4-3.1)
Age (years)	1.0 (0.9-1.0)	1.0 (0.9-1.0)	1.0 (0.95-1.1)
Work seniority (years)	1.0 (0.9-1.0)	1.0 (0.9-1.0)	0.96 (0.9-4.7)
Atopic dermatitis	0.82 (0.5-1.5)	-	-
Job tasks			
• Food industry (ref)	1		
• Bakers	0.5 (0.1-1.9)		
• Pastry makers	1.6 (0.4-6.7)		
• Cooks	0.9 (0.2-3.2)		
Sensitization to wheat flour	0.9 (0.4-2.0)		
Sensitization to house dust mites	0.6 (03-1.2)		
Atopy by prick test	**0.5 (0.3-1.0)**	0.7 (0.2-1.4)	0.5 (0.2-1.4)
Factors associated with respiratory symptoms	Univariate analysis	Multivariable analysis Respiratory symptoms	 Only respiratory symptoms
Women	**0.6 (0.3-1.0)**	0.7 (0.3-2.1)	**0.3 (0.1-0.8)**
Age (years)	0.9 (1.0-1.1)	1.0 (1.0-1.1)	1.0 (0.9-1.1)
Work seniority (years)	**1.1 (1.0-1.1)**	1.1 (1-1.1)	1.0 (1.0-1.1)
Atopic dermatitis	1.9 (0.9-4.1)	-	-
Smoke habit	1.1 (0.7-1.8)	-	-
Job tasks			
• Food industry (ref)	1		
• Bakers	2.1 (0.6-7.4)		
• Pastry makers	1.2 (0.3-4.7)		
• Cooks	1.0 (0.3-3.4)		
Sensitization to wheat flour	**2.3 (1-5.3)**	1.5 (0.5-5.2)	0.8 (0.32.5)
Sensitization to house dust mites	**2.0 (1.0-4.0)**		
Atopy by prick test	**2.3 (1.2-4.5)**	2.1 (0.8-5.7)	2.0 (0.3-2.5)

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Longitudinal Changes in Work Ability, Well-Being, and Psychosocial Risk Factors Among Older Workers: The ProAgeing Study

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Keywords: Aging; Longitudinal Studies; Occupational Stress; Work Ability; Technostress; Psychological Health

Abstract

Background: *As the workforce ages, older employees face increasing challenges in adapting to changing job demands, including technological advances and ongoing occupational risks such as shift work and physically demanding tasks. Work ability is a reliable indicator of older workers' capacity to meet both physical and mental requirements of their jobs. The ProAgeing study, a multicenter investigation specifically focused on workers over 50 years old, examined long-term patterns in work ability, perceived health, and psychosocial risk factors, along with their interactions across this demographic.* **Methods:** *Participants completed self-reported questionnaires at baseline and after one year, including the Work Ability Index (WAI), technostress, sleep quality, perceived stress, health, and psychosocial risk factors. A first-difference linear regression model was used to assess predictors of changes in WAI. Subgroup analyses examined differences across occupational roles (bank employees, administrative employees, and manual workers).* **Results:** *Of the 470 workers enrolled, 356 (76%) completed the follow-up. A significant decline in average WAI score was observed over 12 months (-1.2 points, p<0.001), mainly in subscales related to work demands and physical illness. Technostress levels slightly decreased, suggesting adaptation over time. Bank employees showed less favorable trends than manual workers, indicating that digitalization and higher job demands significantly affected employees' well-being, especially older workers. Improvements in perceived health and reduced stress mostly contributed to enhanced work ability.* **Conclusions:** *These findings highlight the importance of targeted interventions to enhance health and lower stress among aging workers, supporting their well-being and subsequently their work ability.*

1. Introduction

Worldwide, the aging population and increased life expectancy are significantly transforming workplaces, with more workers over 50 remaining active. These demographic shifts create new challenges, as age-related cognitive and physical decline can directly affect workplace performance [1, 2]. Previous literature highlights that work ability is a good indicator of aging quality, reflecting both workers' health

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status and their capacity to meet job demands [3]. Work ability represents the balance between personal resources and work requirements, with higher levels linked to better performance and well-being, and lower levels associated with increased sickness absence and early retirement [4-6]. The likelihood of reduced work ability rises with age, as older workers may struggle to meet the physical demands of their roles and are more susceptible to health problems [7]. Studies emphasize that physical health is a key factor in work ability, with sensory and muscular functions typically declining after 45 years of age [2]. Additionally, chronic conditions such as musculoskeletal, gastrointestinal, and cardiovascular diseases can further impair work ability, leading to decreased productivity, sickness absence, and even exits from the labor force [8-10].

Beyond physical health, recent research has broadened the analysis of work ability determinants to include work-related and psychological factors. Organizational research on work ability commonly adopts the Job Demands-Resources (JD-R) model as a theoretical framework, which distinguishes between job demands—such as shift work, extended hours, and role demands—and job resources, including support from supervisors and colleagues, autonomy, and flexible work schedules [11-13]. In this context, essential resources such as relationship-oriented leadership, decision-making autonomy, skill-job fit, meaningfulness of work, and emotional resilience play crucial roles in enhancing work ability [14-17]. Conversely, job demands and work-related stress significantly reduce work ability [18]. Excessive mental and physical workloads, poor working conditions, and other stressors contribute to negative emotional states, which in turn reduce well-being, job satisfaction, and motivation. This, in turn, diminishes job performance, organizational commitment, and work ability, while increasing staff turnover.

Recent research concentrates on these factors to sustain work ability and promote a healthier, more engaged workforce [7]. However, the impact of these variables depends on the nature of the job, as different occupations impose distinct physical, cognitive, and psychological demands on workers [18, 19]. While some longitudinal studies have examined aspects of work ability, to our knowledge, no studies have comprehensively integrated all these previously mentioned factors. The aim of this study is to explore longitudinal work ability, health, work-related, and psychosocial factors, as well as their interactions, in a population of older workers across various occupations.

2. Methods

This multicenter longitudinal study invited eligible workers to participate during routine medical surveillance visits, as mandated by Italian occupational safety regulations (Legislative Decree No. 81/2008). Data were collected from three selected companies representing different sectors—finance, packaging, and steel—to capture diverse roles and work environments. Eligibility criteria required participants to be full-time employees over 50 years old, with at least 10 years of seniority in their current role. There were no exclusion criteria regarding gender, ethnicity, or clinical characteristics. All participants provided written informed consent before enrolling, and participation was voluntary. Participants completed a series of self-reported questionnaires administered through the REDCap platform [20]. They were followed up after one year. The same set of questionnaires was administered, and information on any changes in job roles during the follow-up period was collected. The study protocol has been previously published [21].

The set of questionnaires included the Work Ability Index (WAI, [22]), a technostress scale specifically designed for older adults [23, 24], the Pittsburgh Sleep Quality Index (PSQI, [25]) to evaluate sleep quality, and the Perceived Stress Scale (PSS, [26]). Additionally, it incorporated measures of perceived general health (one item), job satisfaction (one item, [27]), and psychosocial risk factors (Management Standard (MS) Indicator Tool, [28, 29]). We also collected socio-demographic data (e.g., age, gender, BMI) and occupational information (e.g., role, shift work, job seniority).

Descriptive statistics included mean values and standard deviations for continuous variables and frequencies and percentages for categorical variables. Differences in scores between baseline (T0) and follow-up (T1) were analyzed using paired t-tests. For each variable, the change over time was calculated as the difference between T1 and T0 scores. Positive or negative scores indicated an improvement or deterioration in work ability, job satisfaction, perceived general health, psychosocial risk factors, technostress, sleep quality, and perceived stress. Subgroup analyses were performed to examine differences between occupational roles (bank employees, administrative employees, and manual workers) using one-way ANOVA. A first-difference linear regression model was employed to investigate the factors associated with changes in work ability, considering variations in WAI scores as the primary outcome and changes in other variables as potential predictors. The first-difference approach estimates the relationship between within-individual changes over time, effectively controlling for unobserved time-invariant confounders and reducing the risk of omitted variable bias. The model was adjusted for gender, occupational role, and whether participants experienced any job changes in the past year. There was no missing data. All analyses were performed using R software.

3. Results

Of the 470 subjects who participated at T0 (November 2021-November 2022), 356 (76%) completed the follow-up (November 2022-November 2023). Socio-demographic and occupational characteristics of follow-up participants were comparable to those of the original sample [19]. The mean age of participants was 55 years, with 78% men (N=279). A total of 148 (41%) were manual workers, while 208 (59%) were white-collar workers, including 157 (44%) employed in banking and 51 (14%) in administrative roles. Additionally, 24 individuals (7%) reported a change in job role within the past year. Overall, a significant decrease of approximately 1.2 points in the average level of work ability was observed (T0: 42.8 ± 4.6, T1: 41.4 ± 4.6, $p<0.001$). Notably, the WAI subscales of work demands and physical illnesses showed the most significant decrease (Table 1).

Technostress showed a significant decrease of 0.6 points (T0: 12.9 ± 2.1, T1: 13.3 ± 2.8, $p<0.001$), particularly in the areas of overload and complexity. Job satisfaction also showed a significant decline (from 5.6 to 5.4, $p<0.001$). In contrast, perceived stress levels decreased slightly. Among psychosocial risk factors, significant reductions were observed in role clarity ($p = 0.03$) and change ($p = 0.003$) domains. Perceived overall health and sleep quality remained stable.

Significant changes in work ability, perceived health, sleep quality, social support, and relationships were observed across different roles (Table 2).

Banking professionals experienced the biggest drop in overall work ability across all areas, while manual workers saw a slight increase in WAI scores. Bank employees reported declines in perceived health and sleep quality, whereas administrative workers showed improvements in these areas, as well as in management support and relationship domains.

Significant changes in perceived health and perceived stress were marginally significantly linked to positive changes in work ability (β=0.92 and β=-0.11, respectively) (Table 3).

4. Discussion

This study examined changes in work ability, technostress, perceived stress and health, sleep quality, psychosocial risk factors, and job satisfaction over one year in a sample of older workers. Overall, we found that work ability, job satisfaction, role clarity, and change management showed significant declines during the study period. Conversely, technostress and perceived stress improved significantly. However, these changes varied across occupational roles, with opposite trends emerging between banking professionals and other occupations. Manual workers, in particular, showed relatively stable trends.

The decline in WAI scores, especially in the health-related subscales, is expected among workers over 50, as work ability typically decreases with age-related physical and health challenges. This trend aligns with previous research on work ability in older workers [30]. Interestingly, technostress showed a slight improvement, particularly in areas related to complexity and workload. This suggests that, despite initial challenges with new technologies, older workers gradually adapt over time. As

Table 1. Summary statistics (mean ± sd). Questionnaire's score at T0 and at T1 and corresponding p-value (paired t-test).

	T0	**T1**	**T1-T0**	**p-value**
Work ability (WAI)	42.8 ± 4.4	41.6 ± 4.5	-1.2 ± 4.6	<0.001
Current work ability compared with the lifetime best	8.2 ± 1.4	8.3 ± 1.1	-0.1 ± 1.5	0.16
Work ability in relation to the demands of the job	8.8 ± 1.3	8.5 ± 1.3	-0.3 ± 1.6	<0.001
Current disease diagnosed by a physician	5.1 ± 1.5	4.6 ± 1.9	-0.5 ± 1.9	<0.001
Estimated work impairment due to disease	5.8 ± 0.6	5.8 ± 0.6	-0.04 ± 0.7	0.30
Sick leave during the past year (12 months)	4.3 ± 0.9	4.3 ± 0.8	0 ± 1.1	1
Own prognosis of work ability two years from now	6.7 ± 1.0	6.7 ± 1.1	-0.05 ± 1.4	0.50
Mental resources	3.6 ± 0.6	3.6 ± 0.6	-0.04 ± 0.7	0.33
Technostress	12.9 ± 2.1	12.3 ± 2.8	-0.6 ± 2.3	<0.001
Overload	2.3 ± 0.7	2.2 ± 0.9	-0.1 ± 0.8	0.003
Invasion	2.5 ± 0.9	2.4 ± 1.1	-0.1 ± 1.1	0.06
Complexity	2.5 ± 0.7	2.2 ± 0.9	-0.2 ± 0.7	<0.001
Privacy	2.2 ± 0.7	2.2 ± 0.9	-0.04 ± 0.9	0.38
Inclusion	3.3 ± 0.6	3.3 ± 0.8	-0.06 ± 0.7	0.12
Perceived health	3.9 ± 0.7	3.9 ± 0.7	0.01 ± 0.7	0.70
Job satisfaction	5.6 ± 1.2	5.4 ± 1.4	-0.2 ± 1.3	<0.001
Sleep quality (PSQI)	5.5 ± 3.1	5.4 ± 2.8	-0.1 ± 2.4	0.34
Perceived stress (PSS)	12.4 ± 6.1	11.6 ± 6.1	-0.7 ± 5.0	0.02
Demands (MS)	4.1 ± 0.8	4.1 ± 0.8	-0.02 ± 0.9	0.64
Control (MS)	3.7 ± 0.8	3.7 ± 1.0	0.02 ± 0.9	0.65
Colleagues' support (MS)	4.1 ± 0.5	4.1 ± 0.7	0.01 ± 0.7	0.65
Management's support (MS)	4.0 ± 0.6	4.0 ± 0.8	-0.003 ± 0.8	0.95
Role clarity (MS)	4.6 ± 0.7	4.5 ± 0.7	-0.1 ±0.9	0.03
Change (MS)	3.6 ± 0.7	3.5 ± 0.8	-0.1 ± 0.9	0.003
Relationships (MS)	4.7 ± 0.5	4.7 ± 0.5	0.04 ± 0.6	0.21

workers become more familiar with technological tools and their work environments evolve, they perceive less stress related to technological demands [31]. A small but significant decrease was observed in job satisfaction, as well as in two distinct psychosocial risk factors, namely role clarity and change, whereas demands, control, social support, and interpersonal relationships remained stable over time. Similarly, sleep quality, perceived health, and perceived stress did not change significantly. The modest magnitude of these changes may be attributed to the short one-year interval between assessments and the absence of substantial interventions aimed at reducing stress or improving worker well-being within the three companies. Effective strategies to reduce or prevent stress-related outcomes generally involve a multilevel approach that includes both organizational and individual interventions [33, 34]. Research indicates that job satisfaction tends to remain relatively stable over time because it is partly influenced by dispositional factors beyond job-related variables [35]. Additionally, all average scores on the psychosocial risk scales were favorable, indicating relatively good conditions.

Significant differences appeared across occupational roles, with each variable showing different trends. The decline in work ability, perceived health, and sleep quality among banking professionals may be linked to the ongoing transformation of their work environment, which increasingly demands adaptation to technological tools, higher cognitive loads, and pressure to maintain performance

Table 2. Changes (mean ± sd) in work ability, technostress, perceived health, job satisfaction, sleep quality, perceived stress and psychosocial risks between different populations. P-values from one-way ANOVA.

	Bank employees N=157	Administrative employees N=51	Manual Workers N=148	p-value
Work ability (WAI)	-2.77 ± 3.33	-0.86 ± 3.98	0.46 ± 5.36	<0.001
Current work ability compared with the lifetime best	-0.17 ± 1.24	0.04 ± 1.18	0.43 ± 1.78	0.002
Work ability in relation to the demands of the job	-0.64 ± 1.12	-0.60 ± 1.14	-0.02 ± 1.99	0.001
Current disease diagnosed by a physician	-1.36 ± 1.79	-0.39 ± 1.64	0.29 ± 1.81	<0.001
Estimated work impairment due to disease	-0.19 ± 0.63	0.06 ± 0.37	0.09 ± 0.84	0.001
Sick leave during the past year (12 months)	-0.18 ± 0.88	0.14 ± 0.94	0.14 ± 1.25	0.02
Own prognosis of work ability two years from now	-0.15 ± 0.95	0.06 ± 1.27	0.02 ± 1.87	0.49
Mental resources	-0.10 ± 0.52	-0.25 ± 0.72	0.11 ± 0.85	0.002
Technostress	-0.54 ± 2.04	-0.77 ± 2.33	-0.52 ± 2.63	0.79
Overload	-0.17 ± 0.71	-0.10 ± 0.76	-0.09 ± 0.86	0.65
Invasion	-0.09 ± 0.97	-0.15 ± 1.31	-0.11 ± 1.14	0.95
Complexity	-0.20 ± 0.62	-0.31 ± 0.66	-0.24 ± 0.88	0.64
Privacy	0.08 ± 0.81	-0.37 ± 0.90	-0.06 ± 1.03	0.009
Inclusion	-0.17 ± 0.68	0.14 ± 0.62	-0.01 ± 0.80	0.01
Perceived health	-0.11 ± 0.62	0.25 ± 0.74	0.06 ± 0.70	0.002
Job satisfaction	-0.23 ± 1.33	-0.22 ± 0.92	-0.31 ± 1.41	0.85
Sleep quality (PSQI)	0.25 ± 2.22	-0.23 ± 2.68	-0.64 ± 2.57	0.05
Perceived stress (PSS)	-0.51 ± 4.58	-1.00 ± 4.59	-0.90 ± 5.66	0.82
Demands (MS)	-0.10 ± 0.68	0.09 ± 0.83	0.02 ± 1.00	0.26
Control (MS)	0.02 ± 0.73	0.08 ± 0.67	-0.004 ± 1.04	0.82
Colleagues' support (MS)	-0.01 ± 0.62	0.08 ± 0.64	0.01 ± 0.72	0.68
Management's support (MS)	-0.01 ± 0.73	0.27 ± 0.73	-0.07 ± 0.94	0.04
Role clarity (MS)	-0.14 ± 0.66	-0.21 ± 0.76	-0.02 ± 1.04	0.28
Change (MS)	-0.23 ± 0.77	-0.09 ± 1.04	-0.07 ± 0.98	0.27
Relationships (MS)	-0.11 ± 0.41	0.12 ± 0.54	0.17 ± 0.65	<0.001

Table 3. First-difference linear regression model of WAI. Coefficients are adjusted for gender, occupational role, and potential job changes during previous year. Δ=difference T1-T0.

	Δ WAI	T value	p-value
Δ Technostress	0.10	0.78	0.44
Δ Role clarity (MS)	0.34	0.96	0.34
Δ Change (MS)	0.55	1.66	0.09
Δ Sleep quality	-0.14	-1.14	0.24
Δ Job satisfaction	0.42	1.70	0.09
Δ Perceived stress	-0.11	-1.86	0.05
Δ Perceived health	0.92	1.96	0.05

standards. This finding aligns with previous research in Italy, highlighting how digitalization and higher job demands in the banking sector significantly affect employees' well-being, especially older workers [32]. In contrast, manual workers experienced smaller variations across variables; particularly, they reported less change in perceived health and psychosocial risks, but showed the most pronounced decline in sleep quality compared to administrative and bank employees. This aligns with theoretical expectations, as prolonged exposure to night shift work tends to deteriorate sleep quality over time. Overall, these results highlight the heterogeneity of the workforce and suggest that different occupational roles should be analyzed separately when studying work ability and health.

Although this study did not test specific interventions, we found that improvements in perceived health and decreases in perceived stress mainly contributed to better work ability, regardless of job role. These findings highlight the importance of targeted programs to enhance health and lower stress for all workers, supporting their well-being and, in turn, their work capacity.

This study has certain limitations. First, the one-year follow-up may be too brief to fully capture long-term changes in work ability and related factors among older workers, especially since aging-related trends are usually more noticeable over longer periods. We hope our findings encourage future research with extended follow-ups in aging populations. Second, reliance on self-reported questionnaires introduces potential response bias, as participants might inaccurately report their experiences. To address this, interviews were conducted by experienced occupational physicians with extensive backgrounds as company doctors, who carefully collected responses. However, the observational design limits causal interpretations because no specific interventions were tested to address changes in work ability or well-being.

Despite these limitations, our findings, particularly the decline in work ability, highlight the importance of tailored interventions to support aging workers, including health management and stress reduction programs. While ensuring the health and productivity of older workers is a global priority, there remains a lack of widely available, effective health programs [36]. Future research with longer follow-ups and more diverse industries will be important to better understand long-term trends and the factors influencing work ability in older workers. Addressing the physical, cognitive, and psychosocial needs of older employees will be crucial for promoting sustainable work ability, enhancing overall job satisfaction, and improving performance and well-being in the workplace.

5. Conclusion

This study shows a decline in work ability among older workers over a one-year span, especially in cognitively demanding roles like banking. Improving perceived health and lowering stress were key factors in supporting work ability, highlighting the importance of targeted, occupation-specific strategies to enhance well-being in an aging workforce. Occupational health professionals should focus on early detection of at-risk workers and implement customized approaches, such as stress management programs and health promotion efforts, to help maintain work ability and extend working life.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Committee of the Foundation IRCCS Ca' Granda Ospedale Maggiore Policlinico on June 22, 2021 (Milan Area 2 Ethical Committee, with decree number 616_2021bis).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Gender Disparities in Workplace Violence Among Italian Healthcare Workers: A Cross-Sectional Study

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Keywords: Workplace Violence; Gender Disparities; Transgender & Gender Expansive; Healthcare Workers; Workplace Safety

Abstract

Background: *Workplace violence (WPV) is a prevalent issue globally among Healthcare Workers (HCWs). Moreover, WPV may disproportionately impact marginalized groups within the healthcare workforce, such as women and gender minorities. This study aims to examine the prevalence of WPV experienced by HCWs through a gender-focused lens and to investigate factors influencing the risk of WPV.* **Methods:** *A cross-sectional observational study was conducted over a month in Apulia, Italy, involving employees from major healthcare institutions, including hospitals, Local Health Authorities, selected correctional facilities, and Residences for Execution of Security Measures. The study used the Italian-validated WHO Workplace Violence in the Health Sector questionnaire, modified to include 'Other' in the gender definition.* **Results:** *3,259 HCWs participated, representing 88.8% of the 3,670 invited participants. The prevalence of violence incidents within the last 12 months was 29.6% in the HAW group and 57.1% in the CRW group. Within the HAW group, transgender and gender expansive (TGE) workers exhibited a higher prevalence of verbal, physical, and sexual harassment. Logistic regression analysis identified gender, job type, night shifts, interactions with specific patients, and the type of medical settings as significant predictors of experiencing various kinds of violence.* **Conclusions:** *The study underscores the vulnerability of TGE and female HCWs to workplace violence. These findings underscore the imperative for comprehensive yet gender-sensitive interventions promoting safety, equity, and inclusion in the healthcare workplace.*

1. Introduction

Workplace violence (WPV) has been defined by the National Institute for Occupational Safety and Health (NIOSH) as an act or threat of violence at the workplace or against persons in charge. It includes verbal abuse, psychological harm, physical or sexual harassment, and cyber persecution [1]. Healthcare workers (HCWs) face an increased risk of WPV exacerbated by heavy workloads, stress, and societal pressures, with reports showing a surge in violence during the COVID-19 pandemic [2-4].

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Despite the healthcare sector's vulnerability to violence, effective methods for risk reduction have not been statistically established. WPV can result in injuries, psychological distress, and occupational issues like work overload and decreased job satisfaction, leading to high absenteeism, medical errors, and organizational performance decline [5, 6]. However, although aggressive acts are broadly impacting in the healthcare setting, they are still underreported for several reasons, including the stigma of victimization, the threat of further violence, the risk of desensitization to violence that may be perceived as a part of the HCWs job [7], The impact of WPV can be particularly severe within vulnerable working populations, such as women and gender minorities.

Global surveys consistently show that female HCWs are disproportionately affected by WPV and are more likely to underreport incidents compared to their male counterparts [8-10]. Furthermore, current assessments of the risk of WPV have not adequately considered diverse gender identities, including transgender and/or gender-expansive (TGE) workers. This umbrella term encompasses all gender identities that extend beyond the traditional binary framework, such as nonbinary, agender, or genderqueer [11].

There is limited understanding of the experiences of transgender and gender expansive (TGE) medical professionals. However, WPV against healthcare workers may stem from the stigmatization of gender non-conformity and gender expression by colleagues and/or patients [12]. TGE physicians often hide their identity due to fears of discrimination, with few institutions having policies addressing this. This distress and lack of inclusivity can lead to a lack of psychological and physical safety [13]. Although tools have been developed to measure WPV [14], they are not commonly utilized in health facility surveys. Consequently, it is crucial to investigate how gender-related factors influence practices and interactions in healthcare settings. From a gender-related perspective, our study aims to address the prevalence of HCWs experiencing WPV in healthcare settings, investigate the factors that impact this risk according to HCWs' gender, identify barriers and facilitators to inclusion, and suggest strategies to promote an inclusive healthcare workplace.

2. Methods

2.1. Study Design

A cross-sectional observational study was conducted from November 20, 2023, to December 20, 2023. The study was conducted in all 10 prominent healthcare institutions in Apulia (Southern Italy), operating within the framework of the National Health Service, and in six local health authority (ASL) services. Each ASL is a body with public legal personality and entrepreneurial autonomy that includes hospital facilities and different types of ambulatory and territorial sanitary services. Moreover, HCWs from three correctional facilities previously described by Stufano et al. (2021) [15] and from two Residences for the Execution of Security Measures (REMS), healthcare services provided by the Italian Law 81/2014 to accommodate persons suffering from mental disorders, perpetrators of crimes, to whom the Court applies the custodial security measure, all placed in Apulia, were asked to participate in the survey.

Following a training meeting on violence against HCWs, the occupational physicians of each healthcare facility included in the survey joined the trial. All the HCWs called by the Occupational Health Service of each facility during the study period for the mandatory health surveillance periodic visit, according to the Italian Law concerning the protection of workers' health (D. Lgs. 81/2008), were recruited for voluntary participation in the study. Differently, all the HCWs from correctional facilities and REMS were invited to participate in the survey voluntarily by the respective ASL management.

2.2. Study Population

The study included HCWs aged 18 years and older who had been employed in the same healthcare facility for at least the previous 12 months. Given the specific characteristics of the setting in which prison and REMS HCWs operate, all the subsequent analyses have been performed subdividing the HCWs in those operating in the hospital and ASL services (Group 1: Hospital and

ASL workers - HAW) and those operating in correctional and REMS facilities (Group 2: Correctional and REMS workers - CRW). Moreover, HCWs were divided into three main occupational groups: physicians, nurses, and "Other Healthcare Professionals and Employees in Related Services" (OHPERS). Participation was anonymous and voluntary. The principles of ICH Good Clinical Practice, the 'Declaration of Helsinki', and national and international ethical guidelines were strictly followed during this study. The research was approved by the Bari University Hospital Ethics Committee (Protocol N. 6663, 2021).

2.3. Questionnaire

The study used the validated version of the WHO Workplace Violence in the Health Sector Country Case Studies Research Instruments Survey (WVHS) questionnaire for the Italian population [16, 17]. The questionnaire collected self-reported information on WPV in the previous 12 months. The original WVHS questionnaire includes a binary categorization of sex (male, female). In our study, aiming to inclusively capture experiences that might reflect gender diversity beyond traditional binary definitions, we introduced an additional response option labeled 'Other'. Given practical constraints related to questionnaire length and structure, we did not include a more detailed gender identity assessment or a 'prefer not to answer' option. While this approach helps to highlight potential vulnerabilities of HCWs who identify themselves outside the binary categories, it is acknowledged as an exploratory categorization rather than a comprehensive representation of the diversity within TGE identities.

Due to the sensitive nature of the questions, the questionnaire was administered digitally for self-completion rather than through direct interviews to ensure the confidentiality and discretion of the anonymous participants. Subsequently, the questionnaire was adapted into an online format using Google™ Docs. Workers completed questionnaires in a separate room while waiting for medical examination; the occupational physician was unaware of the workers' decision.

2.4. Data Analysis

Descriptive statistics were computed using IBM SPSS Statistics, Version 24. Given the categorical nature of the data, $\chi 2$ tests were employed to investigate gender disparities, followed by effect-size computations (Phi and Cramer's V) to gauge the practical significance of these disparities. Chi-square tests were applied to compare categorical variables between groups. In contrast, Fisher's exact test was used whenever the expected cell frequency was less than five to ensure accuracy and reliability, particularly in analyses involving the smaller TGE subgroup. As a post hoc analysis, standardized Pearson residuals (referred to as SPRs henceforth) were computed for each cell to identify which cell differences contributed to the results of the $\chi 2$ tests. A significance level was set at 0.05.

A logistic regression model was constructed to assess the predictors of the different types of violence against HCWs. In our a priori hypothesis, gender (male, female, or other) and job (physician, nurse, or OHPERS) were identified as primary predictors. Binary logistic regressions were conducted to examine the impact of both primary (independent) and secondary predictors on the likelihood of violence against HCWs.

3. Results

Of 3,670 HCWs invited to participate in the study, 3259 HCWs were recruited from various healthcare facilities (88.8%), with 3189 belonging to the HAW group and 70 to the CRW group. Table 1 illustrates the demographic and job-related traits of HCWs enlisted in the two healthcare settings investigated (HAW and CRW), categorized by gender. There was a notable contrast in gender distribution across the three job categories (physicians, nurses, and OHPERS) examined in both workplace settings ($p<0.001$ and $p=0.048$, respectively).

The overall prevalence of HCWs reporting violence incidents in the last 12 months was 29.6% in the HAW setting, lower than the 57.1% observed in the CRW setting (Figure 1).

Table 1. Characteristics of recruited subjects are subdivided according to gender and the working set.

	HAW (n. 3189)				RCW (n. 70)			
Variables	**Men (n 1119) N (%)**	**Women (n 2026) N (%)**	**TGE (n 44) N (%)**	**p-value**	**Men (n 32) N (%)**	**Women (n 36) N (%)**	**TGE (n 2) N (%)**	**p-value**
Age (years)								
- 20 - 24	9 (0.8)	37 (1.8)	0 (0.0)	p<0.001	0 (0.0)	0 (0.0)	*	p<0.001
- 25 - 29	123 (11.0)	263 (13.0)	4 (9.1)		2 (6.3)	2 (5.6)		
- 30 - 34	147 (13.1)	235 (11.6)	10 (22.7)		5 (15.6)	3 (8.3)		
- 35 - 40	128 (11.4)	188 (9.3)	3 (6.8)		7 (21.9)	5 (13.9)		
- 40 - 44	96 (8.6)	203 (10.0)	1 (2.3)		2 (6.3)	4 (11.1)		
- 45 - 49	118 (10.5)	255 (12.6)	7 (15.9)		4 (12.5)	6 (16.7)		
- 50 - 54	144 (12.9)	317 (15.6)	5 (11.4)		2 (6.3)	7 (19.4)		
- 55 - 59	159 (14.2)	311 (15.4)	7 (15.9)		6 (18.8)	6 (16.7)		
- 60+	195 (17.4)	217 (10.7)	7 (15.9)		4 (12.5)	3 (8.3)		
Job								
- Physician	321 (28.7)	389 (19.2)	7 (15.9)	p<0.001	5 (15.6)	9 (25.0)	*	p=0.048
- Nurse	374 (33.4)	989 (48.8)	12 (27.3)		5 (15.6)	10 (27.8)		
- Other	424 (37.9)	648 (32.0)	25 (56.8)		22 (68.8)	17 (47.2)		
Marital Status								
- Married	599 (53.5)	1029 (50.8)	14 (31.8)	p<0.001	17 (53.1)	24 (66.7)	*	NS
-Cohabitant	171 (15.3)	273 (13.5)	4 (9.1)		6 (18.8)	2 (5.6)		
- Divorced	68 (6.1)	173 (8.5)	2 (4.5)		1 (3.1)	3 (8.3)		
- Single	273 (24.4)	519 (25.6)	23 (52.3)		8 (25.0)	7 (19.4)		
- Widowed	8 (0.7)	32 (1.6)	1 (2.3)		0 (0.0)	0 (0.0)		
Working seniority								
- 1 - 5	289 (25.8)	546 (26.9)	14 (31.8)	NS	15 (46.9)	8 (22.2)	*	NS
- 6 - 10	142 (12.7)	254 (12.5)	6 (13.6)		4 (12.5)	7 (19.4)		
- 11 - 15	119 (10.6)	200 (9.9)	6 (13.6)		6 (18.8)	6 (16.7)		
- 16 - 20	138 (12.3)	242 (11.9)	6 (13.6)		0 (0.0)	7 (19.4)		
- 20+	431 (38.5)	784 (38.7)	12 (27.3)		7 (21.9)	8 (22.2)		
Night Shift	738 (66.0)	1203 (59.4)	25 (56.8)	p<0.001	23 (71.9)	14 (38.9)		p=0.011

**Demographic data for TGE participants in the CRW group have been excluded to protect anonymity due to the small sample size (n=2).*

The main characteristics of the acts of violence experienced by the two groups of recruited HCWs according to gender are shown in Table 2.

In the HAW, a significantly higher percentage of TGE workers were found to be victims of violent incidents in the last 12 months (36.4% vs. 31.6% women and 25.0% men). Specifically, TGE workers were victims in significantly higher percentages than female and male workers of episodes of verbal violence (45.5% vs. 38.2% and 33.6%, respectively, p=0.01) and sexual harassment (9.1% vs 0.9% and 0.3%, p<0.001). TGE and female workers also experienced a higher percentage than male psychological violence (15.9% vs 15.6% and 11.5%, respectively, p=0.006). Regarding the types of the aggressor, significantly higher percentages of TGE than male and female HCWs experienced violence from colleagues (15.9% vs. 9.1% and 6.3%, p=0.004) or from directors (9.1% vs. 6.4% and 3.8%, p=0.006), whereas no significant differences were found among genders in

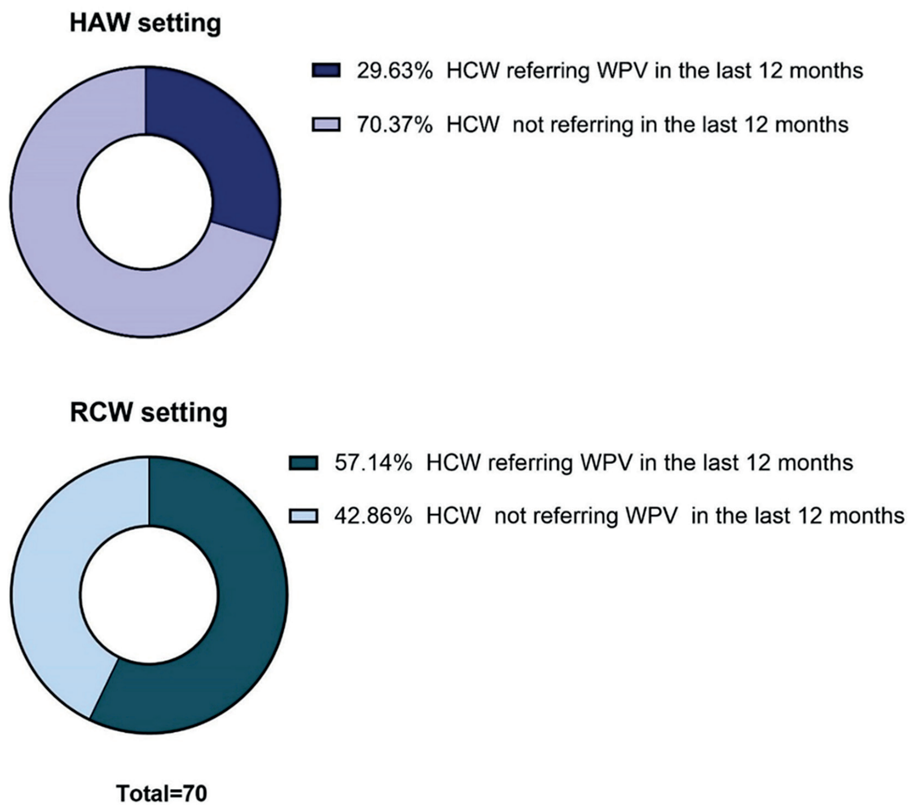

Figure 1. Overall prevalence of incidents of workplace violence (WPV) in health care workers (HCWs) working in hospitals and ASL (HAW) and in the prison and REMS settings (RCW).

their experience of assaults perpetrated by patients, patient relatives or the general public.

In the CRW setting (Table 2), no significant differences were found among the three genders in the experience of both total and specific types of violence incidents that occurred in the past 12 months, except that male HCWs experienced significantly higher rates of physical violence and weapon violence incidents than female and TGE workers (both 62.5% vs. 22.2% and 50.0%, p=0.003). Finally, management or the general public reported no violence perpetrated in the past year. In contrast, a significantly higher percentage of male than female or TGE workers experienced violence from patients (68.6% vs 38.9% and 50.0%, p=0.04). Lastly, a significantly higher percentage of TGE workers experienced violence from coworkers in the past year than male and female workers (50% vs 6.3% and 2.8%, p=0.02).

Logistic regression analysis showed significant models for the likelihood of experiencing all four types of violence investigated (p<0.001 for all) for HAW (Tables 3a and 3b). In contrast, no significant model was observed for CRW (data not shown).

Gender influences the probability of experiencing all types of violence. Compared to males, TGE HCWs showed a statistically significant increase in the odds of experiencing verbal violence (OR 2.06, p=0.026), physical violence (OR 2.04, p=0.045), and sexual harassment (OR 51.62, p<0.001). Moreover, female HCWs showed increased ORs than males for verbal violence (OR 1.23, p=0.012), sexual harassment (OR 4.50, p=0.021), and psychological violence (OR 1.45, p=0.001).

Regarding the job, there was no statistically significant difference in the odds of experiencing any violence for nurses compared with physicians. In contrast, OHPERS were less likely to experience

Table 2. Characteristics of workplace violence (WPV) incidents in the last 12 months in the recruited HCWs, subdivided according to gender and working setting.

	HAW (n. 3189)				RCW (n. 70)			
Variables	**Men (n 1119) N (%)**	**Women (n 2026) N (%)**	**TGE (n 44) N (%)**	**p-value**	**Men (n 32) N (%)**	**Women (n 36) N (%)**	**TGE (n 2) N (%)**	**p-value**
HCW referring WPV incidents in the last 12 months.	288 (25.7)	641 (31.6)	16 (36.4)	p= 0.001	21 (65.6)	17 (47.2)	2 (100.0)	NS
- Physical	213 (19.0)	357 (17.6)	13 (29.5)	NS	20 (62.5)	8 (22.2)	1 (50.0)	p= 0.003
- Verbal	376 (33.6)	773 (38.2)	20 (45.5)	p= 0.01	23 (71.9)	17 (47.2)	2 (100.0)	NS
- Psychological	129 (11.5)	317 (15.6)	7 (15.9)	p= 0.006	8 (25.0)	9 (25.0)	1 (50.0)	NS
- Sexual harassment	3 (0.3)	19 (0.9)	4 (9.1)	p<0.001	0 (0.0)	0 (0.0)	0 (0.0)	NS
Violence with a weapon (last incident)	202 (18.1)	344 (17.0)	12 (27.3)	NS	20 (62.5)	8 (22.2)	1 (50.0)	p= 0.003
Aggressor								
- Patient	211 (18.9)	422 (20.8)	6 (13.6)	NS	22 (68.8)	14 (38.9)	1 (50.0)	p= 0.048
- Patient 's relatives	193 (17.2)	360 (17.8)	9 (20.5)	NS	2 (6.3)	0 (0.0)	0 (0.0)	NS
- Colleague	70 (6.3)	184 (9.1)	7 (15.9)	p=0.004	2 (6.3)	1 (2.8)	1 (50.0)	p= 0.02
- General public	18 (1.6)	39 (1.9)	1 (2.3)	NS	0 (0.0)	0 (0.0)	0 (0.0)	NS
- Management	43 (3.8)	130 (6.4)	4 (9.1)	p=0.006	0 (0.0)	0 (0.0)	0 (0.0)	NS

verbal violence (OR 0.69, p<0.001), physical violence (OR 0.74, p=0.024), and psychological violence (OR 0.63, p=0.002).

The logistic regression analysis also showed that working during night shifts was associated with higher odds of verbal (OR 1.40, p<0.001) and physical (OR 1.86, p<0.001) violence. Moreover, dealing with elderly patients was associated with higher odds of verbal (OR 1.78, p<0.001) and psychological (OR 1.47, p=0.001) violence, whereas dealing with newborn/infants was associated with a higher probability of experiencing psychological violence (OR 1.85, p=0.002).

Regarding the type of medical setting, HCWs performing care work in mental disability showed a higher probability of experiencing all the types of violence investigated, namely verbal (OR 1.41, p=0.006), physical (OR 1.53, p=0.003), sexual harassment (OR 3.95, p=0.008) and psychological (OR1.43,p=0.022).Moreover,working in a workplace health and safety setting showed a higher probability of experiencing physical violence (OR 1.53, p=0.028), sexual harassment (OR 3.57, p=0.043), and psychological violence (OR 1.53, p=0.045). Finally, working in a psychiatric setting showed higher odds for both verbal (OR 2.14, p<0.001) and physical (OR 2.60, p<0.001) violence. In contrast, geriatric settings showed a higher experience of verbal violence (OR 1.27, p=0.019) and home care settings of sexual harassment (OR 6.03, p=0.005). A lower probability of experiencing physical violence was observed for physical disability (OR 0.76, p=0.013) and HIV/AIDS (OR 0.48, p=0.012) settings.

4. Discussion

Our study reveals heightened cross-gender identity violence against transgender and gender expansive (TGE) healthcare workers (HCWs), facing increased risks of verbal abuse, psychological aggression, and sexual harassment. Additionally, the study identifies occupational factors such as night shifts and employment in specific healthcare settings, including psychiatric and geriatric care, as significant

Table 3a. The stepwise logistic regression analysis showed an association between verbal and physical violence and demographic and occupational characteristics of the HAW.

	Verbal Violence				Physical Violence			
Variables	**B (SE)**	**OR**	**95% C.I.**	**p-value**	**B (SE)**	**OR**	**95% C.I.**	**p-value**
Gender								
- Male		1				1		
- Female	0.2(0.08)	1.23	1.05- 1.45	p= 0.012	-0.1(0.1)	0.89	0.73-1.09	p= 0.265
- TGE	0.7(0.3)	2.06	1.09- 3.91	p= 0.026	0.7(0.3)	2.04	1.02-4.10	p= 0.045
Occupation								
- Physician		1				1		
- Nurse	0.1(0.1)	1.15	0.95- 1.40	p= 0.165	0.9(0.1)	1.10	0.87-1.40	p= 0.437
- OHPERS	-0.3(0.1)	0.69	0.56-0.85	p< 0.001	-0.3(0.1)	0.74	0.57-0.96	p= 0.024
Night shift	0.3(0.08)	1.40	1.18- 1.65	p< 0.001	0.6(0.1)	1.86	1.50-2.31	p< 0.001
Type of patients dealing with								
- Elderly	0.5(0.08)	1.78	1.50- 2.11	p< 0.001	-	-	-	NS
- Adults	-	-	-	NS	-0.3(0.1)	0.69	0.54-0.89	p=0.004
Type of medical setting								
- Mental disability	0.3(0.1)	1.41	1.10- 1.79	p= 0.006	0.4(0.1)	1.53	1.16-2.03	p= 0.003
- Workplace health and safety	-	-	-	NS	0.4(0.1)	1.53	1.05-2.24	p= 0.028
- Physical disability	-	-	-	NS	-0.2(0.1)	0.76	0.61-0.94	p= 0.013
- HIV/ AIDS	-	-	-	NS	-0.7(0.2)	0.48	0.28-0.85	p= 0.012
- Psychiatry	0.7(0.1)	2.14	1.55-2.96	p< 0.001	0.9(0.1)	2.60	1.86-3.64	p< 0.001
- Geriatrics	0.2(0.1)	1.27	1.04- 1.56	p= 0.019	0.08(0.1)	-	-	NS
Overall model	χ^2:293.6; p<0.001				χ^2:171.2; p<0.001			

predictors of violence. Violence against HCWs is prevalent globally, with the WHO reporting a 38% incidence rate throughout their careers, 16 times higher than in other professions. European HCWs face exceptionally high risks, with 36.6% experiencing non-physical and 20.1% experiencing physical workplace violence (WPV) over 12 months, varying by sociocultural factors and health system characteristics [18]. In Italy, WPV prevalence fluctuates from 11.9% to 93.3%, highlighting the urgent need for interventions to address this pervasive issue in hospitals, clinics, and community health facilities [19].

However, comparing WPV prevalence across European countries is hindered by diverse data collection methods, ranging from self-reports to workers' compensation claims, often excluding public health facilities. Surveys may have low response rates, small samples, and may focus solely on patient and visitor aggression, neglecting worker-on-worker violence, despite its sometimes higher occurrence rates [20-23]. The results emerging from our study show that TGE HCWs may face higher levels of WPV compared to their male and female colleagues, showing a significant increase in the odds of experiencing verbal and physical violence and sexual harassment. In addition, HCWs identifying with a nonbinary gender reported a significantly higher percentage of violence perpetrated by colleagues and management. Several studies have considered the variable of gender in the analysis of risk factors for violence against HCWs [22, 24]. However, this is the first study with a comparative analysis of workplace violence among nonbinary gender-identifying workers, often overlooked in research focusing on binary gender categories.

Table 3b. Association between sexual harassment and psychological violence and demographic and occupational characteristics of the HAW performed by the stepwise logistic regression analysis.

	Sexual Harassment				Psychological Violence			
Variables	**B (SE)**	**OR**	**95% C.I.**	**p-value**	**B (SE)**	**OR**	**95% C.I.**	**p-value**
Gender								
- Male		1				1		
- Female	1.5(0.6)	4.50	1.25- 16.13	p= 0.021	0.3(0.1)	1.45	1.16- 1.83	p= 0.001
- TGE	3.9(0.8)	51.62	9.74- 273.59	p<0.001	0.5(0.4)	1.72	0.74- 4.01	p= 0.209
Occupation								
- Physician						1		
- Nurse	-	-	-	NS	- 0.7(0.1)	0.93	0.72- 1.20	p= 0.577
- OHPERS					- 0.4(0.1)	0.63	0.47- 0.84	p= 0.002
Type of patients dealing with								
- Newborns/ Infants	-	-	-	NS	0.6(0.1)	1.85	1.26- 2.72	p= 0.002
- Elderly					0.3(0.1)	1.47	1.16- 1.86	p= 0.001
Type of medical setting								
- Mental disability	1.3(0.5)	3.95	1.43- 10.91	p= 0.008	0.3(0.1)	1.43	1.05- 1.95	p= 0.022
- Homecare	1.7(0.6)	6.03	1.72- 21.14	p= 0.005	-	-	-	NS
- Workplace health and safety	1.2(0.6)	3.57	1.04- 12.21	p= 0.043	0.4(0.2)	1.53	1.01-2.33	p= 0.045
Overall model	χ^2:142.6; p<0.001				χ^2:71.5; p<0.001			

TGE people are stigmatized in Western societies characterized by a binary gender system [25], and most of them report experiencing discrimination, prejudice, and violence within a range of social institutions, including workplaces [26]. Social stigma and misconceptions about gender diversity may contribute to hostility and aggression toward TGE HCWs, making them more susceptible to verbal abuse, physical assault, and other forms of violence [27, 28]. TGE individuals in diverse workplaces may encounter verbal harassment due to misgendering and challenges with gender-specific dress codes that conflict with their identity, risking discrimination and violence if these rules are disregarded [29]. Specifically, most TGE physicians highlight prominent stigma among colleagues, 11 and a dearth of gender-inclusive physical spaces, such as all-gender restrooms. Trans-inclusive organizational cultures are not uniform across the spectrum of employment, and inadequate training programs related to TGE inclusivity in healthcare facilities may fail to address the safety concerns of TGE people, further exacerbating the risk of experiencing WPV [30].

In line with other recent reports, the results of our study also showed that female HCWs have a higher risk than males for verbal violence, sexual harassment, and psychological violence [20, 31]. Female HCWs are often in more precarious and lower remuneration and benefits, even when in the same occupational group as men. This occupational vulnerability is heightened by the broader gendered occupational segregation in healthcare [32, 33].

In agreement with previous studies, doctors and nurses showed a higher risk of experiencing violence than OPHERES.5 Furthermore, our results showed a higher risk of psychological violence in the case of activities in contact with both newborns/infants and with the elderly, and verbal violence when dealing with the elderly. Infants are often brought to healthcare facilities by caregivers who may be experiencing high levels of stress or frustration, which can manifest in verbally abusive or intimidating behavior toward healthcare staff [34]. On the other hand, elderly individuals may experience cognitive decline, dementia, or other mental health issues that can lead to confusion, agitation, or aggression, resulting in verbal outbursts or hostile behavior toward HCWs [35]. As found in previous reports [5], our study identified working the night shift as a risk factor for WPV episodes. The reduced staffing levels during nighttime may lead to increased vulnerability, as fewer colleagues are available to assist in case of confrontations [36].

The results of our analysis showed that HCWs working in psychiatric wards or caring for patients with mental disabilities have a higher risk of experiencing physical, verbal, and psychological violence, in agreement with previous studies [18]. This evidence could be explained by the intrinsic nature of psychiatric disorders, which can lead to unpredictable and sometimes aggressive behavior from patients, increasing the likelihood of confrontational situations [37].

Another context associated in our study with an increased risk of physical, psychological, and sexual violence is occupational health and safety services. A possible explanation is related to the nature of their activity in Italy, which involves assessing fitness for work evaluation. This decision can impact employment status and people's lives, increasing the potential for aggression [38].

Many of the individual and social determinants of violence in healthcare settings, such as mental illness and drug and alcohol abuse, are disproportionally common in correctional and penitentiary facilities [15]. Moreover, the complex and often oppositional nature of the relationship between inmates and correctional staff may place correctional HCWs at high risk of WP [39]. Male healthcare workers in correctional facility settings report higher rates of physical violence compared to female or transgender/gender-expansive counterparts, potentially influenced by traditional gender norms linking masculinity with strength, leading male HCWs to be perceived as targets by aggressive inmates. Societal expectations may also discourage men from reporting incidents, fostering a cycle of under-reporting and increasing their vulnerability to violence [40, 41].

Our findings regarding the prevalence of WPV should be contextualized considering the methodological variability across existing literature. Studies relying exclusively on formal reports, such as compensation claims to INAIL or requests for psychological assistance following assaults, generally report extremely low incidence rates (~0.2–0.3%) due to significant underreporting biases [42,43]. Similarly, hospital-based spontaneous reporting systems, even when explicitly encouraging reports, yield incidence rates ranging from just 1–3% [44,45]. Conversely, studies employing systematic data collection integrated into mandatory health surveillance—as adopted in our research—report notably higher and more consistent prevalence estimates, typically between 5–10% [46,47]. Furthermore, ad-hoc surveys conducted in particularly high-risk hospital departments, such as emergency or triage areas, often report prevalence rates close to 100%, demonstrating that context and data collection methods greatly influence reported violence frequencies [48,49]. Therefore, our relatively high response rate (88.8%) and systematic census method significantly reduced underreporting, likely contributing to our study's comparatively higher prevalence rates.

Some potential limitations of this study need to be mentioned. Despite a clear definition of WPV, underreporting persists in anonymous surveys due to fears of retaliation or being blamed for reporting incidents. Moreover, it was not possible to overcome the bias in reporting violence, as HCWs may be more likely to report serious events and exclude less serious ones.

Our study has some further limitations. Regarding the assessment of gender identity, the WVHS questionnaire was initially structured to assess biological sex, and our addition of the 'Other' category intended to offer only a preliminary and generic representation of gender diversity, potentially oversimplifying its complexity. The absence of a 'prefer not to answer' option may also have influenced participant responses. Additionally, the analysis of sexual harassment incidents may have been influenced by the low number of reported sexual harassment cases, especially among TGE workers. This could have limited the significance of our results, requiring cautious interpretation. Finally, given the TGE subgroup's exploratory nature and small sample size, although statistically significant differences emerged between TGE and female respondents for certain forms of violence, these findings should be considered preliminary indications rather than definitive evidence. Future research should utilize validated tools specifically designed to capture nuanced gender identities and adopt more sensitive data collection methods to investigate the experiences and vulnerabilities of gender minority HCWs.

However, the study has several strengths. Firstly, the extensive sample size enabled us to analyze the predictor variables of violence within a sizable population. Also, this study highlighted the often-overlooked aspect of the differential experiences of WPV across gender identities by suggesting TGE workers are particularly vulnerable to verbal, psychological, and sexual violence. In this sense, our findings may contribute to the construction of an impact matrix for the assessment of the risk of aggression for HCWs, emphasizing how it would be essential to consider the variable of gender [38].

In conclusion, this study underscores the urgent need for comprehensive interventions to address WPV in healthcare settings, particularly in light of the differential experiences across gender identities. Trans-inclusive non-discrimination policies, gender-sensitive training programs, and enhanced security measures in the most vulnerable healthcare environments should be adopted to address this aim. By prioritizing the safety and well-being of HCWs and addressing the underlying factors that contribute to violence, we can strive to create environments in which all individuals, regardless of gender identity, can thrive and contribute effectively to the delivery of high-quality patient care.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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The Effectiveness of Ergonomic Intervention in Work-Related Postures and Upper Crossed Syndrome of Metal Industry Workers

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Keywords: Awkward Posture; Ergonomics; REBA; RULA; Upper Crossed Syndrome

Abstract

Introduction: *Upper Crossed Syndrome (UCS) is a musculoskeletal disorder that mainly occurs due to awkward posture in a static position. Considering the impact of musculoskeletal disorders on individual and social life, and the limited studies carried out in metal industries, this study evaluated the effect of ergonomic interventions using engineering controls on work-related postures and skeletal abnormalities caused by UCS in one of the metal industries.* **Methods:** *In this interventional study, 132 welders, press, and warehouse workers who had symptoms related to UCS were included. There were 78 participants in the experimental group (43 welders and 35 press operators) and 54 warehouse workers in the control group. Sitting and standing workstations were evaluated using the RULA and REBA methods, respectively. Then, with the technical committee's decision, the necessary ergonomics interventions were carried out. After three months of applying the interventions, the postures were re-evaluated. The paired t-test method was used for intra-group evaluation, and the independent t-test was used to compare the experimental and control groups using SPSS*. **Result:** *This study showed that ergonomic interventions can significantly reduce the risk score of musculoskeletal disorders in different body segments in sitting and standing workstations. Examining the UCS of the experimental group with sitting activities after the intervention, the average angle of the forward head, round shoulder, and kyphosis was reduced by 3.89, 4.05, and 3.73 degrees, and with standing activities by 3.27, 2.70, and 3.10 degrees, respectively.* **Conclusion:** *The results of the study revealed that modifying the workstation has a significant role in reducing the UCS.*

Introduction

Work-Related Musculoskeletal Disorders (WMSDs) are among the significant problems that advanced and developing countries encounter [1]. Research shows that despite the increasing use of mechanized and automated processes, WMSDs remain the primary cause of lost time and elevated costs. Additionally, they are among the leading causes of work-related disabilities, occupational injuries, early retirement, and a key factor limiting movement and agility [2]. According to the WHO, approximately 1.71 billion people worldwide suffer from musculoskeletal disorders [3]. These conditions are the top causes of disability globally, with low back pain (LBP) being the leading cause of disability in 160 countries [3]. The annual global burden of work-related LBP is estimated at 22 million

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disability-adjusted life years [4]. Studies indicate that the prevalence of WMSDs among Iranian employees is notably high compared to other countries [5-6]. In a study involving 9813 workers, over 36% reported experiencing pain in their neck, shoulders, and back across various body segments [7]. Furthermore, out of 1439 workers studied in Iranian steel industries in 2012, 64.1% suffered from back pain, 47.8% from knee pain, and 44.8% from neck pain within a year [8]. Although musculoskeletal disorders can arise from multiple causes, numerous studies have highlighted that maintaining and repeatedly assuming awkward postures at work is the primary cause of WMSDs, and the main method of treatment involves correcting these positions [9-10].

A prevalent WMSD that occurs due to poor body posture, especially in sitting activities and static posture, is the upper crossed syndrome (UCS) [11-12]. This syndrome involves the musculoskeletal system, and as a result, the posterosuperior and anterior muscles of the neck (such as the pectoralis major and minor, levator scapulae, sternocleidomastoid muscles) are mainly shortened and the anterior deep muscles of the cervical spine and lower back of the shoulder girdle are inhibited, stretched and weakened [13]. These changes show themselves in forward head posture (FHP), round shoulder posture (RSP), and kyphosis [14]. The presence of these three abnormalities together can indicate UCS syndrome. This syndrome can cause abnormal kyphosis, biomechanical changes of the glenohumeral joint, and pain in the shoulder and chest areas [15]. If not treated, these types of disorders cause secondary adverse changes, which include extra load on the neck vertebrae, numerous reports of temporomandibular joint arthrosis (due to forward head), and mechanical pains in the head [16].

The metal industry is one of the most important economic sectors in any country's manufacturing industry. In this industry, due to heavy work, awkward posture, and repetitive movements during work, the prevalence of musculoskeletal disorders is high [17-18]. Therefore, it is necessary to take basic measures to prevent and treat these disorders. Redesigning the workstation is a basic control measure in ergonomics. Ideally, using engineering controls, such as the ergonomic design of the workplace, is the most effective intervention method to eliminate the work environment risk factors [19]. Considering the impact of musculoskeletal disorders on individual and social life on the one hand, and the limited studies that have been carried out in metal industries on the other hand, this study was conducted to evaluate the impact of ergonomic interventions using engineering controls on work-related postures and skeletal abnormalities caused by upper crossed syndrome in one of Iran's metal industries.

2. Method

2.1. Participants

The participants in this study were the workers of a factory producing metal structures. There were 150 male workers in the manufacturing sector working in welding, pressing, and warehouse units. According to the inclusion and exclusion criteria, 132 people could participate until the end of the study. The mean age and work experience were 33.07 (6.46) and 5.94 (2.32) years in the control group and 34.00 (6.24) and 5.66 (3.10) years in the experimental group.

In the present study, there were 78 participants in the experimental group, 43 welders and 35 press operators were examined, of which 40 people were working at standing stations and 38 people were sitting at stations. The control group was selected from among the warehouse workers (54 participants), 35 of whom had sitting activities while 19 were employed for standing activities.

All the workers were employed for the day shift (working from 8:00 a.m. to 4:00 p.m.) and had fixed positions at their workstations. They had a 15-minute break from 9:30 to 9:45 and a 30-minute break from 12:30 to 13:00.

2.2. Task Analysis

The following paragraphs provide the three main job descriptions in the Metal Industry.

2.2.1. Welder

In the industry under investigation, more than 90% of the welders (38 people) had a sitting workstation, and only 5 of them worked standing. Based on the map and experience, and after checking the cut parts, the welding operator connected the surfaces of the parts by welding. In general, 700 pieces were welded per day (about three pieces every 2 minutes). In unfavorable conditions, the welder had to bend down and perform welding to have more control over the piece. Sometimes, the welder had to carry the iron, too. According to the job analysis, the welder has an unfavorable neck and trunk posture in this situation.

2.2.2. Press Operator

The press operator worked standing for a long time (7 hours). When the production director announced the type and the number of the pieces to the press operator and if the mold was installed on the press machine, the operator started his work and he sometimes needed to cut the pieces as well. Improper postures for evaluation were selected while the operator was putting a piece under the press or removing a piece from under the press. Workers pressed approximately 5,000 pieces during their shift (12 pieces per minute).

2.2.3. Warehouse Worker

Since the warehouse workers had a wide range of duties, their activities were divided into two categories: sitting and standing activities, to be compared with the sitting and standing activities of the experimental group. Warehouse workers who had to do sitting activities packed and sorted the goods, and the ones who had standing activities monitored inventory and handled receipts, storage, loading, and unloading the goods.

2.3. Inclusion Criteria

Full-time workers with at least one year of experience in the industry were selected; their forward head angle exceeded 46 degrees; their rounded shoulders measured over 52 degrees; their kyphosis condition was greater than 42 degrees; the visual analog scale index gauged the intensity of their pain and should have been above 3 in the head, neck, shoulder, and thoracic spine areas [11, 20-21].

2.4. Exclusion Criteria

Those who had a history of doing professional sports, a history of fracture and surgery in the spine, shoulder girdle, and/or upper limbs, severe visual impairments that could not be corrected with glasses, and a lack of interest were excluded from the study.

2.5. Data Collection

This research utilized the RULA and REBA posture assessment checklists, a flexible ruler, and a video-camera. Their usage is detailed below.

2.5.1. RULA and REBA Methods

Rapid whole body assessment (REBA) and rapid upper limb assessment (RULA) are two widely used observational evaluation methods in ergonomics.

The REBA method focuses on whole body assessment, while the RULA emphasizes a rapid evaluation of the upper limbs [22-23]. In this study, acknowledging that the upper limb is more involved in sitting workstations and the entire body in standing positions, these two methods are employed to assess ergonomics. For both methods, risk indexes are defined based on the final scores obtained from each body segment, which inform the decision-making process regarding ergonomic measures.

2.5.2. Measuring Forward Head and Round Shoulder

The present study employed the lateral view photography method to measure the forward head angles and round shoulders [21]. For this purpose, the first three anatomical landmarks- the tragus, acromion process, and spinous process of the seventh cervical vertebra- were identified and marked. The subject was positioned standing and photographed from the side (with his left arm against the wall) using a digital camera at a distance of 265 cm. The angle of the connecting line between the tragus and the seventh cervical vertebra with a vertical line (forward head angle), as well as the angle between the acromion process and a vertical line (round shoulder angle), were measured using AutoCAD software

(Figure 1). The reliability of this method is favorable, and it has been utilized in numerous studies [21].

2.5.3. Hyperkyphosis Measurement Method

We used a flexible ruler to check the back arch angle. Different studies have shown that the flexible ruler has excellent sensitivity and validity, even compared to the X-ray machine [24-25]. To measure the angle of the back arch with a ruler, the T2 (second vertebra) spinous process was used as the arc's starting point, while the T12 spinous process served as the arc's end. To locate the T2 spinous process, the subject was asked to flex their neck, allowing for the identification of the most prominent spinous process, C6 (the sixth cervical vertebra), with T2 located three vertebrae below it. The T12 spinous process is at the same level as the lower edge of the 12th rib on both sides, so the edges of these ribs were simultaneously touched with the tips of the thumbs, and their path was traced upward and inward until the soft tissue of the body was no longer felt. By drawing a straight line connecting the tips of the two thumbs, the location of the T12 spinous process was estimated. After determining the intended points, the examinee was asked to stand naturally and comfortably with bare feet on the cardboard, where their feet were to be placed, look forward, and ensure their weight was evenly distributed on both feet [24]. The flexible ruler was then placed along the individual's back. Even pressure was applied along the ruler's length to ensure there was no gap between the ruler and the person's skin, allowing it to contour to the back arch. The ruler's side in contact with the selected points was marked (Figure 1). After that, without altering the shape of the flexible ruler, it was gently and slowly removed from the back with both hands and placed on a piece of white paper. The curvature of its convex part was drawn on the paper, and points T2 and T12 were marked. To calculate the back arch angle from the shape obtained from the flexible ruler, points T2 and T12 were connected with a straight line, and a line was drawn from the deepest part of the curve to this line. These two lines were referred to as L and H, respectively. After measuring lines L and H with a 30-cm ruler, their values were entered into the formula.

$$\varphi = 4 \text{Arctg } 2H/L$$

and the back arch angle was calculated [26-27].

2.6. Data Collection

After the initial investigation, an increase in pain complaints and the emergence of symptoms related to musculoskeletal disorders led to the examination of 132 people by the end of the study.

All participants signed the written consent form after being informed about the study's objectives

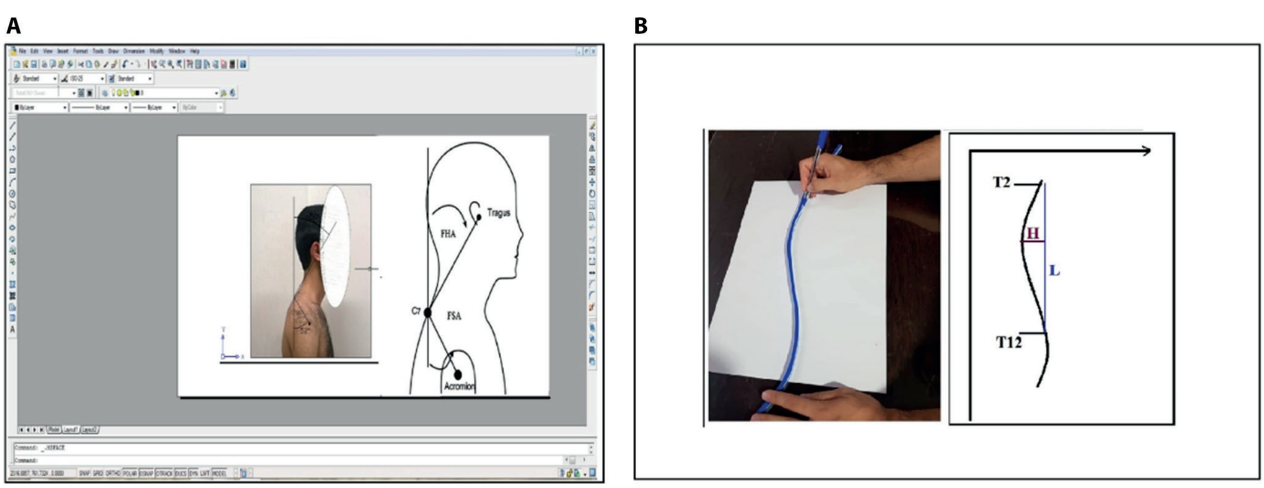

Figure 1. (A) Measurement of forward head and round shoulder; (B) representation of the thoracic curvatures on paper that showing the position of the spinous processes by lateral view photography method.

and evaluation procedures. The performers agreed to keep the workers' information confidential. If participants did not want to cooperate in any part of the study, they had the option to withdraw. This study was approved by the Ethics Committee of the Institute of Physical Education and Sports Sciences with the code IR.SSRC.REC.1402.219. Initially, the sitting and standing workstations in both experimental and control groups were evaluated by an ergonomic expert using the RULA and REBA methods, respectively.

In the RULA and REBA methods, according to the guidelines of both methods, an ergonomic expert selected and photographed the most frequent posture (the body position in which the person often works) after observing repetitive work cycles. In these assessments, both the right and left sides were measured, and the highest final score was considered. This study examined 38 sitting welding stations using the RULA method, along with 5 welding stations and 35 pressing stations using the REBA method.

Following that, based on the proposed protocols, a pathologist evaluated forward head angles, rounded shoulders, and kyphosis. Subsequently, with the decision of the factory's technical committee- comprising the technical manager, HSE and ergonomic experts, a production representative, pathology and corrective consultant, as well as the workers' representative- the necessary interventions were determined and then implemented in the experimental group with the cooperation of management.

It should be noted that, since the aim of this study was to investigate the effect of interventions on UCS, the focus was on interventions that could effectively reduce this syndrome. ISO 14738 and ergonomic documentation were used to implement these interventions [28].

In seated welding stations, based on ISO 14738, a plate with an angle of 30 degrees was added to the work table in an attempt to maintain the spine and shoulder girdle in a normal posture (Figure 2-A). Additionally, considering the height of the chairs, three footrests at heights of 10, 15, and 20 centimeters were provided to the workers on the condition that a 90-degree knee angle was maintained. Cold foam was also used for the seat material. Part of the welders' activity required carrying a piece of iron; therefore, a wheelbarrow was designed to move and transport iron (Figure 2-D).

The press workers' primary focus was designing a chair and a footrest. Some chairs for press workers were prepared according to Figure 2-C.

For five welders and nearly half of the press workers, a sit-stand chair was designed according to ISO 14738 to prevent the head and trunk from bending forward. The adjustable height of the sit-stand chair was calculated based on ISO 14738. This height was determined from the 95th and 5th percentiles of Iranian men, 89.4 and 74.1 cm. Consequently, the adjustable seat height was set to range from 74 to 90 cm.

$$F_{max} = 0.9\ h_6\ (P95) + X_1$$

$$F_{min} = 0.9\ h_6\ (P5) + X_1$$

h_6 = Crotch height: Vertical distance from the floor to the distal part of the inferior ramus of the pubic bone.

X_1= for shoes add 30 mm

After three months, the workstations were reevaluated using postural risk assessment methods (RULA and REBA). Forward head angles, rounded shoulders, and kyphosis were also measured.

2.7. Statistical Analysis

Descriptive statistics were used to analyze qualitative variables, and indices of central tendency, such as the mean, along with dispersion indices, such as standard deviation, were applied for quantitative variables. The Shapiro-Wilk test yielded a p-value of 0.34, indicating that the normality assumption of the data is supported.

The paired t-test was utilized for intra-group evaluation (pretest-posttest), while the independent samples t-test was employed to assess and compare the experimental and control groups using SPSS (version 22) software.

3. Results

In the present study, conducted in a metal industry, the posture and upper crossed syndrome of

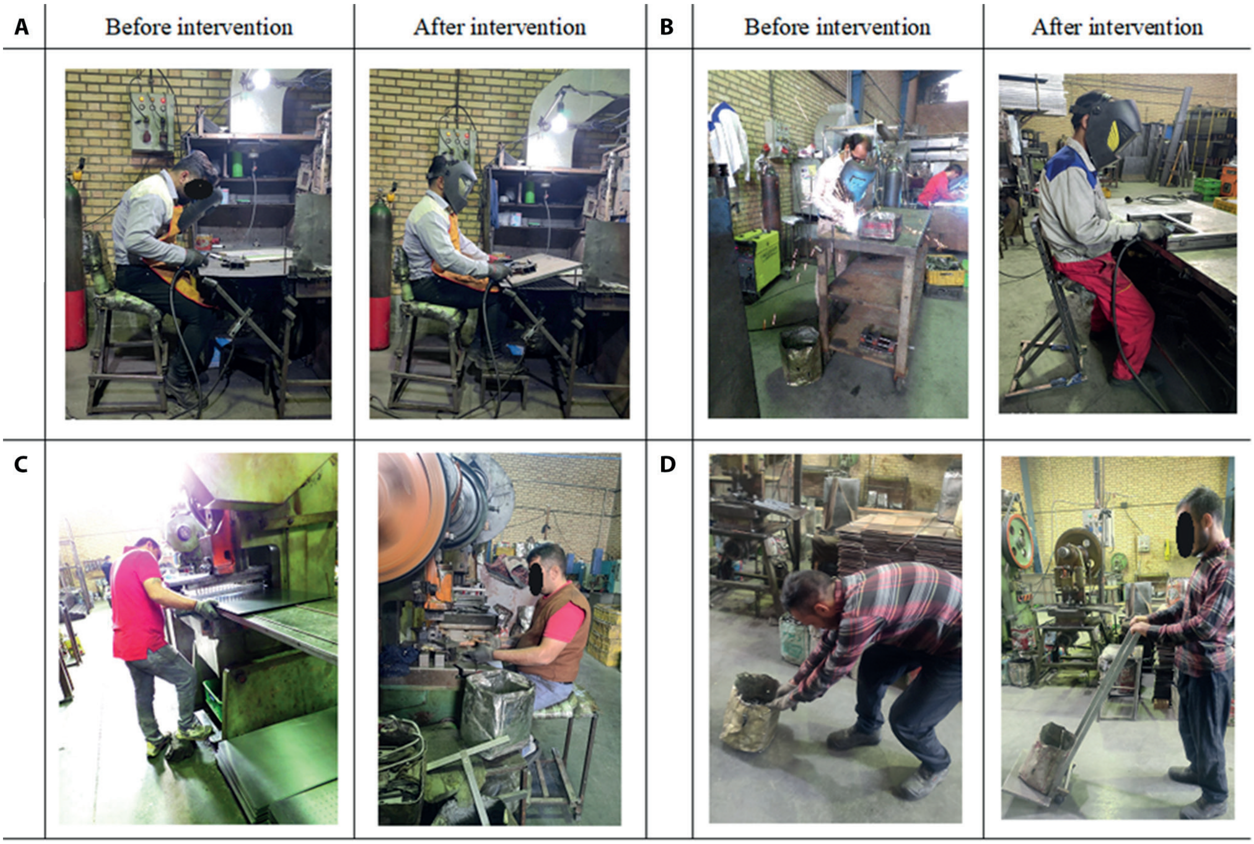

Figure 2. Some workstations before and after ergonomic intervention. A) Welding workstation, B) Welding workstation, C) Press workstation, D) Iron carrying posture.

132 workers who worked in sitting and standing workstations were evaluated before and after ergonomic interventions. The results are listed below by workstation.

3.1. Posture and Upper Crossed Syndrome Evaluation in a Sitting Workstation

3.1.1. Posture Evaluation in a Sitting Workstation

Assessment of posture in the sitting workstation was conducted using the RULA method. Table 1 presents the mean and standard deviation of the final scores obtained from the evaluation via RULA; the level of musculoskeletal disorder risk is also displayed separately for the control and experimental groups, both before and after the intervention. The difference in the experimental group's final score before and after the ergonomic intervention is clear; this change indicates a reduction of approximately 2 points in the final score from the evaluation methods. In contrast, the control group showed no difference in scores.

Table 1. Final score in the control and experimental groups in the sitting workstation (No. = 38).

	Sitting Group (RULA)	
Variables	Intervention Mean (SD)	Control Mean (SD)
Score c – Before (B)	4.74 (1.34)	3.14 (1.14)
Score c – After (A)	2.82 (0.80)	3.11 (1.10)
A-B	1.92 (0.94)	0.02 (0.01)

Comparing the scores of different areas in the experimental group, the mean final score for the body

Table 2. Forward head, kyphosis, and round shoulder angles in the control and experimental groups in sitting activities.

		Sitting group (Mean(SD) degree		
Variables (degree)	**Condition (time)**	**Experimental (n=38)**	**Control (n=35)**	**p-value**
Forward head	Before intervention	52.45 (3.108)	51.91 (4.097)	0.18
	After intervention	48.55 (3.696)	49.86 (4.097)	0.16
Round shoulder	Before intervention	55.82 (4.125)	54.37 (4.346)	0.15
	After intervention	51.76 (4.629)	54.20 (4.471)	0.02
Kyphosis	Before intervention	50.03 (4.044)	49.29 (4.315)	0.45
	Before intervention	46.29 (4.466)	49.23 (4.291)	0.006

segment changed. All body segments decreased ($p<0.001$) after the interventions.

3.1.2. Examining the Upper Crossed Syndrome in a Sitting Workstation

Table 2 compares the mean scores for forward head angles, kyphosis, and round shoulders in the control and experimental groups (sitting workstation). There is no significant difference between the angles in the control and experimental groups before the intervention; however, after the intervention, a difference appears between the two groups in the angles of kyphosis and round shoulders ($p<0.05$). In the experimental group, a difference exists between the mean scores for forward head angles, kyphosis, and round shoulders before and after the intervention.

3.2. Posture and Upper Crossed Syndrome Evaluation in a Standing Workstation

3.2.1. Posture Evaluation in a Standing Workstation

Table 3 presents the REBA scores of the experimental and control groups from standing workstations. Changes in the total REBA scores of the experimental group after the intervention period were significant, with p values of less than 0.05. On the other hand, the REBA scores of participants in the control group were consistently high before and after the intervention periods. The difference in the mean final score before and after correction in the experimental group shows a decrease of about 3 points in the final score of the evaluation methods. However, in the control group, no score difference was observed.

Table 3. Final score in the control and experimental groups in the sitting workstation (No. = 40).

	Group (REBA)	
Variables	**Intervention Mean (SD)**	**Control Mean (SD)**
Score c – Before (B)	7.82 (3.00)	6.84 (1.83)
Score c – After (A)	4.77 (2.16)	6.89 (1.76)
A-B	3.05 (1.11)	-0.05 (0.41)

The score postures of the upper arm, lower arm, wrist, neck, trunk, and leg before and after the intervention in the standing workstation. The mean REBA scores for different body segments before and after intervention in the standing workstation showed a highly significant difference ($P < 0.001$) by paired sample tests.

3.2.2. Examining the Upper Crossed Syndrome in a Standing Workstation

Table 4 compares mean scores descriptively for forward head angles, kyphosis, and round shoulder in the control and experimental groups in the standing workstation. The results show no significant difference between the angles in the control and experimental groups before the intervention. After ergonomic interventions, a difference was observed between the control and experimental groups in forward head and rounded shoulders ($0.007>p<0.001$).

Table 4. Forward head angles, kyphosis, and round shoulder in the control and experimental groups in standing activities.

Musculoskeletal disorders	Condition (time)	Standing group (Mean(SD) degree		p-value
		Experimental (n=40)	Control (n=19)	
Forward head	Before intervention	52.90 (4.01)	52.95 (5.08)	0.96
	After intervention	49.63 (4.08)	53.05 (5.14)	0.007
Round shoulder	Before intervention	56.15 (4.03)	56.58 (4.69)	0.26
	After intervention	53.45 (4.44)	56.53 (4.63)	0.001
Kyphosis	Before intervention	49.68 (4.27)	51.00 (4.07)	0.26
	Before intervention	46.58 (4.11)	51.05 (4.02)	0.001

Ergonomics interventions on the upper crossed syndrome from different angles of the experimental group for the standing workstation show a reduction of angles after the intervention.

4. Discussion

Major health problems in all societies include WMSDs, which are caused by various factors, including poor posture [29]. Awkward posture and workstation modifications have been identified as key goals of ergonomics. Therefore, the present study evaluated the effectiveness of ergonomic interventions utilizing an engineering control approach in workstations, as well as their effects on work-related posture and upper crossed syndrome.

4.1. The Effect of Interventions on Posture and Upper Crossed Syndrome in a Sitting Workstation

4.1.1. The Impact of Interventions on Posture in a Sitting Workstation

In this study, it was revealed that using an ergonomic intervention with an engineering control approach positively affects the working postures of the workforce. When assessed in the experimental group (sitting workstation), the mean final score of the RULA method decreased from 4.73 to 2.81 after three months of intervention, indicating that the level of musculoskeletal disorder risk shifted on average from medium risk (further investigation, change soon) to low risk (change may be needed).

Based on the redesign (Figure 2), a significant difference was observed between the scores of all the investigated segments, before and after the intervention. This indicates the positive effects of ergonomic interventions on work posture.

After applying the ergonomic interventions in different body segments, the most significant changes were in sitting activities related to the arm and wrist areas, with an average difference of 0.95. The decrease in the score of each segment can indicate the role of interventions in reducing the risk of musculoskeletal disorders. One reason interventions on the upper limb have a greater impact is the redesign of the desk and chair, where the access limit is closer and the worker's upper limb is more within normal reach while working.

Considering the importance of workstation modification and its role in reducing musculoskeletal disorders and increasing productivity, various studies have investigated the effect of ergonomic interventions according to the nature of the job. In many studies, observational methods such as RULA and REBA have been used to evaluate the effectiveness of ergonomic interventions [30-31]. However, the number of studies in the metal industries is limited. A 2021 study conducted in the metal casting industry showed that complaints from musculoskeletal disorders are highly prevalent and that ergonomic interventions can reduce both musculoskeletal complaints and fatigue [32]. In general, the findings of this study and other studies show that interventions, especially technical-engineering interventions, can be effective on workstation posture [33].

4.1.2. The Effect of Interventions on Upper Crossed Syndrome in the Sitting Workstation

The results of ergonomic interventions in this study demonstrated a positive effect on reducing upper cross syndrome in the evaluated workstations. In the experimental group's sitting workstation, after three months of intervention, three abnormalities—kyphosis, forward head, and rounded shoulders—decreased by 3.73, 3.89, and 4.05 degrees, respectively. Significant differences were found in rounded shoulder deformity and kyphosis before and after intervention ($p<0.001$), while no significant change occurred in the forward head angle.

Given that the workers were welders, job analysis revealed they had to bend their trunks and necks extensively, which placed pressure on their spines. Similar studies indicate high pressure on the spine and related muscles during welding. Therefore, we aimed to alleviate this tension by focusing on the design of the chair, work table, and footrest. The interventions appeared to positively impact all three angles over the three-month period, ultimately reducing upper cross syndrome issues by improving posture.

4.2. The Effect of Interventions on Posture and Upper Crossed Syndrome in a Standing Workstation

4.2.1. The Effect of Interventions on Posture in a Standing Workstation

Using the REBA method, the experiment's results on workers who engaged in standing activities revealed that the final score changed from 7.82 to 4.77. This indicates that the risk index has shifted from high risk (investigate and implement change) to medium risk (further investigate), requiring changes soon.

Based on the redesign of the standing workstation (Figure 2), a significant difference was observed between the scores of all areas before and after the intervention, indicating the positive effects of ergonomic interventions on work posture.

The most significant changes after applying the ergonomics intervention in standing workstations and different body segments were related to the trunk and arm areas, respectively, with average differences of 0.63 and 0.43.

It should be noted that since most of the workers in the standing workstation were press operators, according to the experts, most alterations focused on changing the standing workstation into a sitting or sitting-standing station. It seems that with the redesign of the workstation, which now supports the trunk area more than before and increases the safer reach limit, the scores have decreased, especially in the trunk and arm areas.

4.2.2. The Effect of Interventions on Upper Cross Syndrome in a Standing Workstation

In the standing activities of the experimental group, after the intervention, kyphosis, forward head, and round shoulder decreased by 3.10, 3.27, and 2.70 degrees, respectively. The difference between the two evaluations (before-after) was significant ($p<0.01$).

The press machine operator had to bend his neck and trunk while working, and there was no support for his lower body. However, due to the modification and redesign of the press operators' workstation, which includes the design of a standing-sitting chair or a high chair with a footrest, efforts were made to reduce the pressure on the trunk and neck. Additionally, footrests during long-term standing activities increase comfort by relieving pressure on the cardiovascular system. It seems that modifying workstations helps the posture of different body segments align more closely with a neutral position, thereby reducing the angles of abnormalities.

Most similar studies have focused on corrective exercises and their effect on upper crossed syndrome, the results of which indicate the positive effect of these interventions [34-35]. Limited studies have been conducted on the impact of ergonomic interventions on upper crossed syndrome, which aligns with the present study. However, their results show the improvement of abnormalities related to forward head, rounded shoulders, and kyphosis [12, 36]. Modifying the workstation, on one hand, results in the stretching of shortened muscles; on the other hand, it strengthens weak muscles. Future studies should investigate the effects of engineering, educational, and management ergonomic interventions in complementary and combined methods to reduce WMSDs.

5. Conclusion

The results of the present study showed that by applying interventions with an engineering approach that focused on modifying the workstations of welding and pressing operators by using measures like adjusting the height of tables and chairs and using footrests, employees' posture improved, especially in the upper limbs and trunk. Also, the findings of the statistical tests showed that the implementation of ergonomic interventions has an effective role in reducing the upper crossed syndrome.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of SPORT SCIENCES RESEARCH INSTITUTE (SSRI.REC_2310_2490 and The date of acceptance is 22 - 11 - 2023)."

Informed Consent Statement: Informed consent was obtained from all subjects involved in this article.

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Association of Psychosocial Factors with Shoulder Tendinitis: A Cross-Sectional Study in Patients of a Tunisian Hospital

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Keywords: Tendinitis; Rotator Cuff; Risk Factors; Psychosocial-Organization

Abstract

Background: *To assess the association between rotator cuff tendinitis (RCT) occurrence and socio-professional constraints among a sample of professionally active patients.* **Methods:** *This study was based on a questionnaire that collected information on sociodemographic, occupational characteristics, and medical information about shoulder injuries. The assessment of psychosocial constraints at work was performed using the Karasek Job Content Questionnaire.* **Results:** *A total of 100 patients participated in this study. The population was predominantly female (89%), with a mean age of 45±9.5 years. Sixty-five percent of the patients worked in the manufacturing sector, and working as a machine operator was the most common occupation (48%). The average job seniority was 22±9 years. Regarding organization, the most common constraints were the need to respect production standards and deadlines (93%), to work quickly in 96% of cases, and Repeatability (92%). Eighty-eight percent of the patients reported high psychological demands, and 96% had low social support at work. Most of the patients (83%) were under occupational stress or had been subjected to a job-strain situation.* **Discussion:** *In this study, high psychological demand, low decision latitude, and low social support were predominantly reported in the population with percentages of 88%, 93%, and 96%, respectively.*

1. Introduction

Degenerative shoulder pathologies involve lesions of the rotator cuff muscles' tendons, known as "Rotator Cuff Syndrome" (RCS) [1]. RCS is a frequent disorder among working populations, with prevalence rates ranging from 2% to 8.5% [2, 3]. Shoulder tendinitis, a specific type of upper limb musculoskeletal disorders (MSDs), is recognized to have a multifactorial origin, with individual factors such as age and gender playing a crucial role. Women are more likely to develop shoulder tendinitis reflecting both biological predisposition and disparities in occupational conditions between genders [4]. However, defining and classifying shoulder tendinopathies remains challenging due to the lack of universally accepted terminology. The Consensus on arm, neck, and shoulder (CANS) model provides a standardized classification, distinguishing between specific and non-specific musculoskeletal

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complaints to improve diagnostic clarity and research consistency [5].

Occupational stress is an increasing concern, with 56% of European workers reporting excessively high workloads. Recent research highlights the strong link between stress and the development of shoulder tendinitis. Elevated stress levels can lead to muscle tension, altered pain perception, and a breakdown in regulating vital systems, including the central nervous, autonomic, endocrine, and immune systems. These are adverse physiological effects. Additionally, a recent systematic review has emphasized the role of specific occupational risk factors, demonstrating that a combination of forceful, repetitive movements—especially when the arm is flexed above 45 degrees—alongside prolonged arm elevation and excessive exertion substantially raises the likelihood of developing shoulder tendinopathy. Employers must recognize these risk factors and implement preventive measures to protect workers from these debilitating conditions [6].

Further evidence confirms the association between occupational biomechanical overload and shoulder tendinopathies, particularly in jobs that require sustained arm elevation combined with forceful exertion [4].

According to the European Communities, identified risk factors include work-related stressors, inadequate social support at work and home, genetic predisposition, pre-existing conditions, and coping difficulties with pain and functional limitations [7]. Specific work-related stressors, such as high job demands, low job control, and poor social support, have been associated with the development of shoulder disorders [8]. Karasek's job strain model suggests that a combination of high job demands, low job control, and poor social support creates a highly stressful work environment, which may accelerate the onset and progression of shoulder tendinitis [9].

Despite these findings, the relationship between RCS and occupational risk factors remains complex and poorly understood. In this context, we hypothesize that psychosocial factors and work-related constraints significantly influence the occupational prognosis of employees suffering from shoulder disorders, especially rotator cuff tendinitis (RCT). This study assesses the relationship between RCT and work-related factors, applying Karasek's job strain model to a cohort of professionally active patients.

2. Methods

2.1. Participants

This is a retrospective cross-sectional study among employed patients suffering from shoulder pain, followed by the Department of Occupational Medicine at the University Hospital of Taher Sfar of Mahdia-Tunisia between January 2019 and December 2022. Patients with less than two years of job tenure were excluded from this study.

2.2. Questionnaire

Data were collected through direct interviews with patients who consented to participate in the study. We used a pre-established and anonymous questionnaire with several measures:

- Sociodemographic characteristics: age, gender, marital status, education level, etc.
- Medical history and lifestyle: tobacco use, physical activity, etc.
- Occupational characteristics: work sector, job position, job seniority, work schedule, etc.

Characteristics and medical information about the RCT were collected by reviewing the patients' medical records, including data from the physical examination, ultrasound results of the painful shoulder, and details about the treatment provided. Based on the shoulders' ultrasound findings, we dichotomized the participants into two groups:

- RCT (-): No ultrasound-detectable tendon lesions;
- RCT (+): presence of ultrasound abnormalities consistent with tendonitis.

** Psychosocial constraints at work:

They were assessed using the Job Content Questionnaire with 29 items in its validated French version. This instrument explores three dimensions [10, 11]:

- Psychological demand (PD), which assesses the psychological overload of work (9 items);
- Decisional latitude (DL) refers to employees' control over their duties and how they want to perform these tasks. It includes both competence and decision-making authority (9 items);
- Social support (SS) at work, which Evaluates the level of social and emotional support provided by superiors and co-workers (11 items).

Responses to the questionnaire items were collected using a four-point Likert scale, ranging from (1) "Strongly Disagree" to (4) "Strongly Agree." A score was assigned for each of the three dimensions mentioned above.

The scores are interpreted as follows [12]:

- A score of DL ≤ 69 indicates that the subject experiences a low degree of work flexibility;
- A score of PD ≥ 21 means that the person is experiencing high psychological demands at work;
- A score of SS≤ 23 indicates poor SS from colleagues and management.

The combination of high PD and low DL defines "job strain." The "Iso-strain" describes the situation associated with "job strain" and "social isolation," i.e., low SS. Table 1 shows the psychometric properties of the French version of the JCQ. Cronbach's alpha coefficients, all between 0.73 and 0.83, confirm the instrument's internal consistency.

2.3. Statistical Analysis

Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 21.0.

Table 1. Cronbach's alpha coefficients for the JCQ scales.

Cronbach's alpha coefficients	Women	Men
Decision latitude	0.81	0.83
Psychological demands	0.73	0.74
Social support	0.82	0.80

The χ^2 and Fisher's exact tests were performed to assess differences in proportions of categorical variables between the two groups: those with and without RCT.

Multivariable logistic regression was employed to predict factors influencing the occurrence of RCT. In this model, only significant variables of interest at a threshold of 20% ($p < 0.2$) were introduced. A significance level of $p < 0.05$ was considered for statistical significance.

3. Results

3.1. General and Medical Characteristics of the Study Population

The present study included 100 patients with a mean age of 45±9.5 years (24-61 years) and a female predominance (89%). Almost all patients (90%) were right-handed. The mean BMI of the study population was 28±4.3 kg/m2 (20.2-39 kg/m2), and most participants (79%) were classified as overweight or obese.

3.2. Medical Characteristics of the Participants

More than 90% of the participants exhibited positive signs of shoulder impingement (Neer, Hawkins, and Yocum signs), and 86% had at least one positive tendon test (Gerber, Palm Up, Jobe, and Patte tests). Sixty-nine participants (69%) showed tendon abnormalities on shoulder ultrasound and were classified in the RCT (+) group.

3.3. Occupational Characteristics of the Participants

Clothing manufacturing was the most represented sector in the study (65%), followed by automotive wiring (12%) and food industry (10%). The average job seniority of the participants was 22±9.1 years, with 58% having more than 20 years of seniority. Half of the patients worked as sewing machine operators. In 95% of cases, participants worked 8 hours a day, and 88% held fixed daytime jobs, while 12% had shift and/or night work.

3.4. Organizational Constraints

Eighteen percent reported experiencing all seven organizational constraints simultaneously: multitasking, dependence on co-workers' work, adherence to production standards or deadlines, continuous monitoring or supervision, external demand, automatic pace, and work repetition.

3.5. Psychosocial Constraints at Work

The average scores of mental strain, PD, and job DL were 16±3.7, 25±4.7, and 39±5.1, respectively. Eighty-eight percent of participants were exposed to high PD, and most (83%) were in a job-strain situation. Iso-strain was present in 82% of all cases.

3.6. Factors Associated to the Occurrence of RCTs

In the present study, RCT was significantly associated with gender (p=0.03), type of occupational sector (p ≤0.001), workstation (p≤0.001), PD (p=0.04), and job strain (p=0.03) (Table 2). RCT was significantly more prevalent among female employees (p=0.03), those in machine work positions (p≤0.001), and individuals in the clothing sector ($p \leq 10^{-3}$). Organizational constraints significantly associated with RCT included a work schedule enforced by continuous supervision (p=0.001) and/or an automatic pace (p=0.008). In the univariate analysis, the incidence of RCT was more common among employees facing high psychological demands (p=0.04) and those in job strain situations (p=0.03). The reported p-values indicate the statistical significance of the results based on χ^2 tests.

3.7. Determinants of the Occurrence of RCTs

In the multivariate analysis, the risk of RCT was multiplied by a factor of 1.3 among machine workers (p≤0.001; OR=1.3; 95% CI = [1.09; 2.03]), by a factor of 3.7 among participants subjected to continuous monitoring by superiors at work (p<0.001; OR=3.72; 95% CI = [1.05; 9.8]), and by a factor of 4.9 among those with low SS (p=0.08; OR=4.9; 95% CI = [1.17; 9.4]). (Table 3).

4. Discussion

Rotator cuff tendinitis (RCT) is a significant health issue for workers, and its occupational relationship has been established for a long time [13]. Among physical workers, shoulder tendinopathy is estimated to affect between 15 and 20% [14] with a reported incidence of 19.9 per 10,000 workers per year in Washington by Silverstein et al. [15]. In our study, RCT was diagnosed in 69% of the cases referred for shoulder pain during the study period. For the diagnostic criteria of RCT, we opted for a combination of ultrasound and clinical diagnostic tests.

According to the literature, the etiology of RCT is a complex process influenced by numerous personal and occupational risk factors. The higher prevalence among women may be linked to biological predispositions, partly explained by physiological hormonal changes women experience throughout their life cycle. For instance, menopause can lead to accelerated bone loss, increasing the risk of musculoskeletal disorders (MSDs). Additionally, a genetic predisposition may contribute to findings that being white and female significantly increases the risk of developing RCT [16].

The predominance of women can also be explained by differences in working conditions between the sexes [4]. In fact, women are often overexposed to monotonous and repetitive tasks that generate localized constraints, particularly on the extremities. Advanced age appears to be an important factor in the intrinsic etiology of RCT among the active population [3, 17]. The high prevalence of RCT in our workforce may be partly attributed to age, as more than half of the patients were older than 40 years. However, the association between age and the risk of RCT occurrence was not statistically significant. This aligns with existing knowledge about age-related degenerative diseases and changes in the rotator cuff tendons due to aging [18, 19, 20].

In our study, overweight and obesity were observed in 41% and 38% of the cases, respectively, but these conditions did not constitute significant risk factors for RCT. The relationship between RCT and overweight has been discussed in the literature [21, 22]. According to Miranda et al. and Roquelaure et al., there is no statistically significant relationship

Table 2. Factors associated with the occurrence of RCT.

	RCT(+) N(%)	RCT(-) N(%)	p
Gender:			
Male	3(4.3)	8(25.8)	0.03
Female	66(95.7)	23(74.2)	
BMI (Kg/m2):			
< 25	17(24.6)	4(5.7)	0.18
[25-30]	30(43.4)	11(15.9)	
≥ 30	22(31.8)	16(23.1)	
Age group:			
<to 40 years	19(27.5)	4(12.9)	0.08
≥ to 40 years	50(72.4)	27(87.1)	
Dexterity:			
Right-handed	61(88.4)	29(93.5)	0.71
Left-handed	8(11.6)	2(6.5)	
Sector:			
Manufacturing	55(79.7)	10(32.2)	$\leq 10^{-3}$
Others	14(20.3)	21(67.8)	
Job Position:			
Machine worker	42(60.8)	6(19.3)	$\leq 10^{-3}$
Other	27(39.2)	25(80.7)	
Job seniority:			
< 10 years	9(10.5)	7(20.6)	0.37
[10– 20] years	20(26.3)	6(13.3)	
>20 years	40(63.2)	18(56.1)	
Number of work hours per day:			
≤8h	68(94.7)	29(93.5)	0.50
>8h	1(5.1)	2(6.5)	
Multitasking:			
Yes	40(57.9)	20(64.5)	0.53
No	29(42.1)	11(35.5)	
Dependence on other colleagues' work:	38(55.1)	13(41.9)	0.22
Yes	31(44.9)	18(58.1)	
No			
Respect of production standards			
Yes	65(94.2)	28(90.3)	0.67
No	4(5.8)	3(9.7)	
Continuous monitoring or supervision			
Yes	65(94.2)	21(67.7)	10^{-3}
No	4(5.8)	10(32.3)	
External demand			
Yes	47(68.1)	25(80.6)	0.19
No	22(31.9)	6(19.4)	
Automatic rate			
Yes	69(100)	27(87.1)	0.008
No	0	4(12.9)	

(*Continued*)

	RCT(+) N(%)	RCT(-) N(%)	p
Job decision latitude			
Low	66(95.7)	27(87.1)	0.19
high	3(4.3)	4(12.9)	
Psychological demand			
low	5(7.2)	7(22.6)	0.04
high	64(92.8)	24(77.4)	
Social support			
low	68(98.5)	28(90.3)	0.08
high	1(1.5)	3(9.7)	

RCT: Rotator Cuff Tendinitis.

Table 3. Determinants of the occurrence of RCT.

	RCT(+)	RCT(-)	p	OR	95% CI
Gender					
Male	4.3	25.8	0.03	0.33	[0.03; 2.9]
Female	95.7	74.2			
Age group					
<to 40 years	27.5	12.9	0.08	0.2	[0.03; 1.3]
≥ to 40 years	72.4	87.1			
Job Position					
Machine worker	60.8	19.3	$\leq 10^{-3}$	1.3	[1.09; 2.03]
Other	39.2	80.7			
Continuous monitoring or supervision					
Yes	94.2	67.7	$\leq 10^{-3}$	3.72	[1.05; 9.8]
No	5.8	32.3			
Social support:					
low	98.5	90.3	0,08	4,9	[1.17; 9.4]
high	1.5	9.7			

between BMI and RCT [3, 18]. However, some studies have shown a positive association; for example, Reichardt et al. reported a significant association between being overweight and the occurrence of RCT in a study that included 6 237 participants [23].

Occupational risk factors for RCT remain a debated topic. Risk assessments related to biomechanics, psychosocial factors, and work organization have primarily focused on highly exposed workers, which may limit the generalizability of findings to the broader population experiencing varying levels of exposure to work-related shoulder constraints [18]. Overall, MSDs impact all occupational sectors with varying prevalence, as indicated by numerous scientific studies. The industrial sector is the most affected, followed by agriculture and public administration [24, 25].

In our study, 65% of the patients were employed in the clothing industry. These results can be attributed to the significant dominance of this sector in the central region of Tunisia, which accounts for 34% of all Tunisian manufacturing industries [26]. Activities in this sector are characterized by rapid and repetitive movements that engage localized muscle tendons and require the maintenance of constrained postures, necessitating considerable endurance [27].

These results are consistent with findings from several studies. For instance, Ghram et al. reported that, in a study involving 359 textile industry workers (89.7% women and 10.3% men) in the Monastir region, the shoulder was the most severely affected area (56% of cases) [28]. Working in the textile industry increased the risk of minor to moderate disability by 1.7 times compared to other manufacturing industries or office workers, according to Brisson C et al. [29]. In this sector, workers face postural and gestural constraints that affect the humeroscapular articulation, including repetitive external rotation and ante-pulsion of the upper limbs, along with static abduction without shoulder support [30].

While there is an extensive bibliography on physical risk factors for rotator cuff tendinopathy, there is less focus on psychosocial risk factors. Furthermore, research on organizational risk factors for RCT is limited. These factors can be defined as objective aspect of work organization. According to the SUMER surveys (medical surveillance of employee exposure to occupational risks) and working conditions surveys, authors have noted an intensification of work over the years, marked by increased organizational constraints—both industrial (e.g., automatic movement of products, machine cadence, and production deadlines) and commercial (e.g., external demand requiring immediate response) [32, 33]. In 1984, only 3% of unskilled workers were subject to these two constraints, compared to 27% in 2013 (3% and 39% among commercial employees, respectively) [34].

Referring to the study by Bodin et al. in 2017, it was reported that workers exposed to high levels of rhythm constraints (aside from those imposed by external demands), repetitive tasks, shift work, job rotation, and low decision latitude experienced more frequent shoulder pain and had higher rates of diagnosed rotator cuff syndrome than employees in other job categories [35]. This was confirmed in our study; in fact, being subjected to organizational constraints such as a work rhythm depending on continuous controls ($p=0.001$) or an automatic pace ($p=0.008$) was strongly associated with the risk of RCT. However, a work rhythm imposed by other employees' work, external demands, or production standards did not influence the occurrence of RCT in our study population.

Recent studies on RCT have highlighted the importance of psychosocial factors in exacerbating these occupational diseases. Generally, "psychosocial factors" refer to an individual's subjective assessment of the work environment, which can positively influence performance by enhancing motivation, happiness, and well-being [36]. However, these factors can also serve as sources of occupational stress [37]. Regarding psychosocial risk factors for RCT, Bongers et al. proposed two potential pathways of influence [38]: 1. Direct effects on biomechanical constraints: When workers perceive psychosocial factors such as high job demands or low control, they may feel compelled to adapt by accelerating their movements or adopting uncomfortable postures. This increased biomechanical strain can directly contribute to the onset of RCT. 2. Indirect effects through physiological stress responses: When workers perceive psychosocial factors as threats needing resolution, this can activate a cascade of stress-related physiological responses involving the immune, endocrine, central nervous, and autonomic nervous systems. The activation of these processes can adversely affect muscles and tendons, consequently increasing the risk of RCT. In summary, the findings of this study regarding organizational constraints as psychosocial risk factors for RCT can be understood within the broader context of how work-related psychosocial factors—through both biomechanical and physiological pathways—contribute to the development of MSDs like RCT in working populations.

Pope et al. (1997) reported a direct relationship between psychosocial factors, aspects of the work environment, disability, and shoulder pain [39]. In this study, we utilized the Karasek questionnaire, which examines the effects of mental stress at work on overall health. This questionnaire assesses each employee's level of PD, decision-making power, and SS in the workplace [10]. In our study, high PD, low DL, and low SS were predominantly reported in the population with the following percentages: 88%, 93%, and 96%, respectively. Only high PD was significantly related to the RCT.

In a recent systemic review, Leong et al (2019) [17] noted that several psychological factors—such as high PD, low work control or decision-making power, low commitment to safety, job dissatisfaction, and low coworker support—have been identified by multiple authors as risk factors for RCT in the workforce. However, their meta-analysis indicates that only high PD is significantly associated with an increased risk of RCT.

Similar findings have been extensively documented in the literature. Pougnet et al. (2014) reported that 50% of the 30 agents in the sterilization department were experiencing stress related to job strain, which largely contributed to the incidence of MSDs [40]. Additionally, in a 2017 study involving 254 patients, Fennani found that 90% of the patients were suffering from occupational stress and experienced job strain, which was significantly correlated with multisite musculoskeletal damage [41]. Exposure to psychosocial factors is intertwined with organizational and physical constraints, creating a complex relationship among various occupational risk factors for RCT. In this context, Niedhammer et al. (2016) noted that workers exposed to various pace-related and physical constraints (such as heavy lifting, poor posture, and vibrations) were more likely to experience work-related stress and job strain [42].

In the present study, the multivariate analysis identified several predictive factors for the risk of RCT: being a machine worker ($p \leq 0.001$; OR=1.3; 95% CI = [1.09; 2.03]), being subjected to continuous monitoring by superiors ($p < 0.001$; OR=3.72; 95% CI = [1.05; 9.8]), and having low social support at work ($p=0.08$; OR=4.9; 95% CI = [1.17; 9.4]). Furthermore, research has examined how individual patient characteristics influence the impact of RCT on professional activity. A 2014 study by Dunn et al. evaluated 393 patients with rotator cuff tears and found that the level of shoulder activity was significantly correlated with the patient's age, sexe, and occupation but not with the size of the tear or the severity of the injury [43]. The current study revealed similar findings, with female gender ($p = 0.005$) identified as the only personal factor associated with a reduction in professional activity.

In conclusion, preventing RCT should focus on modifiable factors within employees' professional environments. While organizational factors play a role, they primarily impact employees' physical and psychological strains. Work organization highlights the dual technical and social dimensions of professional risk factors. On the technical side, prevention efforts should concentrate on improving working conditions, particularly regarding rhythms and cadences, and seek ergonomic solutions to enhance psychological well-being.

This is the first study to emphasize the influence of psychosocial constraints on RCT occurrence among Tunisian workers. However, some limitations exist: the study's cross-sectional nature may lead to selection and recall bias, and there was no objective assessment of workers' biomechanical constraints. Additionally, data collection coincided with the emergence of the SARS-CoV-2 virus, which caused significant upheaval and stress, potentially affecting pain perception and study results. Lastly, using self-administered questionnaires for risk assessment could lead to inaccuracies in exposure reporting, as workers with RCT might overreport pain, while those who changed jobs may underreport exposure.

5. Conclusion

The present study highlights the critical role of psycho-organizational constraints in the occurrence of RCT among Tunisian workers, particularly those in manufacturing industries. These constraints significantly influence work activity and can be considered predictors of the ability to return to work after a rotator cuff tendon injury. Given the high prevalence of these disorders and their impact on employees' quality of life and work capacity, it is essential to implement appropriate preventive measures. Notably, only high PD was significantly associated with RCT. In a recent systematic review, Leong et al. (2019) also noted that high PD can be associated with an increased risk of RCT.

Consent to Participate: Written consent from the participants was obtained.

Conflict of Interest Declaration: The Authors declare no conflict of interest.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Availability of Data and Materials: The raw data used in this study are available in an SPSS file. The questionnaire used can be obtained upon request from the corresponding author.

Competing Interests: The Authors declare no conflict of interest.

Authors Contribution: N.B.: study conception, design analysis, and interpretation of results; M.L.: data collection. N.G.: draft manuscript. I.R. and A.K.: contributed to researching data sources and reorganizing the text. T.K. and A.M.: discussed and revised the manuscript. All authors approved the final version of the manuscript.

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Subjective and Objective Evaluation of Physical Activity Level and Its Relationship With Work Ability of Nurses In Different Hospital Departments

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Keywords: Physical Activity; Work Ability; Smart Wristband; Nurses

Abstract

Background: *Due to the nature of shift work, nurses experience very high mental and physical pressure, which can ultimately affect their work ability (WA). One factor that affects work ability is the level of physical activity (PAL). Since nurses are responsible for providing healthcare for the public, it is necessary to evaluate their WA and PAL. Therefore, the present study used subjective and objective evaluation to test the relationship between PAL and WA among nurses in different hospital departments affiliated with Isfahan University of Medical Sciences.* **Methods:** *A descriptive-analytical study was conducted over 6 months. A questionnaire was used to measure the work ability index (WAI). The International Physical Activity Questionnaire (**IPAQ**) was used for subjective evaluation, and the Xiaomi smart wristband Mi Band Five was used for objective assessment. These tools extracted the components of behaviors related to physical activity for 7 days. One hundred nurses were selected for subjective evaluation, and then 40 of them were randomly selected for objective assessment. The SPSS software version 23 was used for data analysis. Multiple regression analysis was used to test the effect of physical activity on the work ability index by controlling other demographic variables.* **Results:** *7% of participants had poor WAI, and 45% had moderate work ability. Also, the ability to do good and excellent work was 32% and 16%, respectively. In this study, 31% of participants had low PAL, 42% moderate PAL, and 27% high PAL. In the objective evaluation, 12.5% of participants had a PAL of 100, 35% less than 100(poor), and 52.5% had a PAL above 100(High). In the subjective evaluation, the highest PAL belonged to the emergency department. The results of the subjective and objective methods to check the correlation between WAI and PAL showed a positive and significant correlation.* **Conclusion:** *In the present study, subjective and objective evaluations showed a significant relationship between work ability and PAL. The present findings can be used to develop future interventions to improve nurses' health and work performance.*

1. Introduction

In many countries, the labor force is aging [1, 2]. This challenge has driven governments to emphasize improving work ability and increasing working life [3]. Work ability is fundamental to well-being and health; thus, maintaining and enhancing it is crucial in ergonomics and occupational health. It reflects one's capacity to perform work efficiently based on health, needs, and cognitive abilities [4].

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Research indicates that most job stress stems from a mismatch between abilities and job requirements. Studies have identified job stress as a key risk factor affecting work efficiency and capability. The work ability concept underlies workstation design and employee selection [6, 7]. The Finnish Occupational Health Institute's model effectively addresses the interplay between work-related, personal, and social factors and work ability. It asserts that work ability is influenced by individual capabilities (health and functional capacities), knowledge (skills and competencies), values, motivation, work-related factors (physical, mental, and social needs), and external factors (family, friends, and social bonds). Central to this model are physical and mental health. Additionally, the model identifies PAL as a factor affecting work ability [8].

Physical activity is key to health management worldwide [9]. It is crucial for preventing disorders like cardiovascular diseases, obesity, type 2 diabetes, osteoporosis, and back pain [10]. Increased mobile phone usage has led to more musculoskeletal disorders [11]. Continuous physical activity reduces cancer-related mortality by 25-30%, with men benefiting by 59% [12]. Health and Human Services recommend 150 minutes of moderate-intensity aerobics weekly [13].

Nursing is central to healthcare, exposing individuals to high mental and physical stress from shift work [14]. This can lead to sleep disorders, psychological issues, and heart and digestive problems, affecting work ability [15]. Assessing nurses' work ability is essential, as it is influenced by stress [15]. Evaluating personal factors, including physical activity, is crucial for determining their work ability index [8]. Grabara et al. found that female teachers with moderate to severe physical activity levels had good work ability [10]. Micalos et al. compared paramedics and nurses, determining that nurses had lower physical activity levels [16]. Few studies have explored the relationship between physical activity levels (PAL) and work ability index (WAI) among nurses.

This study aims to examine this relationship, measuring PAL objectively and subjectively and comparing these evaluations for their effect on WAI among nurses in a hospital setting.

2. Methods

The present descriptive and analytical study was conducted for 6 months on nurses working in a hospital affiliated with Isfahan University of Medical Sciences. The main objective was to test the relationship between WAI and PAL. The data were collected using the demographic questionnaire, the WAI questionnaire, the IPAQ questionnaire, and the Xiaomi Mi Band 5 smart wristband. The IPAQ questionnaire and the Xiaomi Mi Band 5 smart wristband measured the PAL subjectively and objectively, respectively. The sample size was estimated as the correlation coefficient of the two variables of interest with a confidence interval of 95% and test power of 80%. This relationship was interpreted as statistically significant if the correlation coefficient was 0.3 or more. Finally, the sample size was estimated using the following formula:

$$P0 = 0/3$$

$$Z0 = 0/31$$

$$N = (Z_{1-\alpha/2} + Z_{1-\beta})^2 / Z_0^{\,2} + 3$$

To compensate for the sample attrition and potential incomplete questionnaires, an attrition rate of 15% was anticipated, and the final sample size was obtained by dividing 0.85 by 85; thus, 100 nurses needed to be included in the study. To adhere to ethical rules, the following were observed: (i) obtaining written consent from nurses to participate in the study; (ii) assuring the nurses that their information would be kept confidential; (iii) thoroughly explaining the work and research steps to all nurses who participated in the study.

To conduct the study, 100 nurses were proportionally divided based on department size, with more participants from departments with a higher nurse count. A list of nurses was created for each department, and 40 were randomly selected to use the smart wristband. Inclusion criteria were (i) over two years of nursing experience at the hospital, (ii) voluntary participation, and (iii) no physical disorders (verified through medical records or individual reports). Exclusion criteria were: (i) smoking most days; (ii) pregnancy or breastfeeding within the past 3 months. The extracted data were classified and statistically analyzed. The Work Ability Index (WAI) questionnaire measures work ability at the workplace, adapted from the Finnish Occupational Health Research Institute. Its reliability and validity were assessed by Mazloumi et al. in Iran [17]. The WAI final score ranges from 7 to 49, classifying workers as 7 – 27 (poor), 28 – 36 (moderate), 37 – 43 (good), and 44 – 49 (excellent). The IPAQ is one of the most accurate instruments for measuring physical activity levels (PAL) over the past 7 days [17].

The intensity of physical activity over the past week was measured in MET-minutes per week. MET is a unit used to estimate the energy expended during physical activity. All physical activities can be expressed as multiples of the energy consumed at rest. One MET is nearly equivalent to the energy burned in a resting state [18]. This questionnaire consists of 27 items divided into five sections: evaluation of physical activity in daily work, commuting, domestic chores, leisure time, and sedentary time. Based on the MET scores, this questionnaire categorizes individuals into three groups: low physical activity, moderate physical activity, and high physical activity.

- Low: This is the lowest level. Individuals who do not meet the criteria for Categories 2 or 3 are considered to have a 'low' physical activity level.
- Moderate: The pattern of activity to be classified as 'moderate' is either of the following criteria: (i) 3 or more days of vigorous-intensity activity (at least 20 minutes per day) OR, (ii) 5 or more days of moderate-intensity activity and/or walking (at least 30 minutes per day), OR (iii) 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET-minutes/week. Individuals meeting at least one of the above criteria be classified as 'moderate'.
- High: This category was computed to describe higher levels of participation. The two criteria for classification as 'high' are: a) vigorous-intensity activity on at least 3 days achieving a minimum Total physical activity of at least 1500 MET-minutes/week, OR b) 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum Total physical activity of at least 3000 MET-minutes/week. To calculate the total intensity of physical activity in a week we used this Formula as defined in IPAQ guideline:
- Walking MET-minutes/week = 3.3 * walking minutes * walking days;
- Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate days Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days;
- Total physical activity MET-minutes/week = sum of Walking + Moderate + Vigorous MET minutes/week scores [18].

In the present study, nurses used the Xiaomi Mi Band 5 smart wristband for 7 days to measure behaviors related to occupational physical activity at work. The reason for using the wristbands for this duration was that the IPAQ also assessed physical activity levels over the past 7 days. The nurses wore the Xiaomi Mi Band 5 wristband 24 hours a day for the entire week. The data retrieved from the smart wristband includes the number of steps, distance traveled, heart rate, and PAL. This wristband calculates PAL as a total score based on height, weight, and other personal information. The device's accuracy in measuring these indices has been validated by several previous studies [19-22]. Data analysis was conducted using SPSS23 along with descriptive and analytical statistical tests. Additionally, multiple regression analysis was performed to evaluate the impact of physical activity (both occupational and general) on work ability while controlling for other demographic variables variables.

3. Results

The overall work ability and physical activity of 100 nurses were assessed. The participants' average

age was 33.12 ± 5.05 years. Regarding sex, 21% of the nurses were male, and 79% were female. One of the significant challenges during the COVID-19 pandemic was the shortage of nursing staff to provide services to COVID-19 patients. Hospitals have always struggled with a shortage of nursing staff, which became more apparent during the COVID-19 crisis.

Additionally, during the second peak of the outbreak, many nursing staff became infected, leading to their removal from service. This situation doubled the workload due to staff shortages, and the workload was high in all hospital departments. We speculated that the physical activity and work ability of personnel differ across departments.

Testing the distribution of participants in the hospital departments showed that 10% of nurses worked in the CCU, 11% in the ICU, and 18% in the emergency department. Moreover, 14% were in the operating room and maternity departments, while 10% worked in the anesthesia and other departments. The results indicated that 12% of the participants had cardiovascular disease, 21% had mild mental illness, 14% had hearing problems, 7% had anemia, and 2% had high blood pressure. The questionnaire-based assessment of Work Ability Index (WAI) in this study showed that the mean and standard deviation of WAI were 36.39 and 6.15, respectively. In this study, 7% of the participants had poor work ability, 45% had moderate work ability, 32% had good work ability, and 16% had excellent work ability. To assess the nurses' physical activity, the IPAQ was utilized. The mean and standard deviation of participants' physical activity were found to be 4310.24 and 3371.28 MET-minutes/week, respectively.

For assessing physical activity in 40 of the 100 nurses, with an average age of 30.75 ± 5.5 years, wristbands were used. The results showed that 20% of these nurses were men (n=8) and 80% were women (n=32). The wristband used in this study had a default score of 100 as a measure of physical activity. If the physical activity indicated by the wristband was above 100, it was interpreted as good physical activity, while a score below 100 indicated poor physical activity. The mean and standard deviation of physical activity among these nurses was 98.85 ± 7.87. The results showed that 12.5% of the sample (n=5) had a physical activity score of 100, 35% (n=14) had a score less than 100, and 52.5% (n=21) had a score higher than 100.

To assess the nurses' work ability in relation to the study variables, the Mann-Whitney U-test was used, indicating that the mean work ability score was higher in single nurses compared to married ones. This difference in the mean WAI scores was statistically significant between male and female nurses (p=0.032). Regarding the relationship between nurses' WAI and employment status, the Kruskal-Wallis test showed that the mean WAI score was highest among permanent nurses (i.e., 45.01). The difference in the WAI across nurses' employment status was statistically significant (p=0.01). Furthermore, in exploring the relationship between WAI and having a sideline, the results indicated that nurses with a sideline had a WAI of 33.87, while those without a sideline had a WAI of 36.60, which was statistically significant. The results of measuring the WAI by work shifts also showed that nurses with day shifts had a higher WAI (see Table 1).

The results of measuring the physical activity of male and female nurses indicated a significant difference (p=0.02), particularly concerning the mean score of physical activity by employment status. The findings showed that the mean physical activity scores for permanent and contractual nurses were significantly higher than those of other employment types (p=0.008). Finally, when assessing nurses' physical activity across different departments, there was a significant difference in the mean physical activity score among the nurses (Table 2).

Spearman's correlation test was employed to examine the relationship between quantitative variables such as age, weight, height, work experience, number of shifts, and working hours over the past week with the Work Ability Index (WAI). The findings indicated a significant negative correlation between age and the WAI. Additionally, a significant positive correlation was observed between work experience and the WAI. There was also a significant positive correlation between working hours (in a week) and the WAI. Notably, significant negative correlations were found between work ability, the number of shifts in the past week, and the WAI, as

Table 1. Correlation between work ability index (WAI) and variables of study.

Variable	Level	N.	WAI		P value
			Mean	SD	
Sex	male	21	37.09	1.29	0.557
	female	79	36.20	0.70	
Marital status	single	42	37.92	0.93	0.032
	married	58	35.27	0.79	
Shift type	day	11	43.36	1.04	0.001
	day-night	88	35.52	0.62	
Sideline	yes	8	33.87	2.15	0.04
	no	91	36.60	0.64	
Employment	Project-based	15	37.33	1.59	0.01
	contractual	10	33.54	1.90	
	temporary-to-permanent	69	36.01	0.69	
	permanent	5	45.01	1.83	
Hospital departments	general	13	35.61	1.34	0.224
	emergency	18	39.01	1.94	
	CCU and ICU	21	36.23	1.52	
	Operation room	14	37.78	1.78	
	Obstetrics and gynecology	14	34.07	1.49	
	Anesthesia	10	33.7	1.59	
	Other(s)	10	37.02	2.40	

well as between height and the WAI. No correlation was identified between the participants' weight and the WAI (Table 3).

Spearman's correlation test of the physical activity based on IPAQ and demographic variables showed a significant negative correlation between age and physical activity, weight and physical activity, and work experience and physical activity ($P < 0.05$). Moreover, no correlation was found between height, working hours, number of shifts within the past week and working hours per week ($P > 0.05$) (Table 4).

Figure 1 summarizes the Spearman's test results. A significant positive correlation between physical activity assessed with the wristband and the WAI ($r=0.677$, $P < 0.01$). As can be seen, one's work ability is increased with increased physical activity.

4. Discussion

The purpose of this study was to investigate the relationship between WAI and PAL in nurses. The mean index of work ability in this study was moderate. Similarly, in Rypicz et al.'s study, which aimed to investigate the work ability index in nurses, the results showed that the average work ability index was moderate. [23]. In some research by Grossi et al., nurses' WAI was found to be good. Similarly, in another study, Sivan Sobhani et al. reported nurses' WAI to be good [24].

A primary reason could be the average age of the research participants. In the study by Grossi and Sobhani, the participants had average ages of 24 and 31 years, respectively. In contrast, the nurses in the current study had an average age of 33. Consequently, younger individuals tend to have higher

Table 2. Correlation between physical activity (PA, MET-minutes/week) and variables of study.

Variable	level	n.	PA Mean	PA SD	P Value
Sex	male	21	5892.33	4429.34	0.02
	female	79	5239.86	4876.24	
Marital status	single	42	5870.25	4860.45	0.72
	married	58	3890.24	2780.22	
Shift type	day	11	4116.23	3783.36	0.35
	day-night	88	4740.20	3670.32	
Sideline	yes	8	3790.23	2980.34	0.52
	no	91	4830.69	3760.27	
Employment	project	15	3747.66	2936.10	0.008
	contract	10	4760.21	3680.63	
	temporary-to-permanent	69	4734.24	3670.76	
	permanent	5	3679.45	3010.61	
Hospital departments	general	13	4380.22	3740.34	0.004
	emergency	18	5434.79	4842.09	
	CCU and ICU	21	4499.95	3950.78	
	operation room	14	3490.25	2933.42	
	obstetrics and gynecology	14	3298.49	2887.30	
	anesthesia	10	5225.30	4815.48	
	other(s)	10	3390.32	2993.19	

Table 3. Spearman's correlation coefficient between the final WAI score and variable of study.

Variable	Correlation coefficient (r)	P-value
Age (year)	-0.611	0.001
Weight (kg)	0.037	0.71
Height (cm)	-0.085	0.4
Work experience (year)	0.066	0.001
Work hours (h)	-0.226	0.02
Frequency of shifts (past week)	-0.422	0.001

Table 4. Correlation between the physical activity score and variables of study.

Variable	Correlation coefficient (r)	P-value
age	-0.307	0.002
weight	-0.219	0.02
height	0.077	0.44
work experience	-0.250	0.01
work hours	-0.150	0.12
frequency of shifts in the past week	-0.10	0.92

work ability. Additionally, the survey by Selorzi et al. found that nurses' working ability was moderate, which aligns with the present study [25]. One possible explanation is the similarity in age range between Selorzi's research and the current one. The present findings reveal a significant negative correlation between Work Ability Index (WAI) and the demographic variable of age ($p < 0.001$), consistent with the study by Ehsan Elah Habibi et al. ($p < 0.05$) [26]. Thus, as the age variable increases, the average WAI decreases.

Furthermore, Monteiro et al.'s study found a significant negative relationship between age and WAI, which is consistent with the current findings [27].

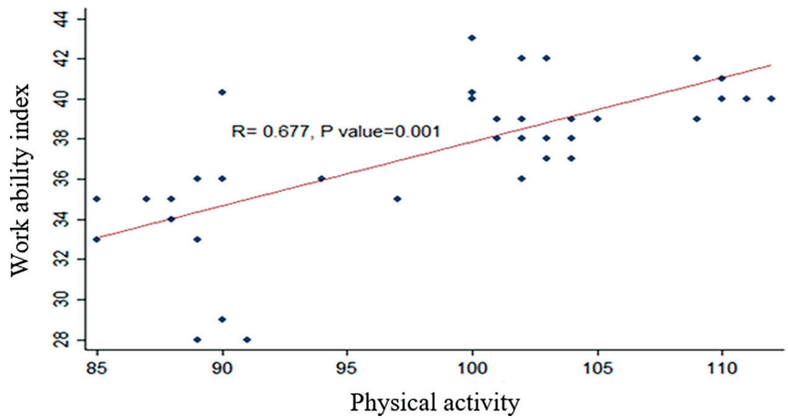

Figure 1. The relationship between the WAI and physical activity.

In the study of TIJ van den Berg to test the effect of occupational factors related to work and personal factors on the WAI as a systematic review, the results showed a significant relationship between age and the WAI [6]. Among the reasons for the agreement between the study mentioned above and the present findings is the similar research populations in the two studies. However, in the study of Bugajska J et al., to test the physical work capacity (VO2 MAX) and the WAI in employees of the Polish Electricity Bureau, the mean index was found to be positively correlated with the demographic variable of age (the age below 35 years) [28]. The reason for the contradictory findings is that the research populations were different. The results of testing WAI by different work shifts showed that nurses with day shifts had a higher work ability. This difference in nurses' work ability across different work shifts was also statistically significant (p=0.01). The mean score of this index in Costa et al.'s research has the highest value for day-night shift workers and the lowest value for day shift workers [29]. In the present study, a significant negative correlation was found between the WAI and the age variable. It can be argued that with increasing age, the level of nurses' health will decrease, which can affect the work ability index. A significant negative correlation was found between age and work ability [30].

In the present study, there was no significant relationship between BMI and work ability. The reason is that there is a significant negative correlation between height and WAI in this study, yet no correlation between weight and WAI. In their study, Ardudri et al. found a significant correlation between BMI and WAI [30]. In fact, there was a positive and significant correlation between nurses' weight and WAI and between height and WAI. In another cross-sectional study, Giacomo Garzaro et al. investigated the relationship between physical health and WAI among healthcare workers. The results showed a significant negative relationship between WAI and age [31]. The findings showed no significant re-lationship between the department type and the WAI. In some research on nursing and midwifery hospital staff and employees of a factory, Celedova et al. found that the former had a lower work ability than the latter [32].

In Monteiro's study, the nurses of the conservative department had a higher WAI than the surgical depart-ment [27]. It is noteworthy that the present study was conducted in only one hospital. In Gharibi et al.'s study, more than one-third of workers did not have a high enough WAI. Moreover, the overall mean score of WAI was at an moderate level. In Gharibi et al.'s study, more than one-third of workers did not have an adequate work ability index (WAI < 36) [33]. In the present study, as the work ability index questionnaire showed, 12% of the participants had a cardiovascular disease, 21% mild mental illness, 14% hearing problems, 7% anemia and 2% high blood pressure. This shows that there is a significant relationship between the disease index and the work ability index. In another study, Abdul Alizadeh et al. aimed to check the validity of the Iranian version of the WAI questionnaire. They found a significant relationship between the work ability index and affliction with a disease ($p<0.05$) [34] because more suffering from diseases reduces one's ability to work.

The present study found a significant and positive correlation between work experience and work ability index. So-leimani et al. showed that with increasing age and work experience, the safety attitude and knowledge and the work ability index increase [35]. In the present study, there was a negative correlation between age and physical work activity ($p >0.002$ and $r=0.307$), which was in line with the study by Legaz-Arrese A [36]. Also, Lorna H's study, which aimed to investigate the effect of individual and social factors on changes in physical activity in the working community, led to similar findings [37]. In the present study, the total mean score of physical activity was higher in men than in women, This score was 15996.76 and 6271.86 in men and women, respectively, which is similar to the study of Shook RP et al., which was conducted using an international questionnaire to measure physical activity based on physical fitness [38]. It was also consistent with the study of Vafai Najjar, which aimed to investigate the effectiveness of physical activity training in the emotional exhaustion of employees in Agh Qola city [39]. Also, Moradi et al.'s study showed that female participants had low and moderate physical activity [40]. One reason for the similarity of the findings of these studies to the present study can be the greater metabolism and, as a result, physical activity of men than women. In the study of Andrea Piccinno and Dario Colella, which aimed to test the relationship between cardiac complications and PAL in adolescents with this complication, no significant difference was found between sex and PAL [41]. One reason for the divergent findings can be that the research sample consisted of patients rather than nurses.

The results of the correlation test showed a significant negative correlation between weight and physical activity ($P = 0.02$, $r = 0.219$), which was in line with the study of Pasdar et al., which aimed to investigate the intensity of physical activity and its effect. This study was conducted on body composition and quality of life in female employees of Kermanshah University of Medical Sciences in 2013 [42]. One reason can be that with increasing weight, one's mobility and physical activity decrease. Also, Tucker SJ's research, which aimed to investigate the effect of physical activity on working nurses with children, is also in line with the present study ($P <0.03$) [43]. In this study, the nurses working in the emergency department had a higher mean score of physical activity than other departments. In another study by Baghani Moghadam et al., the highest physical activity levels belonged to housewives [44].

As the present study showed, a significant relationship was found between the PAL index and WAI in both subjective and objective assessments. However, in the study of Erdodri et al., which aimed to investigate the relationship between PAL and WAI in administrative and operational jobs, no significant relationship was observed between these two indices [30]. In their study, Bugajska et al. found a significant correlation between physical activity and work ability, consistent with the present study [28]. One reason for the consistency of findings can be the effectiveness of physical activity in reducing different diseases and increasing personal abilities. However, in the study of Van Den Berg et al., which evaluated the job-related effects of individual factors on the work ability index [6], and also in the study of Grabara et al. on the relationship between physical activity and work ability among teachers, a significant relationship was found between BMI and WAI [10]. Any study may have its limitations. In this study, the following limitations are noted: (i) a significant number of nurses did not participate in the physical activity evaluation due to the time-consuming nature of completing the extended version of the physical activity questionnaire, which limits the external validity of the results; (ii) the cross-sectional study design (6 months) does not allow for any inferences about causality. Despite these limitations, the study suggests that (i) nurses should adopt healthier lifestyles to increase their physical activity, potentially improving their work ability index and reducing the risk of early retirement; (ii) a broader evaluation of physical activity within a larger statistical community of nurses should be conducted to investigate the impact of physical activity on the work ability index; (iii) further studies should be carried out with diverse communities to explore these issues.

The present study found a significant correlation between the work ability index and physical activity (both subjective and objective evaluations). Enhancing physical activity can not only prevent overweight, boost skeletal-muscular capacity, and increase physical-mental strength, but also promote nurses' health. Given the impact of physical activity on nurses' work ability index, the present findings can be employed to develop future interventions aimed at improving nurses' health and work performance.

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