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Differences in Risk Perception Between the Construction and Agriculture Sectors: An Exploratory Study with a Focus on Carcinogenic Risk

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Keywords: Occupational Risks; Personality Traits; Carcinogen Exposure; Risk Perception

Abstract

Background: *Risk perception is crucial in occupational health and safety, particularly in high-risk sectors like agriculture and construction. This study investigates the influence of personality traits, emotional states, and socio-demographic variables on perceived risks, explicitly focusing on carcinogenic exposure. The aim is to identify key factors shaping risk perception to inform safety interventions.* **Methods:** *Using a correlational research design, 91 Italian workers (49 from construction and 42 from agriculture) completed a comprehensive questionnaire assessing personality (Big Five model), emotional state, self-perceived safety knowledge, and risk perception across 14 dimensions. Statistical analyses included correlations, ANOVA, and regression models to explore relationships between variables.* **Results:** *Openness, emotional stability, and extraversion were inversely related to perceived risk levels, while conscientiousness and agreeableness correlated positively. Workers in agriculture reported higher awareness of carcinogenic risks than construction workers, though no significant differences emerged in perceived risk levels. Negative emotional states predicted higher risk perception, while self-perceived safety knowledge had only minor correlations with specific risk dimensions. Gender, age, and service length did not significantly influence risk perception.* **Conclusion:** *Personality traits, particularly openness and emotional stability, strongly influence risk perception, highlighting the importance of considering individual psychological profiles in occupational safety interventions. Although emotional state plays a notable role, self-perceived safety knowledge showed limited impact, suggesting a need for targeted education.*

1. Introduction

Institutional and corporate attention to occupational health and safety has led to an impressive body of research on risk prevention. This attention has resulted in regulatory developments and various stakeholders' involvement in producing good practices in the field of occupational health and safety. Scientific research on this topic represents a multidisciplinary field in which technical approaches are mixed with health and psychological ones, primarily

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when referring to the study of behaviors that may or may not expose individuals to different risks [1].

The term 'risk' represents the possibility of suffering harm linked to foreseeable circumstances; consequently, it is a variable related to the frequency (or probability) of the occurrence of damage and the magnitude of said harm to the individual [2]. While risk is commonly defined through quantitative models, its interpretation in everyday contexts is inherently subjective and influenced by human behavior. Several factors are indicated in the literature as influencing risk perception: socio-demographic factors, such as gender, age, length of service, and education; risk competence factors, such as the degree of experience with risk exposure, knowledge of individual risks or regulations, and whether or not one is an expert in risk management and assessment processes; and organizational-contextual factors, including trust in the safety management system, perceived working conditions, and the presence of a safety-oriented organizational culture, all of which can enhance or reduce one's risk perception and competence [3]. In addition to these factors, it is widely known that the so-called human factors (which include both cognitive factors, such as biases, and personality factors) play a role in risky behaviors and accidents at work; several studies have focused on the possible predictive role of some personality traits in environmental and risk perceptions [4, 5].

A thorough understanding and awareness of health risks can lead to safer behaviors: effective risk perception significantly impacts them and ultimately enhances the safety and health of the community [6, 7].

The perception of the individual risk appears to be determined by a complex set of cognitive and psychological factors: the perceived possibility of harm to health, the subjective importance of the harm being more or less possible, and the personal uncertainty associated with exposure to a specific risk factor [8, 9, 10]. Research investigating the role of individual and cognitive factors in risk perception has found that factors such as the degree of emotional involvement in the perceived consequences of different risks or specific personality dimensions which determine emotional and behavioral attitudes influence various aspects of risk perception [1, 11, 12]. Among the approaches most frequently used in analyzing the psychological processes involved in risk perception is undoubtedly the so-called psychometric paradigm [12]. This paradigm has helped to identify differences and similarities between workers concerning personal risk dispositions and highlights how the concept of risk can take on different meanings for different subjects [13].

Some research has focused more specifically on subjective variations in risk perception due to personality structure using the so-called Big Five model [14], which identifies five major factors, each of which can aggregate several characteristics. Moreover, emotional factors such as fear, for example, tend to amplify the assessment of the consequences of risky events. At the same time, anger can significantly reduce risk perception, leading to errors and altered perceptions of evaluating risks and hazards [11, 12]. An analysis of the literature seems to highlight, in the perception of different types of risk, the clear role of circumstantial emotional states, such as anxiety and fear [15, 16].

The literature indicates a combined influence of personality, emotional factors, and knowledge or experience with specific risks in risk perception [17]. A correlational research was conducted involving workers who completed a questionnaire assessing their personality, emotional state, knowledge of safety regulations, socio-demographic factors, the size and level of perceived risk, and job satisfaction to investigate the relationships among these factors. As is well-known, many workers in agriculture and construction may be exposed to carcinogens used for various purposes. In agriculture, for example, workers are frequently exposed to pesticides, herbicides, and ultraviolet radiation, factors that increase the risk of developing different types of cancer. Epidemiological studies have shown farmers have an elevated risk of non-Hodgkin's lymphomas, multiple myelomas, and skin melanomas [18]. Exposure to specific herbicides such as 2,4-D has been linked to an increased risk of gastric cancer and haematological cancers [19].

Workers are often exposed to carcinogens such as silica and asbestos during demolition and remediation activities in construction. Several authors [20, 21] indicated an increased risk of lung cancer among these workers. Other types of cancer, such as laryngeal and bladder cancers, are also more prevalent among construction workers exposed to industrial dust [22]. The research involved data collection from workers in the agricultural and construction sectors, focusing on carcinogenic risk and aiming to compare these relationships across two work sectors. The study considered personality, emotional state, socio-demographic factors, and self-perceived knowledge of safety regulations as independent variables. At the same time, the size and level of perceived risk and job satisfaction were treated as dependent variables.

There are few indications in the literature on the relationship between personality characteristics (capable of determining emotional and behavioural attitudes) and risk perception. The studies that have focused on the topic have provided results that are not always appreciable regarding the relationship between personality and risk perception [9, 16]. What is clear is that extraversion and openness have a positive relationship with risk-taking propensity [23, 24] and an inverse relationship with perceptions of the level of risk. Conversely, agreeableness, conscientiousness, and emotional stability predict perceived risk levels [25, 26].

A study on a sample of Italian workers in the transport sector confirmed part of the evidence regarding the relationships between personality and levels/dimensions of risk [27, 28]. Friendliness, emotional stability, and openness were the personality factors most sensitive to the different dimensions and levels of risk [28]. Based on the literature mentioned above, this research aimed to test the following hypothesis:

- H1: There is a relationship between personality factors and risk perception. Specifically, it is hypothesised that people with higher levels of extraversion tend to perceive lower levels of risk and danger (H1a), more friendly people tend to perceive higher levels of risk and danger (H1b), more conscientious people tend to perceive higher levels of risk and danger (H1c), people who are more emotionally stable tend to perceive higher levels of risk and danger (H1d), and people with higher levels of openness tend to perceive lower levels of risk and danger (H1e).

An analysis of the literature indicates a relationship between socio-demographic variables and risk perceptions; habit, older age, and longer service lead to a presumption of control over risk [1,9,27]. Previous research with an Italian sample found age and length of service weakly predictive of risk levels but negatively correlated with multiple risk dimensions. Relying on this rationale, we hypothesised:

- H2: There is a relationship between socio-demographic variables and risk perception. As age (H2a) and length of service (H2b) increase, risk aspects will be perceived as less dangerous. Furthermore, we hypothesise that women will perceive higher risk levels than men (H2c). Studies have highlighted risk competence factors, including expertise and knowledge of individual risks and safety regulations [10,13]. In Italian workers, these indications were unequivocal [28]. Based on the literature, this research aimed to test:
- H3: There is an inverse relationship between self-perceived knowledge of safety regulations and risk perception. Additional evidence shows that emotions affect the processing of health risk information [15, 16]. As demonstrated in contexts like health care, negative and positive emotions may play different roles in risky behaviors around health. Hence, we hypothesized:
- H4: There is a relationship between emotional state (inverse for positive and direct for negative states) and perceived risk. This study aimed to examine the relationships between personality traits and perceived risk dimensions using a correlational research design among Italian workers in the construction and agriculture sectors, specifically addressing carcinogenic risk, which is an "invisible" risk often underestimated due to the lack of immediate health effects [7-9]. Research into the connection between personality, emotional state, and risk perception is

a significant area of interest for the practical implications it can foster regarding occupational safety and the prevention of workers' risk behaviors [16, 23, 29].

2. Methods

2.1. Study Design

The study was conducted in November 2023. As part of an occupational safety training intervention aimed at workers and employers in the construction and agriculture sectors operating in the province of Enna, the participants (N = 118) were voluntarily asked to complete a questionnaire regarding their perception of carcinogenic risk. Simultaneously, the participants were requested to sign the informed consent for data processing and were told that completing the questionnaire was completely anonymous.

2.2. Data Analysis

The research design was correlational. IBM SPSS 29.0 was used for data analysis. A correlational study was conducted between the risk perception and personality variables; thereafter, a multiple regression analysis was performed, considering personality dimensions (extraversion, agreeableness, conscientiousness, emotional stability, and openness), sociodemographic factors, and perceived knowledge of safety regulations as independent variables. In contrast, the 14 risk perception dimensions, level of perceived risk, and job satisfaction served as dependent variables. ANOVA and t-tests for independent samples were used to analyse group differences.

2.3. Measures

The questionnaire was prepared in Italian, available to all participants, and distributed by a workplace safety physician before training. It consists of three pages and can be completed in under seven minutes. It covers socio-demographic characteristics through nine questions addressing age, gender, marital status, number of children, educational qualification, nationality, length of service in current employment, total employment length, and job role.

A validated questionnaire [30] measuring occupational risk perception, based on the semantic differential model, assesses 14 bipolar dimensions on a 7-point Likert scale, such as: 1) Assumed voluntarily vs. assumed involuntarily; 2) Immediate vs. deferred health effects; 3) Known risk vs. unknown risk by workers; 4) Known risk vs. unknown risk by science; 5) Controllable vs. uncontrollable harmful effects; 6) New vs. familiar risks; 7) Chronic vs. catastrophic risks; 8) Common vs. terrifying risks; 9) Non-fatal vs. fatal consequences; 10) Absence vs. presence of risk for future generations; 11) Controlled vs. uncontrolled severity of the risk; 12) Observable vs. unobservable harm; 13) Not exposed vs. exposed; 14) Few vs. many exposed to the risk. An item from the perceived workplace risk scale asked participants to identify occupational risk factors in their jobs (e.g., physical, chemical).

A 5-point Likert scale item gauged perceived risk level in their job (1 = low risk, 5 = high risk) [28]. Self-perceived knowledge of safety legislation was assessed using a 4-item scale (e.g., knowledge of the Occupational Health and Safety Act), employing a 5-point Likert scale (1 = poor knowledge, 5 = excellent knowledge; Cronbach's alpha = .86) [28]. Personality was measured using the Big Five Inventory—Italian Short Version (BFI-10) [31], consisting of 10 items rated 1 (completely disagree) to 5 (fully agree). The BFI-10 dimensions were agreeableness (AGR), conscientiousness (COS), emotional stability (EMS), extroversion (EXT), and openness (OPEN). An item example is "Tends to find fault with others and does a thorough job." The emotional state was captured using the Italian short version of the Positive and Negative Affect Schedule [32], a 10-item self-reported questionnaire using a 5-point Likert scale, assessing positive (Cronbach's alpha = 0.81) and negative (Cronbach's alpha = 0.93) effects. Job satisfaction was gauged using a 3-item scale (e.g., 'How satisfied are you with your working life?") on a 5-point Likert scale (1 = totally dissatisfied, 5 = totally satisfied; Cronbach's alpha = .92) [33].

3. Results

Out of 118 individuals who participated in the training intervention, 91 (77%) participated in the study and completed the survey instrument accurately. All participants were Italian. Of these, 49 worked in the construction sector (response rate = 74%; 46.2% of respondents), while 42 were employed in agriculture (response rate = 81%; 53.8%). The respondents had an average age of 45.9 years (*SD* = 11.2) and an average length of service of 11.92 years (*SD* = 7.19). Understandably, given the working sectors, the sample was unbalanced in terms of gender, with 61 men (67%) and 30 women (33%). Tables 1 and S1 summarise the socio-demographic characteristics of the sample across different sectors and the composition by role, respectively. Regarding marital status, 29 subjects (31.9%) were single, 55 were married (60.4%), and seven were in another situation (7.7%; divorced, widowed, etc.). In terms of educational qualifications, 44 had a high school diploma (48.4%), 7 had a university degree (7.7%), and 40 had a middle school diploma (43.9%). All operators received training as mandated by Article 37 of Legislative Decree 81/08.

Table S2 describes the differences between sectors concerning the declared basic knowledge of occupational safety and risks. In both sub-samples, most workers (more than two-thirds) declared having a basic understanding of occupational safety. At the same time, the use of personal protective equipment (PPE) appeared to be lower in both sectors.

Table S3 shows the differences between sectors for the perceived presence of specific risks. Workers in agriculture perceived themselves to be exposed mainly to physical risks, while those in construction perceived chemical risks; however, it should be emphasised that the differences were not statistically significant.

Concerning the risk from exposure to carcinogens and mutagens as defined by Italian Legislation (Legislative Decree 81/08), in the two groups examined, to the specific question, the frequency analysis showed that a higher percentage of workers in the agriculture sector, compared to those in the construction sector, had a high perception of this type of risk (Table S4). However, ANOVA and Student's *t*-test showed no significant differences between industries in the perceived level of risk from exposure to carcinogens and mutagens.

Openness and agreeableness were the personality traits that correlated most strongly with the different risk dimensions. Several risk dimensions – voluntariness of risk, control of risk, severity of consequences, observability of harm, and personal exposure to risk – were significantly correlated with at least three personality traits (see Table 2).

The multiple regression analysis showed that personal exposure, terrifying risk, and risk control were the risk dimensions most strongly predicted by personality traits and by openness, extraversion, and emotional stability (see Table 3).

Friendliness and emotional stability were also the most predictive personality traits of perceived risk level (Table 4). Table 4 compares multiple regression data from the current sample (sectors aggregated) with a previous study in the transportation sector [28].

The analyses showed no gender differences in perceived risk levels (via Student's *t*-test) nor significant correlations between perceived risk and age or length of service (data not shown).

Table S5 shows significant correlations between safety knowledge and risk dimension and level. However, the self-perceived understanding of safety at work only had substantial relationships with some risk dimensions.

Table S6 shows the correlations of positive and negative affectivity with outcomes (satisfaction and perceived risk level). The level of risk from exposure was significantly correlated with negative affectivity.

Table 1. Description of the sample and sub-samples by gender, age, and length of service.

	Gender (*f*, %)		Age	Length of service
	Male	**Female**	**M, SD**	**M, SD**
Agriculture	25 (59.2%)	17 (40.5%)	46 (11.6)	13.8 (7.2)
Construction	36 (73.5%)	13 (26.5%)	45.7 (10.9)	10.3 (6.8)
Total	61 (67%)	30 (33%)	45.9 (11.2)	11.9 (7.2)

Table 2. Correlations between risk dimensions and personality traits in the total sample of workers.

	Personality – Big Five				
Risk Dimension	**Extraversion**	**Agreeableness**	**Consciousness**	**Emotional Stability**	**Openness**
Voluntariness of risk	.061	.141	.298**	.248*	.249*
Immediacy of damage	-.041	.012	.059	.247*	.304**
Personal knowledge of risk	-.036	.129	-.007	.306**	-.319**
Science's knowledge of risk	.222*	.227*	-.103	.011	-.109
Risk Control	-.039	-.372***	-.300**	.072	-.272**
Risk knowledge	.171	-.115	.127	.024	-.033
Pervasiveness of the damage	-.033	.091	-.167	.076	-.329***
Common risk	.038	-.249*	-.133	-.319**	-.348**
Severity of consequences	.182	.020	-.355***	-.272**	-.353***
Threat to future generations	.176	.153	-.267*	.097	-.374***
Controllability of risk severity	-.227*	-.015	.016	.025	-.221*
Observability of damage	-.213*	-.216*	.001	-.265*	-.430***
Personal exposure to risk	-.084	-.324**	-.174	.219*	-.335**
Collective risk exposure	.066	.143	-.016	.132	-.101

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Table 3. Multiple regression of personality traits (predictor) on different risk dimensions.

Risk	**Extraversion**		**Agreeableness**	**Consciousness**		**Emotional Stability**			**Openness**		**Adj.**
Dimensions	**β**	***t***	**β**	***t***	**β**	***T***	**β**	***t***	**β**	***t***	**R^2**
Voluntariness	.013	.22	.01	.19	-.06	-.57	-.273	-2.3*	.178	1.7	.08
Immediacy	-.18	-1.59	-.036	-.14	.048	.36	-.06	-.58	.341	3.1**	.14
Risk Control	.308	3.2**	-.16	-1.2	.167	1.21	.024	.143	-2.96	-3.01**	.21
Terrifying risk	.341	3.7***	.052	.51	-.015	-.16	.208	-2.0*	-.331	-3.5***	.26
Severity	.211	2.6*	.114	1.1	-.005	-.05	.241	2.7*	-.298	-3.1*	.20
Observability	.266	2.8*	-.043	-.37	.048	-.48	.015	.162	-.423	-4.4***	.25
Personal Exhibition	.251	2.7*	.005	.03	-.38	-3.9***	-.246	-2.5*	-.32	-3.9***	.31

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Negative affectivity predicted the level of risk (adjusted R^2 = .094; $F(1, 90) = 9.24$, $p < .003$; Beta = .303; $t = 3.041$, $p < .003$).

4. Discussion

The role of human factors in behaviours and risk perceptions at work appears indisputable, but the exact influence of personality remains unconfirmed [34]. This research investigated the effects of personality and other variables, such as emotional state, knowledge of safety legislation, and socio-demographic factors, to explore and compare risk perceptions among workers from different sectors.

First, the direction of the relationship between personality traits and risk level [27] was generally confirmed across all dimensions [H1]: extraversion and openness showed an inverse relationship with

Table 4. Personality traits (predictors) on perceived risk level.

	Perceived Risk (Agriculture/ Construction)		Perceived Risk (Transport)	
Personality	**β**	***T***	**β**	***t***
Extraversion	-.087	-.91	-.098	-.94
Agreeableness	.216	2.48*	.199	1.39*
Conscientiousness	.148	1.26	.118	1.04
Emotional stability	-.227	-2.76*	-.432	-.3.27*
Openness	-.175	-1.77	-.338	-2.81*
R^2	.097		.221*	

*$p < .05$.

perceived risk levels, whereas conscientiousness, agreeableness, and emotional stability positively correlated with perceived risk. While the outcomes aligned with findings in the Italian transport sector [28], the correlation values were moderate. Among all personality traits, openness, extraversion, and emotional stability significantly predicted several critical risk dimensions, including risk control, observability, severity, and terrifying risk.

Contrary to other studies and H2[5, 35], including the Italian sample [28], no socio-demographic factors were significantly related to the size and levels of risk. However, these results may have been influenced by the small sample size. Self-perceived knowledge of safety legislation exhibited a significant but minimal correlation with risk levels and only for some specific risk dimensions [H3]. The role of this factor requires confirmation in future studies. Notable insights emerged regarding the impact of emotional state on risk perception [H4]; despite few significant relationships with risk dimensions, negative affectivity was identified as a strong predictor of risk level.

Risk perception among these workers may be skewed. Many farmers, particularly migrant and seasonal workers, often neglect necessary preventive measures while acknowledging the risks associated with pesticide exposure. Socioeconomic barriers, such as fear of job loss and lack of access to accurate information, hinder them from demanding adequate protection [19, 36]. Additionally, education levels regarding occupational health and safety are frequently insufficient, heightening the vulnerability of these worker groups. Numerous initiatives have been implemented in the construction sector to mitigate carcinogenic exposure, including the ban on asbestos use. Equally significant is the collaboration between public and private health companies and the Labour Inspectorate, which has been conducted through training events and inspections related to PPE usage [22].

The interpretation of the research results must consider the study's exploratory nature and other limitations, such as low sample size and convenience sampling. The findings need to be validated in larger samples. Future research should corroborate this data and develop new research designs (longitudinal, experimental, etc.) that could provide more empirical insights into the roles of personality and human factors in risk perception, as well as indications of causal relationships among factors.

5. Conclusion

Workers in the agricultural and construction sectors face numerous risks, including exposure to carcinogens and mutagens that may increase their cancer risk. However, the perception of these risks and the preventive measures adopted can vary significantly and may be influenced by socioeconomic, personal, and informational factors. Although the role of these factors in shaping workplace risk behaviours is well established, current findings do not fully confirm the nature of the relationships between personality traits and other human factors that affect risk perception. Furthermore, the impact of socio-demographic factors appears to be diminished, while research results indicate that knowledge of legislation and emotional states play a role in shaping risk perception. Future research will need to verify these findings to provide additional insights into how accurate perceptions can foster preventive behaviours and improve the effectiveness of safety measures. [37, 38].

Supplementary Material: Six additional tables are provided in the Appendix section of this article as Supplmentary. material (description of sample and sub-samples, knowledge of safety at work and presence of specific risks, correlations between different variables).

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APPENDIX

SUPPLEMENTARY MATERIAL

Table S1. Description of sample and sub-samples by role (n, %).

	Sector		
Role	**Agriculture**	**Construction**	**Total**
Owner	21 (50%)	29 (59%)	50 (54.9%)
Employee	17 (40.5%)	9 (18.3%)	26 (28.6%)
Technician	4 (9.5%%)	11 (22.5%)	15 (16.5%)

Table S2. Basic knowledge of safety at work.

	Agriculture, *f* (%)		**Construction, *f* (%)**	
	Yes	**No**	**Yes**	**No**
Have you ever heard of Law 81/2008?	31(74%)	11 (26%)	44 (89%)	4 (11%)
Do you know what Law Decree 81/2008 is about?	27 (64%)	15 (36%)	37 (75%)	12 (25%)
Do you know what a prevention and protection service is?	37 (88%)	5 (12%)	43 (87%)	6 (13%)
Do you regularly use PPE?	4 (9.5%)	38 (90.5%)	2 (4%)	47 (96%)
Do you think your job is at risk?	31 (74%)	11 (26%)	41 (83%)	8 (17%)

Table S3. Presence of specific risks in different sectors (f, %).

	Sector		
Type of Risk	**Agriculture**	**Construction**	**Total**
Physical	25 (59%)	21 (43%)	46 (50%)
Traumatic	20 (47%)	21 (43%)	41 (45%)
Chemical	19 (45%)	25 (51%)	44 (48%)
Biohazard	13 (31%)	9 (18%)	22 (24%)
Psychological	2 (5%)	2 (4%)	4 (4%)
Relational	2 (5%)	1 (2%)	3 (3%)
Organisational	3 (7%)	4 (8%)	7 (7%)
Others	3 (7%)	4 (8%)	7 (7%)

Table S4. Level of perceived risk from exposure to carcinogens and mutagens in the area (f, %).

	Health Risk Level		
Sector	**Low**	**Medium**	**High**
Agriculture	4 (9.5%)	29 (69%)	9 (21.4%)
Construction	3 (6.1%)	41 (83.7%)	5 (10.2%)
Total	7 (7.6%)	70 (77.1%)	14 (15.3%)

Table S5. Correlations between safety knowledge, risk dimensions, and risk level.

	Safety Knowledge
Risk level	.272*
Immediacy of risk	.244*
Science knowledge	.241*
Common risk	-.258*
Personal exposure	-.299**

* = *p* < .05; ** = *p* < .01.

Table S6. Correlations between emotional state, satisfaction, and perceived risk level.

	1	**2**	**3**	**4**
1. Level of risk	-			
2. Satisfaction	-.246*	-		
3. + Affectivity	-.195	.375***	-	
4. – Affectivity	.307**	-.237*	-.379***	-

* = *p* < .05; ** = *p* < .01; *** = *p* < .001.

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Neurosensory Response of the Hand and Foot to Vibration Exposure

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Keywords: Vibrotactile Perception Threshold; Temporary Threshold Shift; Foot-Transmitted Vibration; Hand-Transmitted Vibration; Aging

Abstract

Background: *This study investigated the vibrotactile perception threshold (VPT) changes in the fingers and toes of twenty-eight healthy subjects (15 males and 13 females aged 20 to 62 years) exposed to hand- and foot-transmitted vibration.* **Methods:** *The VPT was measured before and after the exposure of the hands and feet to 5 minutes of tri-axial white noise pseudorandom vibration. The post-vibration VPT was measured immediately after and 15 minutes after the end of the exposure to assess the temporary threshold shift (TTS) of vibration perception. The effects of the anatomical district (index finger and big toe), measurement time (before and after vibration exposure), test frequency (8, 31.5, and 125 Hz), age group (Under30s and Over 40s), and gender (male and female) on the changes in VPT were investigated.* **Results:** *The findings revealed that the index finger and the big toe exhibited comparable profiles in the vibrotactile sensitivity at the low-middle vibration frequencies and in the recovery of the perception threshold after vibration exposure. The big toe showed a higher perception threshold than the index finger, and the difference increased with the test frequency. In addition to vibration frequency, age and skin temperature influenced the results of VPT and TTS measurements.* **Conclusions:** *The findings of this study can contribute to outlining alternative frequency weighting functions for the neurosensory response of the hand and foot to vibration exposure, and to update the current guidelines for evaluating human vibration exposure.*

1. Introduction

In many activities, people are exposed to vibration affecting different parts of the body: hand-transmitted vibration (HTV) occurs when using hand-held powered tools, whole-body vibration (WBV) arises from sitting on vibrating surfaces. In contrast, foot-transmitted vibration (FTV) happens when standing on a vibrating floor [1, 2]. HTV may lead to vascular, neurological, and musculoskeletal disorders, collectively called the Hand-Arm Vibration Syndrome (HAVS). Symptoms and signs include numbness and tingling in the fingers, decreased tactile sensation, impaired manual dexterity, digital vasospasm ("white finger" or Raynaud's phenomenon), and carpal tunnel syndrome [2,3]. The risk of developing HAVS is considered by the international standard ISO 5349 [4], but the ISO metrics for assessing neurosensory impairment are not fully understood [5]. Different frequency

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weightings of HTV showed comparable effectiveness in predicting the likelihood of finger numbness in the exposed workers, indicating no significant difference in their predictive accuracy. As a result, alternative frequency weightings of HTV should be investigated to provide valid predictions of neurosensory outcomes [6-9].

Risk assessment for FTV exposure follows the ISO standard 2631 [10], which details the measurement and evaluation of WBV and restricts the review of health effects to musculoskeletal disorders. Nevertheless, several studies [11-14] have shown that the ISO standard for WBV underestimates the neurological and vascular effects of FTV. Concerning the vascular effects, FTV exposure leads to "vibration white foot" (VWFt), which is characterized by episodes of Raynaud's phenomenon (blanching attacks) in the toes. VWFt occurs typically in workers who also have a history of disorders from HTV or who are directly exposed to FTV [15-18]. Specific methodologies for measuring FTV are currently under development within a working group of ISO TC108/SC4.

Vibration-induced neurosensory effects in the fingers and hands are assessed by detecting vibrotactile perception thresholds (VPT). The methods for measuring and interpreting the VPT are described in the ISO standard 13091 [19]. The similarities between the hand and the foot regarding pathophysiological effects and biomechanical response to vibration [1, 11] suggest that VPT could be used to detect vibration-induced sensorineural disorders of the foot.

VPT at the fingertips is used to investigate the changes in vibrotactile perception, either in HTV workers affected with neurosensory symptoms [20] or in a laboratory setting with short-term exposure to HTV to identify workers potentially at risk of developing neurosensory disorders [21]. There is a limited body of literature exploring vibration perception sensitivity in the feet; some studies focused on the dependence of VPT on contact pressure, frequency, locations on the sole, and skin mechanical properties [22-24]. Only two studies measured the vibrotactile perception in both hands and feet in an adult population. Morioka et al. [25] compared the sensitivity to vibration stimuli between the fingertip, big toe, heel, and volar forearm in different contact conditions. Ekman et al. [26] measured multi-frequency VPT at the finger pulps and metatarsal heads of the foot in 924 healthy subjects divided into different age groups to obtain normative values to be used in clinical and diagnostic practices. Neither of the studies above explored the acute effect of vibration exposure on tactile perception in the foot and hand in an age-stratified population.

Based on the similarities between hands and feet regarding vibration-induced neurovascular disorders, the present study examined the changes in VPT after exposure to vibration, as well as the recovery of VPT over time, in the fingers and toes. The aim was to provide valuable insights into the neurosensory impairment caused by FTV exposure in occupational settings compared to that provoked by HTV. The effect of age was also considered to investigate the potential influence of aging on the digits' response to vibration. To update the current normative guidelines, the study focuses on determining if the VPT method offers a valid approach for evaluating neurosensory effects in both hands and feet.

2. Methods

2.1. Participants

Twenty-eight healthy volunteers (15 males, 13 females) participated in the study. All subjects had no history of use of hand-held vibrating tools in occupational or leisure activities. They were divided into two age groups:

- Under 30s: 10 males and 8 females with the following mean ± standard deviation characteristics: age 24.1±2.8 years (males: 23.1±2.2 years, females: 25.3±3.1 years), body height 1.72±0.1 m (males: 1.79±0.6 m, females: 1.64±0.7 m), body mass 69.6±15.1 kg (males: 78.8±12.7 kg, females: 58±8.4 kg);
- Over 40s: 5 males and 5 females with the following mean ± standard deviation characteristics: age 53.5±8.4 years (males: 52.4±9.6 years, females: 54.6±8.0 years), body height: 1.70±0.1 m (males: 1.78±0.1 m, females:

1.62±0.0 m), body mass 72.9±15.9 kg (males: 85.2±11.4 kg, females: 60.6±7.8 kg).

The following exclusion criteria were applied: lower and/or upper limb injuries in the last 6 months; chronic orthopaedic conditions; diabetes; cognitive disabilities or developmental disorders; history of motion sickness; muscular or neurological diseases; cardiovascular and/or respiratory diseases; skin problems (e.g. burns and cuts). All subjects signed a consent form before the start of the experimental session, and data were collected according to the criteria of the General Data Protection Regulation. The experiments were approved by the Ethics Committee of Politecnico di Milano (n° 17/2024) and followed the Declaration of Helsinki.

2.2. Experimental Setup

The VPT was measured at 8, 31.5, and 125 Hz in the right hand's index finger and the right foot's big toe before and after exposure to HTV or FTV, respectively.

2.2.1. Vibration Stimulus

The hands and feet were exposed to 5 minutes of triaxial Gaussian white noise pseudorandom vibration (0.44 m/s^2 r.m.s acceleration) with frequencies between 8 and 50 Hz applied through a 3-dof vibrating platform [27]. The subjects were instructed to place their palms on the vibrating plate and maintain approximately 15% of their body weight during the HTV exposure. A force platform (KISTLER 9260AA - Kistler Instruments AG, Winterthur, Switzerland) was used under their feet to monitor the ground reaction force. During FTV exposure, the subjects stood barefoot on the vibrating plate. They were instructed to maintain the indicated posture throughout the exposure. Figure 1 shows the placement of the hands and feet during vibration exposure.

2.2.2. Vibrotactile Perception Measurement

The VPT was measured at the frequencies of 8, 31.5, and 125 Hz by means of the Von Békésy

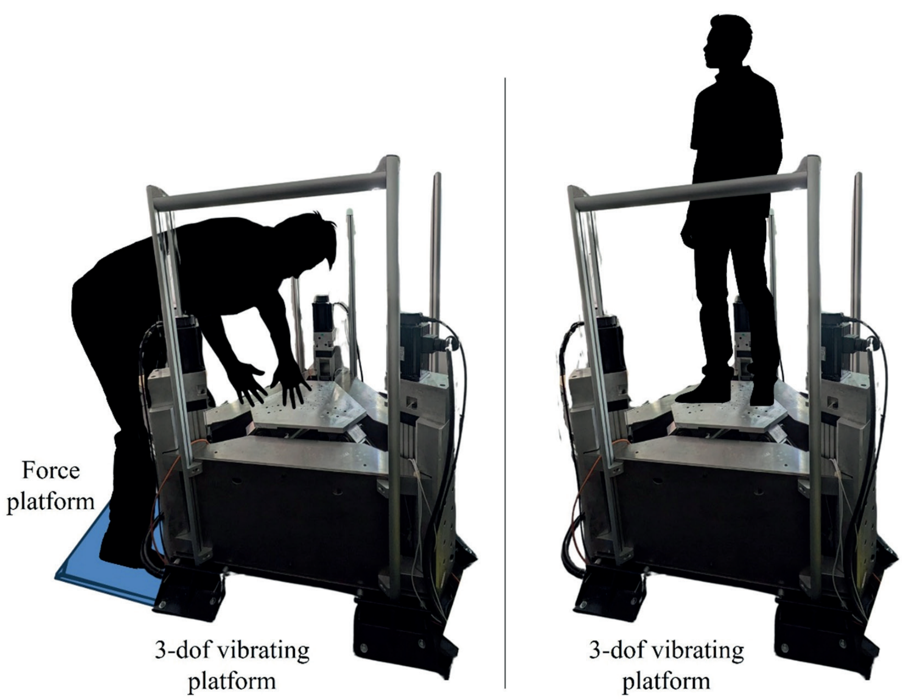

Figure 1. Hands (on the left) and feet (on the right) placement on the vibrating platform during HTV and FTV exposure, respectively.

algorithm using the HVLab Vibrotactile Perception Meter (VPM, University of Southampton, UK) equipped with a vibrometer probe. The test consists of increasing the vibration intensity of the probe on which the anatomical part of interest (i.e., the finger or toe) is laid until the subject perceives vibration and presses a hand-held button, and subsequently decreasing the vibration intensity until the subject no longer feels the vibration and releases the button. VPTs were expressed in decibels (dB) relative to a reference r.m.s. acceleration of 10^{-6} ms^{-2}. The vibrogram consisted of sequences of increasing and decreasing levels of vibration with different frequencies. We set an increasing/decreasing rate of 3 dB/s (with 5 dB/s for the first reversal) with the maximum duration of each measurement of 30 seconds to record at least four reversals. During the test, the subject was asked to maintain a constant contact force by applying 2 N with the toe/fingertip on the static surround around the vibrating probe and by monitoring the force display on the device. At the end of each test, the VPT was calculated as the geometric average of the cycles (excluding the first).

2.3. Test Protocol

The experiments were performed in the Human Vibration Laboratory of the Polo Territoriale di Lecco - Politecnico di Milano.

After preparing and familiarizing with the VPT test, the skin temperature of the tested anatomical district (i.e., index finger and big toe) was measured using a thermocouple. Then, each subject underwent the following experimental protocol:

1. Pre-exposure VPT

   The VPT_{Baseline} was measured at 8, 31.5, and 125 Hz in the distal phalanx of the right index finger and right big toe. The subject's posture and the position of the VPT Meter probe were adjusted to ensure that the constant contact force was applied without muscular tension in the arm and leg. In the case of the hand, the subject was seated on a chair with the arm placed on a flat surface, while in the case of the foot, the subject was sitting on the surface of a table with the leg supported by the table's leg. For both the palm and the sole, contact with any extraneous surface was avoided to ensure that only the targeted area was in direct contact with the vibrating probe. Consistent positioning of the hand and foot was achieved by stably supporting the wrist and heel, respectively, on the table surface or the table leg.

2. Post-exposure VPT

   The VPT measurement was repeated immediately after the end (VPT_{Acute}) and 15 minutes after ($VPT_{15\text{min}}$) the exposure to evaluate the vibration-induced shift in VPT. Between the two measurements, the subject did not use the examined hand or foot.

The protocol was repeated twice, once for the hand and once for the foot, in random order, with a total session duration of 1 hour. The VPT frequencies were randomized for each trial. The subjects wore noise-canceling headphones to prevent the results from being influenced by external factors.

2.4. VPT Shift

The post-vibration VPTs were compared with the baseline values by calculating the temporary threshold shift (TTS), which is the difference between post- and pre-exposure perception thresholds. The TTS was calculated for each of the post-vibration VPTs as follows:

$$TTS_{Acute} = VPT_{Acute} - VPT_{Baseline} \quad (1)$$

$$TTS_{15min} = VPT_{15min} - VPT_{Baseline} \quad (2)$$

These calculations were repeated for each of the selected frequencies and each anatomical district to evaluate the change in vibrotactile perception induced by vibration and its recovery over time.

2.5. Statistical Analysis

VPT and TTS data were summarized with the mean as a measure of central tendency and the standard deviation as a measure of dispersion. The repeated measure ANOVA statistic was used to investigate the effects of the test conditions (anatomical district, measurement time, test frequency) and personal covariates (gender, age) on VPT and TTS. In case of a significant ANOVA F-test, the Tukey or Dunnett (with baseline as control) post-hoc corrections were carried out.

The associations between VPT, TTS and age for each anatomical district at each frequency and measurement time, and the influence of skin temperature on VPT_{Baseline} and TTS_{Acute} were investigated by non-parametric statistics (Spearman rho).

A p-value of .05 was established as the limit of statistical significance.

3. Results

ANOVA results revealed that VPT and TTS were significantly influenced by all the investigated factors, except gender for VPT (Table 1).

Figure 2.(a) reports the means and standard deviations of VPT with the post-hoc significant comparisons between the different categories of the explanatory factors. Figure 2.(b) displays the VPT mean values for the index finger and the big toe in both age groups at each frequency and each measurement time.

All the considered factors significantly influenced the VPT and TTS measurements, which were both frequency-dependent. The index finger and the big toe showed similar threshold shift recovery profiles for both age groups. However, the big toe had a higher threshold than the finger, and the older subjects exhibited lower sensitivity.

Table 2 reports the associations between VPT/TTS and age at each tested frequency in the index finger and the big toe.

Significant associations between VPT and TTS with age were found. In particular, strong correlations (rho>0.60) were observed in the big toe with a positive association for the VPT_{Baseline} at 31.5 Hz and for the VPTs at each measurement time at 125 Hz.

Table 3 provides the results of the correlations for the VPT and TTS measured in the index and big toe at each test condition.

A significant correlation was found between the finger and the toe for the TTS at 125 Hz, both in *Acute* and *15min*. Instead, for the VPT, moderately significant associations (0.40<rho<0.60) were mainly present in the *Baseline* and *15min* measurement time at 8 and 31.5 Hz.

The skin temperature recorded at the beginning of the session averaged (± standard deviation) 26.7 (±4.2) °C in the big toe and 32.7 (±2.9) °C in the index finger. Skin temperature had a limited influence on the neurosensory response of the experimental subjects' digits, showing a negative correlation only for the TTS_{Acute} of the big toe at 31.5 Hz (r=-0.622, p=.001) and 125 Hz (r=-0.507, p=.008).

4. Discussion

The findings of this study indicate that vibrotactile perception measures are affected by factors such as the anatomical district, measurement time, test frequency, and age. VPT and TTS in both the big toe

Table 1. ANOVA results for the main and combined effects (F-test (p-values)) of the investigated factors (measurement time, test frequency, anatomical district, age group, and gender) on VPT and TTS. Only the significant combined effects are reported.

	Measurement time (m)	Test frequency (f)	Anatomical district (d)	Age group (a)	Gender (g)	Combined effect
VPT	F(2,483)=10.49 **(<.001)**	F(2,483)=542.51 **(<.001)**	F(1,483)=258.00 **(<.001)**	F(1,483)=42.17 **(<.001)**	F(1,483)=0.27 (.603)	f x d F(2,483)=44.75 **(<.001)**
TTS	F(1,321)=20.52 **(<.001)**	F(2,321)=8.49 **(<.001)**	F(1,321)=12.23 **(.001)**	F(1,321)=4.08 **(.044)**	F(1,321)=15.53 **(<.001)**	a x g F(1,321)=19.24 **(<.001)**

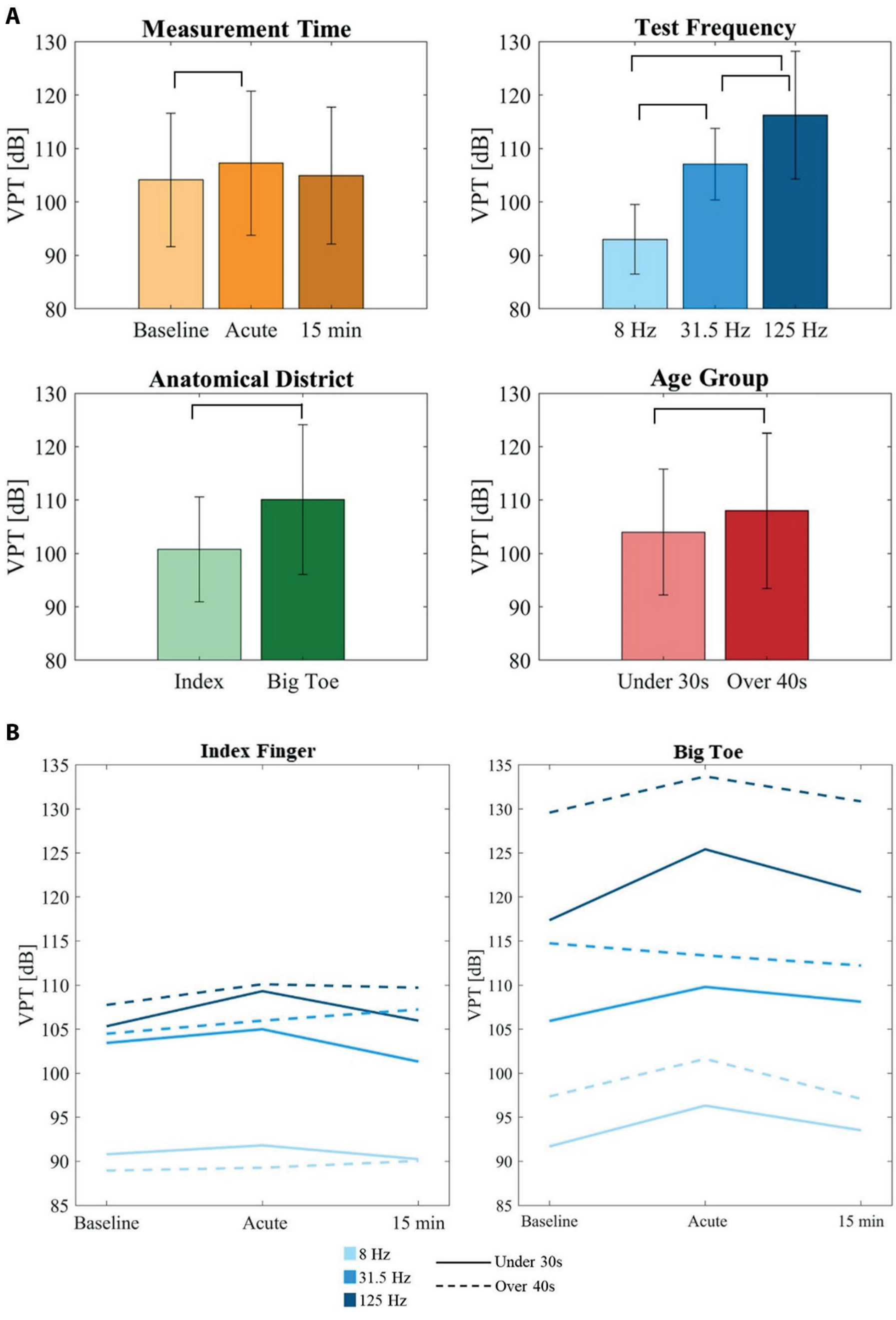

Figure 2. (**a**) The mean and standard deviation values of VPTs grouped by significant factors. The horizontal bars in the figures indicate the significant pairs after post-hoc correction; (**b**) The mean VPT trend over measurement time (i.e., Baseline, Acute, 15min after) for the index finger (left) and big toe (right) in both age groups at each frequency.

Table 2. Spearman correlation coefficients (p-values) between $VPT_{Baseline}$/VPT_{Acute}/VPT_{15min}/TTS_{Acute}/TTS_{15min} and age in the index finger and the big toe at each tested frequency.

Measurement	Anatomical district	Frequency 8 Hz	Frequency 31.5 Hz	Frequency 125 Hz
$VPT_{Baseline}$	Index Finger	-0.123 (.533)	0.076 (.702)	0.218 (.265)
	Big Toe	0.298 (.124)	0.612 **(.001)**	0.634 **(<.001)**
VPT_{Acute}	Index Finger	-0.104 (.597)	0.218 (.266)	0.135 (.492)
	Big Toe	0.224 (.253)	0.301 (.120)	0.478 **(.010)**
VPT_{15min}	Index Finger	0.099 (.617)	0.387 (.042)	0.210 (.284)
	Big Toe	0.189 (.335)	0.332 (.085)	0.654 **(<.001)**
TTS_{Acute}	Index Finger	-0.002 (.991)	-0.007 (.970)	0.014 (.945)
	Big Toe	-0.114 (.563)	-0.457 **(.015)**	-0.298 (.123)
TTS_{15min}	Index Finger	0.248 (.203)	0.382 **(.045)**	0.007 (.973)
	Big Toe	-0.196 (.317)	-0.360 (.060)	0.003 (.986)

Table 3. Spearman correlation coefficients (p-values) for the VPT and TTS measured in the index finger and big toe at each test condition (i.e. each combination of measurement time and test frequency).

	VPT			TTS	
	Baseline	**Acute**	**15min**	**Acute**	**15min**
8 Hz	0.402 **(.034)**	0.246 (.206)	0.625 **(<.001)**	-0.016 (.937)	-0.163 (.407)
31.5 Hz	0.456 **(.015)**	0.256 (.188)	0.463 **(.013)**	-0.105 (.595)	-0.129 (.512)
125 Hz	0.376 **(.048)**	0.172 (.382)	0.290 (.134)	0.507 **(.006)**	0.479 **(.010)**

and the index finger displayed a comparable trend concerning vibration frequency. Specifically, VPT_{Acute} and TTS_{Acute} in these two anatomical districts exhibited an increase as the vibration frequency escalated from 8 to 125 Hz. This observation aligns with the research conducted by Harada and Griffin [28], which reported significant variability in TTS_{Acute} at the middle fingertip following exposure to hand-transmitted vibration, particularly above and below the 63 Hz threshold. Notably, despite the observed similarities, the big toe demonstrated a higher threshold compared to the index finger, with this disparity becoming more pronounced as the test frequency increased, averaging 2.9 dB in the TTS_{Acute} at 125 Hz. These results may be partially explained by differences between the hand and foot concerning skin thickness, distribution, density, and the functional role of skin mechanoreceptors [25, 29]. The higher density of mechanoreceptors in the hand contributes to greater vibration sensitivity compared to the foot, facilitating a superior level of spatial acuity at the fingertips [25, 30, 31]. In contrast, mechanoreceptors in the foot are distributed sparsely along the sole and are primarily involved in balance control and weight-bearing [25, 29, 32]. Despite these distinctions, our findings reveal that fingers and toes exhibit analogous responses at 8 and 31.5 Hz test frequencies, implying that the same mechanoreceptors in the skin mediate thresholds at these frequencies.

The VPT trend over measurement time was similar in both age groups. Still, the Over 40s exhibited higher VPTs in each test condition (mean difference between Over 40s and Under 30s in $VPT_{Baseline}$: 6.9 dB in the toe and 1.1 dB in the finger). This finding aligns with the observation that the difference in tactile sensation between the hand and foot is correlated with aging [33]. It is known that vibrotactile perception declines with age as a sign of deterioration in the peripheral nervous system, leading to delays in stimulus detection [26, 34-37].

Our study found no effect of gender on VPT, while a significant interaction between age and gender was observed for TTS. The influence of gender on tactile sense perception is a controversial subject in the literature. Ekman et al. [26] did not find a significant effect of gender in VPT measured in the pulps of the index and little fingers and the first and fifth metatarsal heads. In contrast, Deshpande et al. [34] reported that males showed significantly higher VPTs than females, although the former were, on average, older than the latter.

The skin temperature affected the shift in vibrotactile thresholds. The TTS in the big toe at the middle-high frequencies increased as the temperature decreased. Cold temperatures influenced vibration response in the feet, suggesting that the combination of vibration exposure and lower air temperature could harm workers occupationally exposed to FTV. Harada and Griffin reported a similar result in the hand [28], finding that the vibration sense thresholds increased with the decrease in finger skin temperature.

4.1. Limitations and Future Developments

Our findings should be interpreted cautiously because of the small sample size and the homogeneity of the participants' occupational titles. The selected population is not representative of a working population exposed to vibration. In addition to gender and age, future studies should consider the effects of other possible confounders linked to lifestyles or occupational risk factors [21].

Since this study revealed that in the big toe, lower skin temperatures were associated with greater TTS immediately after the end of vibration exposure, accurate control of the ambient temperature in the laboratory room and acclimatization of the experimental subjects before testing should be considered.

Given the spatial summation activity of the mechanoreceptors, VPT is influenced by the contact area and pressure [22, 38, 39]. This study selected a contact force of 2 N and a 6 mm diameter probe according to a recommended testing procedure [40]. Although the subjects were instructed to maintain a constant force by monitoring the force display, variability in contact force among subjects could not be ruled out. For future studies, in addition to ensuring that participants are adequately familiarized with the tests to maintain constant force, it may also be beneficial to track the trends of vibrotactile thresholds and pressure over time to identify potential associations. To mitigate the temporal decay of the shift effect, only a single measurement per district and frequency was taken following vibration exposure. Future investigations should include repeated measurements within each condition to account for intra-subject variability and improve measurement accuracy.

Finally, only two anatomical districts and three vibration frequencies were considered to reduce the test duration. Different vibration frequencies and anatomical sites at analogous points of the hands and feet [11], including left laterality, could be explored better to characterize the similarities or differences between the hand and foot. A comprehensive profile of the vibrotactile perception response could provide a valuable basis for defining a specific weighting curve for the neurosensory effects associated with HTV or FTV exposures.

5. Conclusion

In this study, the index finger and the big toe exhibited similar profiles in vibrotactile sensitivity at low-middle vibration frequencies and in recovery of the perception threshold following vibration exposure. Although the big toe demonstrated a higher perception threshold than the index finger, this difference increased with rising test frequency. In addition to vibration frequency, age and skin temperature influenced the results of VPT and TTS measurements. Measuring VPT is a valid laboratory tool for assessing the neurosensory effects of HTV and FVT exposures. Our findings can help outline alternative frequency weighting functions for the neurosensory response of the hand and foot to vibration exposure and update current guidelines for evaluating human vibration exposure.

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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 Politecnico di Milano (n° 17/2024).

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

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Author Contribution Statement: FM and MT contributed to the conception and design of the study, wrote the protocol, and obtained ethics committee approval. FM, NS, and JGS collected, analyzed, and interpreted the data. FM and NS drafted the manuscript. MT and MB revised the data analysis and interpretation. MT, MB, FR, AT, and EM critically reviewed the final draft of the manuscript. AT and EM contributed to the funding acquisition. All authors have reviewed and approved the final version of the manuscript.

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Audiometric Database of Academic Musicians in Uruguay

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Keywords: Audiometric Baseline; Academic Musicians; Occupational Hearing Loss; Hearing Loss; Hearing Health

Abstract

Background: *This paper presents the results of an interdisciplinary study at the Universidad de la República (Uruguay), in which hearing loss is assessed in a group of academic musicians, including lyric singers, choristers, and orchestral musicians.* **Methods:** *Audiometric records from 137 academic musicians were analyzed. The Average Hearing Loss (PAM) methodology, based on Lafon and Duclos combined with the ISO 1999:2013 Standard, was used to convert all the registers to the hearing loss at the age of 35, which were then organized into a permanence curve and compared with reference curves from the ISO 1999:2013 Standard.* **Results and Conclusion:** *The results presented here are estimated to represent more than 27 % of the total population of adult academic musicians nationwide. The findings suggest that academic musicians in Uruguay are at a higher risk of noise-induced hearing loss than the general population in the ISO 1999:2013 Standard.*

1. Introduction

Artists often form a community that lacks adequate occupational health attention [1]. For example, in Uruguay, artists only receive occupational accident and illness insurance if they are employees. This requires institutions to contract the services of the Banco de Seguros del Estado [2]. In the case of professional musicians, there is a common belief that they shouldn't suffer hearing loss due to their profession since they "enjoy what they do." However, this concern has gained traction recently, driven by demands from artists' collectives and more nuanced interpretations of their needs.

In response, a group of teachers from the Universidad de la República (Uruguay) in health, art, and science-technology initiated an interdisciplinary project to quantitatively analyse the hearing health of academic musicians, specifically lyric singers and orchestral musicians. Funded by the University's Interdisciplinary Space, this project has been ongoing for over four years, including workshops, audiometries, and interviews by the Speech and Hearing and Occupational Health teams, processed with an

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epidemiological approach. A methodology combining the Average Hearing Loss (PAM) from Lafon and Duclos and the ISO 1999 Standard guidelines was utilized, which has been in use in Uruguay since 1993 for comparing occupational exposure among worker groups, crucial for assessing regional hearing loss.

We studied three musician groups: the choristers of the National Choir of SODRE, the musicians of the Montevideo Symphonic Band, and the students from the Singing Department of the Faculty of Arts. Members of the Orquesta Sinfónica del SODRE and the Orquesta Filarmónica de Montevideo, each with about 95 performers, also participated in various activities. Occupational hearing damage can develop gradually through prolonged noise exposure or acutely from sudden loud noise, resulting in hyperacusis, which limits conversational understanding [6]. Tinnitus is another symptom indicating noise damage.

It's important to note that noise alone isn't the sole cause of hearing damage. Ototoxic chemicals can also harm the auditory system temporarily or permanently. These include antibiotics like gentamicin, diuretics like furosemide, and NSAIDs like naproxen [7]. Damage begins in the inner ear's organ of Corti, particularly the cochlea's hair cells that detect high-frequency sounds around 4000 Hz. This initial damage often doesn't affect the perception of the human voice, meaning individuals may not notice a hearing loss initially. The resulting damage is a bilateral, symmetrical, and irreversible sensorineural hearing loss. Additional noise effects include sleep disturbances, impaired concentration, anxiety, and stress, alongside impacts on cardiovascular, respiratory, and digestive systems and hormone secretion like cortisol and adrenaline. These effects vary based on individual tolerance. According to the WHO, hearing loss occurs with a threshold increase of at least 20 dB. It can be classified as mild, moderate, severe, or profound, with disabling loss defined as greater than 35 dB in the better-hearing ear [9]. Noise is a primary risk factor in work environments. In Uruguay, Decree 143/012 outlines measures to prevent harmful health consequences from sound pressure exposure, setting an 80 dBA noise limit for an 8-hour workday to ensure preventive measures and regular audiometric surveillance above this level. This work aims to share the method and results of the research project that enabled our team to obtain a reference audiometric database of Uruguayan academic musicians. Since this is a restricted data set, we adapted the methodology for determining the Acoustic Hazard proposed in [5] for its processing. To calculate it, the following steps were employed for the case presented here:

1. Calculate the hearing loss of each participant by applying the criterion (2000+4000)/2). This criterion refers to the arithmetic average of the hearing loss measured at 2000 Hz and 4000 Hz when a pure tones audiogram is performed. It is the PAM defined in [3]. In this case, the average hearing loss of both ears is 2000 and 4000 KHz.
2. Read the value of the mean hearing loss PAM on the abacus of Lafon and Duclos [3] .
3. Construct the permanence curve of the obtained PAM values.
4. Select an audiometric basis for comparison. In this case, we will work with Base A, presented in the ISO 1999:2013 Standard, and with Base B, corresponding to a reference population also presented in the same standard [4]. Base B, corresponding to the US population, was adopted since the other options offered in ISO 1999:2013 correspond to Sweden and Norway [4]; it was understood that the similarity in lifestyle with the latter two countries would be even less than with the United States.

The ISO 1999 Standard, since its 1990 version – now superseded by the 2013 version – defines two types of audiometric databases: the type A database, which is a theoretical database representing the minimum expected hearing loss for different percentiles of a population of a certain age and sex, otologically screened, without previous exposure to environmental noise or ototoxic drugs. It is interpreted as the minimum expected hearing loss. Base A can be calculated mathematically following the methodology provided by [4], assuming that the distribution of hearing loss at each frequency and gender and age range follows a distribution given by two branches of Gaussian bells sharing their vertex. Base B, on the other hand, is empirically derived (it does not admit theoretical calculation) and represents the hearing loss resulting from the lifestyle of a particular society, i.e., it considers both presbycusis (natural aging process) and socioacusis [4].

Hearing loss was calculated using the criterion [(2000+4000)/2] for each audiometric record. According to [11], this is the most preventive criterion among those commonly applied due to the high weighting (50%) given to the loss at 4000 Hz, one of the frequencies at which hearing loss sets in. The losses obtained in this way were averaged, and the average additive loss for both ears was followed. Each of the values obtained was taken to the loss to be expected at the age of 35 years, applying the abacus in Figure 4 [3]. This is the value designated as PAM. Then, the curves of permanence for each of the databases and for our database were constructed and compared to determine the outcomes of this study.

2. Methods

A retrospective observational study was carried out with a primary data source. For this purpose, an instrumental environmental assessment was carried out, and medical and occupational medical records and audiometric studies were performed on the study population. Subsequently, the information collected was processed by means of electronic spreadsheets for subsequent analysis. The audiometric tests were performed by a speech audiology team in a soundproofed environment according to the ISO Standard 8253-1, using an Audiometer MAICO MA-41, and the results were recorded in audiograms.

2.1. Fieldwork

In all cases, the activities began and closed with a workshop. The first workshop aimed to present the project, introduce the subject, explain the activities, ensure participants signed informed consent forms, and address any questions. In the closing workshop, results were shared with participants, who could schedule personal interviews with the Health team for individualized feedback. The Philharmonic Orchestra opted out of the feedback workshop for scheduling reasons.

Before the workshops, a guideline was developed to collect information during participant interviews, covering anamnesis aspects and specific factors related to singing or instrumental performance, such as vocal register, instrument played, artistic activity type and frequency, and regular use of amplification.

Participants made individual appointments with an occupational physician and a speech therapist to fill out the anamnesis form and undergo otoscopy and pure tone audiometry. They were informed to rest their hearing for 12 hours prior to audiometry and avoid optic infections. Importantly, audiometries aimed to assess the threshold of perception in different frequency bands rather than stopping at audiometric zero [5, 11-12].

For singers, a diagnosis of vocal status was conducted, including anamnesis, body assessment based on vocal use, aerodynamic efficiency evaluation, perceptual assessment (GRBASI scale), subjective assessment (S-VHI), and acoustic analysis via Praat Software. Individual results were shared with each participant in a second workshop, along with a summary of joint findings from collected data.

2.2. Characterization of the Study Population

In the survey, 137 subjects were enrolled: 59 women and 78 men; 62 singers (choristers, lyric singers, singing students) and 75 musicians from instrumental ensembles (orchestras and symphonic bands). The institutions from which the participating musicians come are Instituto de Música (EUM) of the Facultad de Artes (teachers and singing students, choristers); Banda Sinfónica Municipal de Montevideo (BSM); Coro Nacional del SODRE (CNS); Orquesta Sinfónica del SODRE (OSSODRE); Orquesta Filarmónica de Montevideo (OFM).

The total population of academic musicians in Uruguay—those engaged in "conservatory" music, such as members of instrumental ensembles, professional solo singers, and other soloists—constitutes a small community. Professional orchestras and choirs are mainly in Montevideo, comprising fewer than

400 individuals. Including other professional musicians and students from the Escuela Universitaria de Música at Facultad de Artes, the estimated total is about 500. This community is roughly 65% male and 35% female, with instrumentalists proportionately similar and singers at about 40% male and 60% female.

To assess sound exposure, the sound pressure level maps of the National Choir and the Symphonic Band of Montevideo are shown in Figures 1 and 2. The lowest recorded levels are at 85 dBA, while the legal occupational sound pressure level is 80 dBA in Uruguay. Notably, the Symphonic Band has implemented a "street" between brass and woodwind instruments to reduce exposure levels for woodwind musicians.

Notably, only one musician's job is assessed, not the entirety of the worker's sound exposure, which is a weakness of the study that the researchers recognize.

3. Results

The PAM permanence curve for the whole database was constructed, and then the results were obtained separately for men and women, singers, and orchestral musicians. In each case, the resulting curves were overlaid with the corresponding curves obtained for each sex and 35 years of age from the data in Bases A and B. The audiometry results are presented as a percentage of the population of each gender, together with the reference

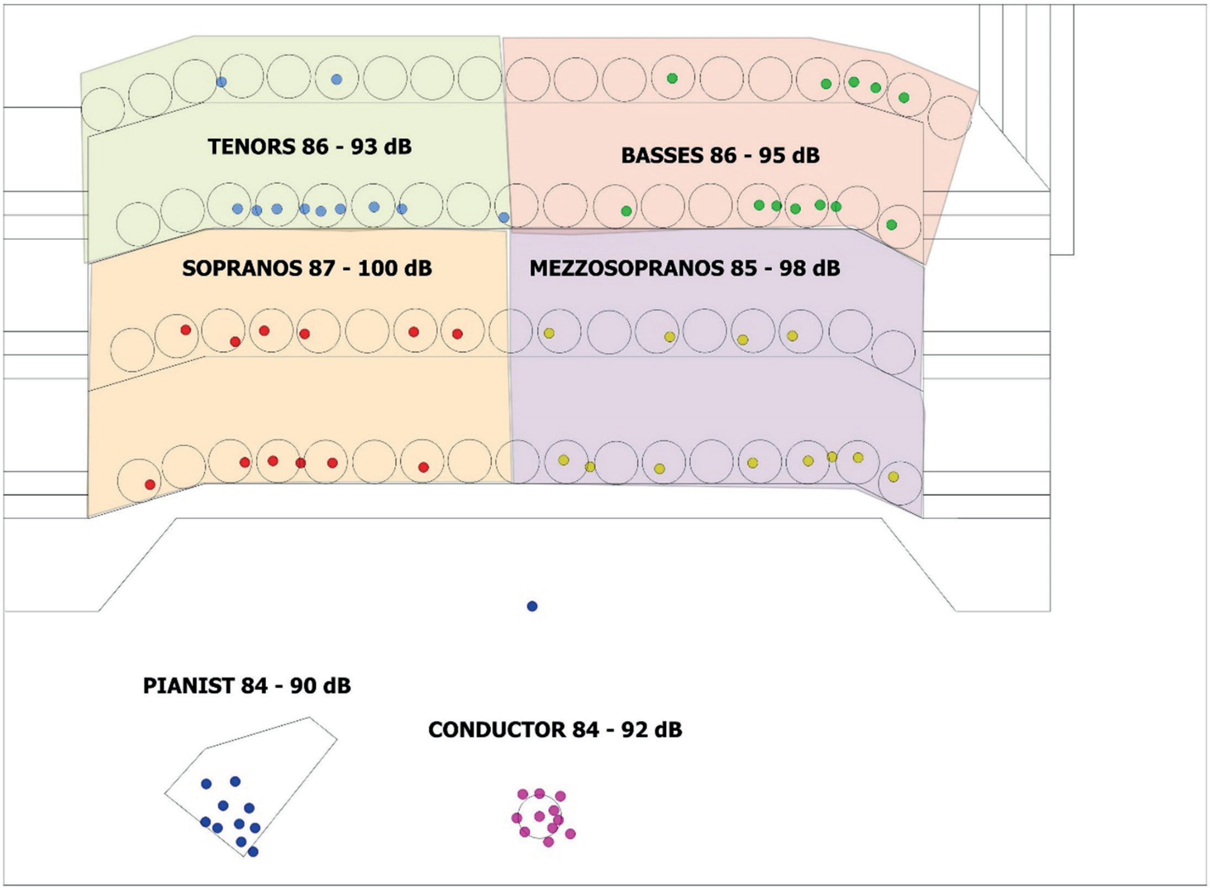

Figure 1. Map of Sound Pressure Levels of the National Choir.

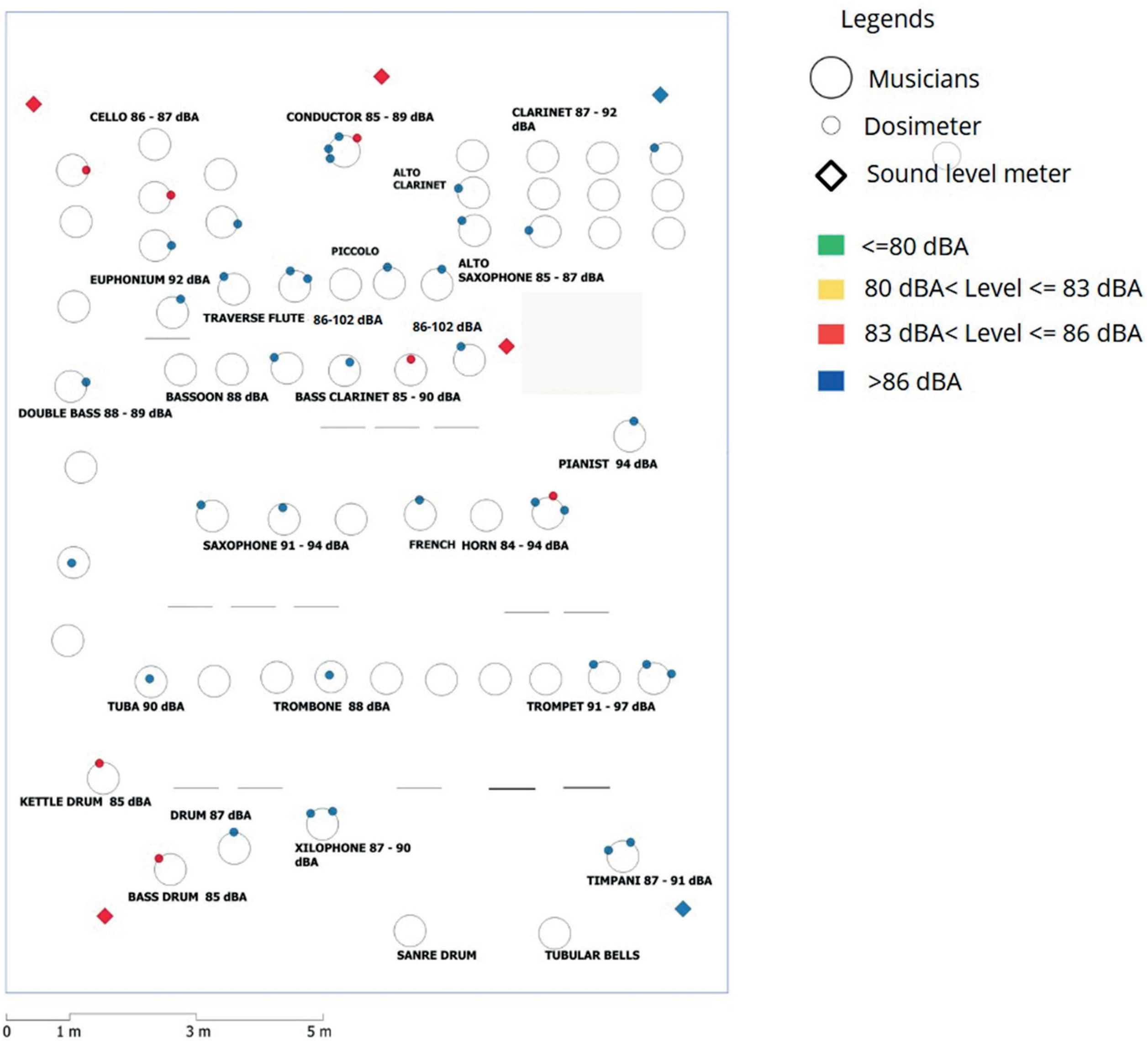

Figure 2. Map of Sound Pressure Levels of the Symphonic Band of Montevideo.

curves corresponding to Bases A and B from [4]. Only the results of the study population in the range of 10 % to 90 % are plotted to follow the range in which ISO A and B bases are defined [4]; as in the reference bases, the PAM values of 10 % by 10 % are used.

Figure 3 represents the minimum expected loss measured as PAM (that is, at 35 years of age) for different percentiles of the study population, considered as a whole, men only (PAM Male) and women only (PAM Female). The results for the total population (PAM) have a precision of 1.4 dB at 95% confidence and the results by gender have a precision of 2.0 dB for men (PAM Male) and 1.6 dB for women (PAM Female).

Figure 4 presents the results for singers (EUM and CNS). Figure 5 presents the results for instrumental ensemble musicians (BSM, OSSODRE, OFM). The singers' and musicians' curves have respective accuracies of 1.6 dB and 1.7 dB. The Singers

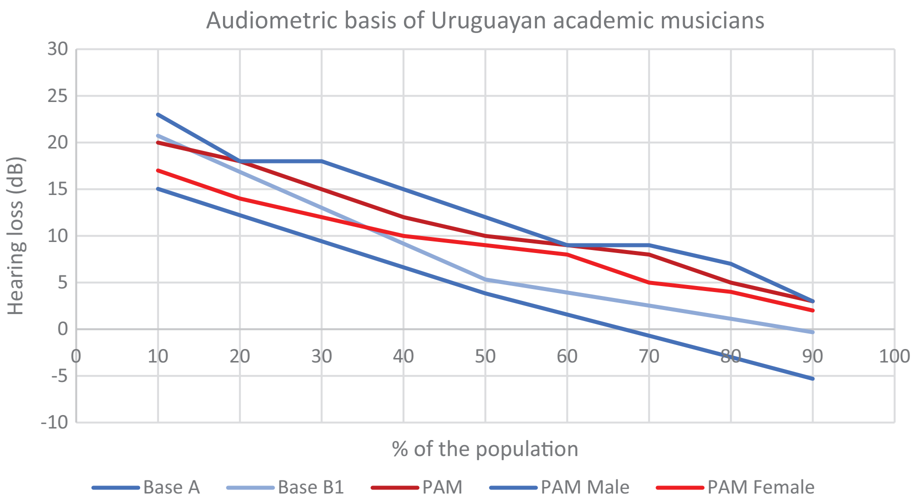

Figure 3. Audiometric basis of Uruguayan academic musicians: average PAM of both ears. Total base (mixed PAM), men only (PAM M), and women only (PAM F).

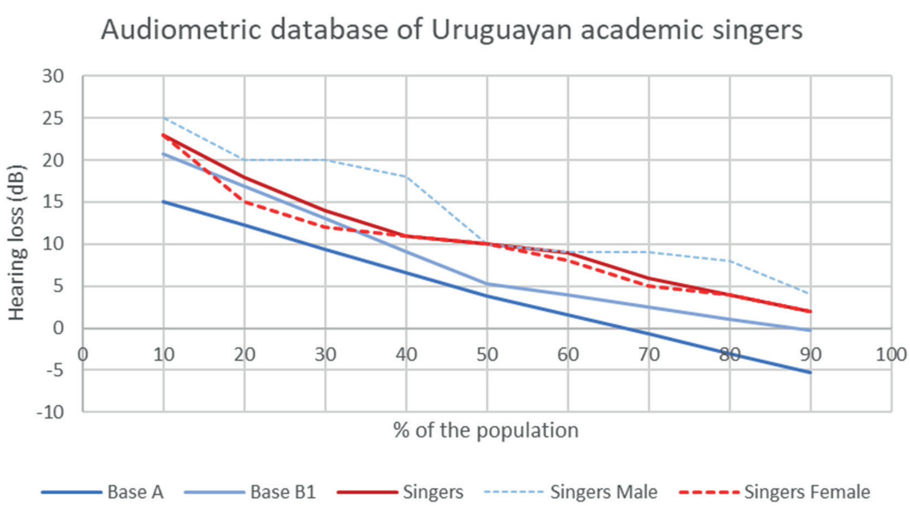

Figure 4. Audiometric basis of Uruguayan singers and choristers: average MAP of both ears. Total base (singers), only men (Male singers), and only women (Female singers).

F and Musicians M curves have 1.5 dB and 1.7 dB errors. The Singers M and Musicians F curves correspond to less than 20 cases each, so their values have not been included in the tables.

4. Discussion

Hearing loss in the population of academic musicians of both genders has a marked tendency to exceed the values of Bases A and B [13]. The whole base and the male base exceed the expected loss curves given by both bases by almost their entire length, while the predicted hearing loss in females is, for the lowest 60% loss, higher than that proposed by Base B for the North American population [14]. Several recent studies reporting similar findings have been reviewed [15].

For singers, the expected loss in the curve exceeds the curve for academic musicians in general. The scheduled hearing loss for male singers seems

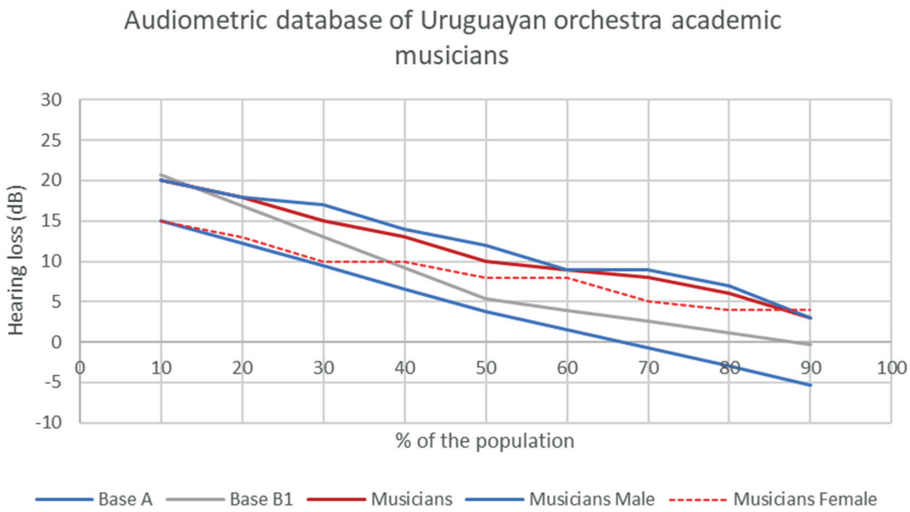

Figure 5. Audiometric basis of Uruguayan musicians in orchestral ensembles: average PAM of both ears. Total base (musicians), only men (Male musicians) and only women (Female musicians).

considerably higher than for female singers, but the number of available cases confers a high error and, thus, low reliability. In the case of orchestral musicians, the expected hearing loss for all musicians is similar to that expected for men but higher than expected for women [15].

In the case of women, the error obtained is 2 dB, at the limit of what has been considered admissible, and for this reason, the curve values have not been noted. The loss of the orchestral musicians can be associated with that of the men in that group and that of the singers with that of the women. The total population of musicians shows higher loss than the unexposed populations, and it is higher for men than women.

Through this study, the exposure of musicians to an environmental risk factor such as noise is made visible, with a potential risk of damaging hearing health. The problem is visible and allows us to work on preventive measures and raise awareness among musicians and those who direct this sector. On the other hand, it is an input for generating health policies in Occupational health.

5. Conclusion

The audiometric results are comparable with the workers' accounts and perceptions of noise in their work environment. Likewise, the decrease in hearing observed in the curves of the population under study, compared to the reference population, shows a real risk of damage to hearing health. Therefore, it is essential to be able to work on occupational health policies that encourage the promotion and prevention of hearing health in this group of workers, as well as in the rest of the risk factors to which they are exposed.

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Institutional Review Board Statement: Although the research involved paraclinical, non-invasive studies such as tonal audiometry, the subsequent analysis was based on anonymized data. For this, the participants were informed and signed an informed consent, which detailed the purpose of the study and the use of the data for research purposes. The audiometry results were delivered to each participant individually, respecting the confidentiality that a medical intervention implies.

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

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Enhancing Hearing Protection: Evaluating Innovative Training Modalities for Optimal Fitting Outcomes

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Abstract

Background: *Measuring the effectiveness of training in properly fitting hearing protection devices (HPDs) is crucial, as it directly influences their attenuation. We assessed an earplug's personal attenuation ratings (PAR) following various intervention modalities.* **Methods:** *The sample consisted of 52 adults without experience using hearing protection devices (HPD). The Personal Attenuation Rating (PAR) was evaluated through real-ear attenuation at threshold (REAT) and microphone-in real-ear (MIRE) measurements after participants fitted the HPD as they saw fit. Participants were then randomly assigned to groups and given instructions on HPD fitting as follows: (G1) individual in-person demonstration; (G2) package reading; (G3) video; (G4) no intervention. PAR was subsequently reassessed. Data analysis was conducted using ANOVA and the Fisher Exact test.* **Results:** *Pre-intervention assessments showed no significant differences between the groups using either method. After training, G1, G2, and G3 significantly increased the PAR compared to G4, through both processes. The comparison of PAR post and pre-intervention revealed significant differences for G1, G2, and G3 (REAT) as well as for G1 and G3 (MIRE), in contrast to G4. Regarding "pass" and "fail" outcomes through MIRE, G1, G2, and G3 had more "pass" results after the intervention, compared to G4.* **Conclusions:** *Intervention, regardless of modality, effectively improved correct earplug HPD fitting, evidenced by increased PAR and higher rates of individuals achieving sufficient attenuation. Individual in-person demonstrations and video instructions proved to be the most effective training modalities.*

1. Introduction

Noise-induced hearing loss (NIHL) is a global public health issue with high prevalence and significant health impacts [1, 2]. In 2019, 7 million (4.76–10.06) years lived with disability, which was attributed to occupational noise exposure, highlighting the need to promote measures to reduce noise exposure [1]. The adverse effects of noise exposure extend beyond hearing; they may also contribute to increased blood pressure, cardiovascular diseases, stress, sleep disturbances, cognitive dysfunctions, and more [3-6]. Workers in construction, mining, the military, agriculture, public services, transportation, industry, and music are among the populations most at risk for noise-related hearing changes [3, 4, 7]. NIHL is irreversible. Therefore, prevention is the best strategy to avoid the adverse effects of noise exposure [3, 4]. Measures such as monitoring and reducing noise exposure, using hearing

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protection devices (HPDs), assessing hearing regularly, and providing health education should be taken to prevent NIHL [2, 3].

Noise mitigation in the workplace should follow the control hierarchy: first, eliminate noise at the source, then utilize individual hearing protection devices (HPD). Although HPDs are integral to preventing hearing loss, their incorrect use can reduce noise attenuation due to poor fitting, inadequate wearing time, or degradation [7]. A systematic review found that training in proper HPD use can decrease noise exposure by ensuring adequate attenuation, which is crucial for preventing NIHL [8]. Workers need guidance and training for effective HPD use in their work environments, making ongoing health education vital [3]. Additionally, studies indicate that laboratory-measured HPD attenuation exceeds that in daily environments, necessitating individual calculations based on fit and variability [10, 12].

Field attenuation estimation systems currently provide the most accurate assessments of personal attenuation rating (PAR) to determine if necessary attenuation is achieved [8]. Standard systems include real-ear attenuation at threshold (REAT) and microphone in the real ear (MIRE). HPD fitting significantly impacts device attenuation [13-16], yet studies comparing educational interventions for fitting and their attenuation effects are limited. This research evaluates and compares the PAR of an insert earplug HPD after various intervention modalities.

2. Methods

2.1. Study Design

This randomized controlled trial (RCT) involves a convenience sample of 52 university students of both sexes, with a mean age of 23.52 ± 3.76 years, who had no prior knowledge of fitting HPDs. The exclusion criteria included previous HPD use, visually inspected changes in the external auditory canal, a history of ear infections and/or otologic surgeries, and auditory complaints. When applicable, individuals were referred to the institution's otorhinolaryngology service. The institution's research ethics committee approved this study under evaluation report no. 114/13. All participants received guidance and explanations about the study and signed an informed consent form before beginning any procedures.

2.2. Procedures

Initially, all participants completed a brief clinical questionnaire addressing their health history and auditory complaints. Then, they underwent an otoscopy (using a Mini 3000 otoscope by Heine) to identify any abnormalities that could interfere with the subsequent procedures. REAT and MIRE were used to obtain the PAR of the insert earplug HPD (model 1100 by 3M).

2.2.1. REAT

Hearing thresholds were measured in a free field with the ear occluded (with HPD) and not occluded (without HPD), using a warble tone as sound stimuli. The free-field pure-tone audiometry used the following equipment: audiometer model AC-40 (Interacoustics); two-channel amplifier model FF-70 (Acústica Orlandi); and sound field system model SO200P (Acústica Orlandi).

The participant was instructed to remain still with their head at a 0° azimuth angle toward the loudspeaker, 60 cm away from it, and was asked to signal to the evaluator whenever they heard the sound stimulus. The difference between the two measures was calculated for each frequency. The PAR was then obtained through a detailed calculation that included the attenuation values obtained across all frequency bands specified in the method [17].

2.2.2. MIRE

The MIRE utilised the E-A-Rfit Validation System™ by 3M™, specifically designed to obtain the PAR of 3M™ HPDs. This equipment consists of a loudspeaker connected to a pair of microphones. The E-A-Rfit™ software, version 3M.4.4.17.0, manages all evaluation procedures. The loudspeaker generates white noise at 100 dB SPL. One of the microphones connects to the HPD explicitly designed for this purpose and is inserted into the external auditory canal (internal microphone). At the same time, the other is positioned near the participant's outer ear (external microphone). The software automatically calculates the difference in intensities captured by each microphone (internal and external) for each ear separately, providing the PAR.

The software also compares the PAR for each ear. It considers the lower attenuation value to classify the individual as "passed" (sufficient protection) or "failed" (insufficient protection), based on the subtraction of the noise exposure level (100 dBA) and a variation value. The latter, automatically calculated by the software, includes a combination of user fit variation, the user's noise spectrum, and the mean variation itself [18]. The cutoff value for sufficient protection was set at 85 dBA, meaning that the PAR plus the variation should achieve a minimum of 15 dB (as calculated by the software). Moreover, the equipment adopts the lower PAR of the two ears as the binaural PAR. The participant was instructed to keep their head at a 0° azimuth angle toward the loudspeaker, 60 cm away from it, and remain still.

The REAT and MIRE evaluations were conducted in an acoustically treated booth: free ear (without HPD) (stage 1); occluded ear (with HPD) before intervention (stage 2); and occluded ear (with HPD) after intervention (stage 3). Hearing thresholds were initially obtained with the free ear (stage 1 – only REAT). Then, participants were instructed to fit the HPD in both ears as they deemed most appropriate, and a new evaluation was conducted using MIRE and REAT (stage 2). Next, participants were randomly assigned to one of four groups (G1, G2, G3, or G4).

The first three groups received educational intervention with standardised instructions on the correct HPD fitting, while G4 (control group) received no intervention (Table 1).

After the intervention (or lack thereof, in the case of G4), participants were instructed to fit the HPD again, and a new evaluation was performed using MIRE and REAT (stage 3). The analysis considered the differences in PAR (stages 2 and 3)—i.e.,

Table 1. Classification of the groups according to the modality of intervention for the fitting of hearing protection devices (HPD).

Groups	**Interventions**	**Procedures**
Group 1 (G1)	Oral instructions with an individual hands-on demonstration	The researcher provided standardized demonstrations of the correct HPD fitting.
Group 2 (G2)	Reading the packaging	The participant read the HPD manufacturer's instructions on the packaging, with images and explanatory phrases.
Group 3 (G3)	Video with oral instructions and demonstration	The researcher provided standardized instructions and demonstrations in an explanatory video on the correct HPD fitting.
Group 4 (G4)	Control Group	The REAT is subjective, in a free field with an audiometer to assess hearing thresholds with the ear occluded (with HPD) and not occluded (without HPD). The difference between the two measures is the PAR of the HPD. The MIRE, in turn, is objective, measuring sound pressure levels (SPL) using two microphones simultaneously – one internal microphone connected to the HPD, inserted in the ear canal, and one external microphone positioned near the outer ear. The equipment automatically calculates the difference (PAR) between the intensities captured by the two microphones [12]. Furthermore, the effectiveness of training for the correct did not receive any type of instructions on the correct HPD use.

Table 2. Comparison between groups for the mean personal attenuation levels (PAR) pre- and post-intervention and for the differences in personal attenuation levels (PAR) between the pre- and post-intervention stages using the REAT method.

Situation	Group	N	Mean PAR	SD	ANOVA p-value	Tukey
Before	G1	13	15.48	12.11	0.619	-
	G2	13	20.13	12.37		
	G3	13	18.35	10.32		
	G4	13	20.50	7.09		
After	G1	13	30.95	11.99	0.001*	A
	G2	13	34.63	8.31		A
	G3	13	36.09	5.43		A
	G4	13	21.87	10.60		B
Difference in PAR before and after intervention	G1	13	15.47	11.99	<0.001*	A
	G2	13	14.50	8.31		A
	G3	13	17.74	5.43		A
	G4	13	1.37	10.60		B

post-intervention PAR pre-intervention PAR—obtained in the two evaluations for each method.

2.3. Data Analysis

Quantitative results were presented as mean ± standard deviation (SD) and analysed using one-way analysis of variance (ANOVA) and Tukey's post-hoc test. The Fisher Exact test was used for qualitative data (MiniTab 18 and Jamovi 0. 19.3 software). All analyses considered a significance level of $p \leq 0.05$.

3. Results

Fifty-two university students (40 women and 12 men) were recruited, with a mean age of 23.36 (± 3.76), minimum 18 and maximum 50, with no difference between groups (p-value 0.814). No significant difference was found comparing PARs between groups before the intervention. However, G1, G2, and G3 differed significantly from G4 after the intervention. The comparison between the groups for the differences in PARs using the REAT (post-intervention PAR minus pre-intervention PAR) showed that G1, G2, and G3 were statistically different from G4 (Table 2).

The mean PARs of the groups before the intervention were not significantly different. However, they were significantly different after the intervention, with G4 having the lowest mean PAR. The comparison of the groups' PAR differences using the MIRE (post-intervention PAR minus pre-intervention PAR) found that G1 and G3 were statistically different from G4 (Table 3).

The "pass/fail" performance before and after intervention (Table 4) was statistically different between the groups. The qualitative results showed that G1, G2, and G3 differed in performance from G4 (G1 – 15% to 54%; G2 – 31% to 62%; G3 – 31% to 62%; G4 – 24% to 15%), that is, all three groups increased their "pass" results, but G4 did not.

4. Discussion

This RCT aimed to evaluate and compare the PARs of insert HPDs obtained after different intervention modalities (in-person demonstration, package reading, and video) and to compare these modalities with the absence of intervention. The four participating groups did not differ in terms of mean age or prior knowledge of HPD use, aiming to minimize potential confounding variables in the results [11]. Moreover, individuals were randomly

Table 3. Comparison between the groups for the mean personal attenuation levels (PAR) pre- and post-intervention and for the differences in personal attenuation levels (PAR) between the pre- and post-intervention stages using the MIRE method.

Situation	Group	N	Mean PAR	SD	ANOVA p-value	Tukey
Before	G1	13	11.85	5.00	0.462	-
	G2	13	14.31	5.77		
	G3	13	14.46	6.31		
	G4	13	11.85	5.46		
After	G1	13	20.31	6.38	<0.001*	A
	G2	13	18.23	6.38		A
	G3	13	20.77	6.54		A
	G4	13	10.85	5.62		B
Difference in PAR before and after intervention	G1	13	8.46	6.38	<0.001*	A
	G2	13	3.92	6.38		AB
	G3	13	6.31	6.54		A
	G4	13	-1.00	5.62		B

Table 4. Frequency of pre- and post-intervention results classified according to the "Pass" or "Fail" criteria by group.

Group	Before Pass / Fail	After Pass / Fail
G1	2 / 11	7 / 6
G2	4 / 9	8 / 5
G3	4 / 9	8 / 5
G4	3 / 10	2 / 11
Fisher Exact test p-value	<0.025*	

allocated into the groups. For both methods (REAT and MIRE), the results of this study showed differences between the groups (G1, G2, and G3 compared to G4) after the intervention, indicating that the three groups that underwent some form of intervention increased their PAR. However, there were no significant differences among them. It was also found that the four groups did not have different PARs before the intervention. Hence, the attenuation was similar at the beginning of the study, and none of them stood out in the correct HPD fitting.

The comparison of differences in PAR (post-intervention minus pre-intervention) between the groups also reveals significant differences for both methods. For the REAT, G1, G2, and G3 (mean values of 15.4, 14.5, and 17.7, respectively) differed from G4 (mean value of 1.3). For the MIRE, G1 and G3 (mean values of 8.4 and 6.3, respectively) differed from G4 (mean value of -1). This indicates that groups G1 (in-person demonstration) and G3 (video) achieved the best post-intervention performances.

The performance of the control group (G4) regarding the differences in PAR before and after the intervention demonstrates that little to no change in HPD fitting was achieved without intervention. In contrast, the performance of the other groups showed higher PAR after the intervention, indicating that all approaches were practical (with a particular emphasis on the in-person and video methods) compared to the absence of instructions. This underscores the importance of training for the proper HPD fitting.

The in-person instruction method is often the most used to train workers [9]. It includes guidance on noise exposure levels, desired attenuation levels, and demonstration of the correct HPD fitting, which has proven effective in increasing PAR in previous studies [19, 20]. A study with 321 recruits in training with the United States Navy, randomly assigned to three groups, examined the effectiveness of different training modalities (video, in-person with a specialized professional, and video combined with in-person training). The study concluded that all methods were effective, with the most significant emphasis on training by a specialized professional [21]. Kim et al. (2019) conducted in-person training for workers annually over 4 years [22]. Using the MIRE, they observed that the PAR improved after each training session, with increasingly better results each year, highlighting the importance of long-term training [20, 23].

The analysis of "pass/fail" results automatically provided by the MIRE found that the approval rates increased by over 30% only for G1, G2, and G3. Thus, it is evident that not only is the PAR higher after training, but also the rate of individuals achieving the target PAR (with sufficient attenuation for protection) increases. These findings are consistent with those obtained by Takada et al. (2020) and Federman et al. (2020) and emphasize the importance of training for the proper HPD fitting to provide the necessary attenuation to reduce noise exposure and prevent NIHL [10, 21]. Nonetheless, some individuals, even among those who underwent training, did not reach the target PAR (G1 46%, G2 38%, G3 38%, G4 85%). In the case of G4, the failure rate can be attributed to the absence of training. However, for the other groups, several variables may contribute to this outcome, such as the need for additional training, the shape and geometry of the ear (which may make this HPD type unsuitable for the individual), and so forth [10, 24, 25].

Previous studies reported similar findings. Their authors noted that the recommendation for a specific HPD type should consider anatomical differences among individuals [21, 26].

Regarding the intervention modalities, our results indicate that video instruction was as effective as in-person training, suggesting that this approach should be increasingly explored, as it requires fewer financial resources and is easily reproducible. It eliminates the constant need for a specialized professional, allowing workers to consult the instructional material whenever necessary. Joseph et al. (2007) observed an increase in the mean PAR, measured by the REAT, after training with audiovisual material on the correct HPD use, followed by in-person training (either individually or in groups) [9]. Thus, the option of using audiovisual materials can complement in-person training.

Studies evaluating the effectiveness of interventions using audiovisual resources are still scarce. However, technological advancements noticeably increase the importance of such strategies to disseminate information and promote health. Other areas of healthcare have already studied and applied this strategy in various contexts. For example, Razera et al. (2016) compared the training of caregivers of children on postoperative care through in-person instructions and video, finding better knowledge retention when acquired via video than via in-person instructions [27].

The limitations of this study include the evaluation method, which did not simulate a real work environment, as participants remained seated and motionless. This setup does not assess whether the PAR decreases throughout the day.

Although the study design (i.e. RCT) is a factor that improves its internal validity, as it has the potential to provide the highest-quality evidence for assessing interventions, the setting and the individuals studied are not similar to the occupational environment, which may limit the generalisation of the findings. However, the controlled laboratory environment reduces the influence of several variables, seeking to isolate the intervention per se. RCTs are difficult to perform in real-world settings because of the presence of many stakeholders and social interaction between participants [8].

Tikka et al. [8] and Morata et al. [28] highlighted this difficulty in their Cochrane systematic reviews. The authors emphasized that, due to the challenges of randomization in the workplace [28] and the need for interventions to prevent occupational hearing loss [8], both reviews chose to include controlled before-and-after studies. In Morata et al.'s review [28], the authors considered including uncontrolled before-and-after studies; however, the absence of a "control group" would complicate determining whether the observed effects could be attributed to the intervention. As a final consideration of this review, more RCT studies were recommended to support the evidence. Therefore, given the scarcity of RCTs in this area and the low to moderate quality of evidence regarding interventions involving hearing loss prevention (including training for appropriate use of the HPDs) [8], we chose to conduct an RCT study, but within the laboratory. Future studies should evaluate the possibility of carrying out a similar methodology, assessing the effectiveness of instructions and HPD use during occupational activities in environments closer to the real world. Situations such as the concomitant use of personal protective equipment and adverse working conditions, among others, make the use of HPD more complex. Potential strengths of this study include the randomization of individuals across the four groups, which reduces the possibility of bias, the inclusion of participants with no prior knowledge of HPDs, and the inclusion of a control group that did not receive any intervention. This is particularly noteworthy since many studies have excluded a control group [9, 10, 21].

5. Conclusion

Our findings highlight that the intervention (regardless of the modality) for properly fitting insert HPDs effectively increased the PAR and the rates of individuals achieving sufficient attenuation. Training through individual demonstration and video instructions proved to be the most effective modalities.

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Posture Assessment of Rubber Tappers: A Comparative Analysis of OWAS, REBA, RULA, and PERA Methods

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Keywords: Agriculture; Ergonomics; Musculoskeletal disorders; Observational Method

Abstract

Background: *The study provides a comprehensive ergonomics assessment of the postures encountered by rubber tappers using the OWAS, REBA, RULA, and PERA methods and compares the risk levels across various ergonomic assessment methodologies.* **Methods:** *The research examines the postures of fifty-one selected rubber tappers from the state of Kerala, India, during rubber tapping, analyzing 1111 different working postures. The postural assessment was conducted by analyzing video recordings of the work tasks and evaluating the postures using OWAS, REBA, RULA, and PERA. Each method's focus and application were considered to comprehensively evaluate the postural risks.* **Results:** *The demographic characteristics indicate that the workforce mostly consists of middle-aged males involved in physically strenuous activities. The result shows that the RULA method, emphasizing upper limb postures, is particularly suited for assessing postural loads in rubber tapping, highlighting the need to match ergonomic tools to the specific demands of work activities. While OWAS provides a general overview, RULA focuses on upper limbs, REBA assesses whole-body postures, and PERA incorporates cyclic work factors, enabling targeted ergonomic interventions. Additionally, it is crucial to consider that each method OWAS, RULA, REBA, and PERA has distinct strengths and applications.* **Conclusions:** *The research highlights the need for tailored ergonomic interventions for tasks such as 'Incision on the Channel'. Ultimately, the study validates implementing a context-specific approach for assessing ergonomic parameters and intervention measures aimed at enhancing the overall occupational health of rubber tappers.*

1. Introduction

In many Asian countries, such as Thailand, Indonesia, Vietnam, China, and India, rubber tapping is one of the most skilled agricultural occupations [1]. It involves making incisions in the bark of the rubber tree trunk in a downward spiral form. Most workers consider rubber tapping a secondary occupation [2]. As a result, many complete the tapping early in the morning and start their primary job during the day. Moreover, rubber tapping in the predawn hours provides maximum yield [3]. Consequently, the working characteristics of rubber tappers are unique, involving precision work, uneven terrains, poor climatic conditions, early working hours, fear, and repetitive tasks. These conditions can adversely affect the workers' physical and mental health.

Musculoskeletal disorders (MSDs) are among the most common physical occupational hazards faced by rubber tappers [4]. Identifying awkward postures and implementing appropriate working postures can improve both the MSDs and the productivity of the workers [5-7]. The following assessment methods are used to identify MSDs [8]:

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- Self-report study;
- Observational methods;
- Direct measurement method.

The self-reported study is the most commonly used assessment method because it can be applied in various working situations, obtaining large samples at low cost and with minimal time investment. However, the accuracy of the data collected from the subjects is low [9]. For high precision and lower subjectivity, the observational method is the best assessment method for postural analysis [10]. Some of the observational methods used for postural assessment include:

- *Ovako Working Posture Analysis System (OWAS):* Focuses on the back, arms, and legs, assessing general postural risks without considering the duration or force exerted [11];
- *Ergonomic Workplace Analysis (EWA):* Evaluates overall workplace ergonomics, focusing on posture, movements, and workstation design to improve working conditions and prevent musculoskeletal disorders [12];
- *Ergonomics Checklist:* Evaluates various factors such as body posture, movement, and workstation design to prevent musculoskeletal disorders [13];
- *Rapid Upper Limb Assessment (RULA):* Targets upper limb postures, including the neck, trunk, and arms, making it particularly sensitive to tasks involving significant upper limb activity [14];
- NIOSH Lifting Equation: Assess the safety of manual lifting tasks by calculating the recommended weight limit based on the load's weight, horizontal and vertical position, distance moved, frequency of lifting, and grip quality to minimize the risk of lifting-related injuries. [15];
- *PLIBEL Checklist*: Focuses on identifying potential hazards in the workplace related to physical load, such as posture, repetitive movements, and manual handling [16];
- *Strain Index:* Evaluate the risk of developing upper extremity musculoskeletal disorders by assessing task-related factors such as intensity, duration, and frequency of exertion, along with wrist posture, speed of work, and duration of task per day [17];
- *Occupational Repetitive Actions (OCRA*): Assess the repetitive tasks by analyzing factors such as the frequency of actions, force exerted, awkward postures, and recovery periods to ensure workplace safety and ergonomics [18];
- *4D Watback:* Evaluate manual handling tasks by analyzing dynamic movements in four dimensions (spatial and temporal) to prevent work-related musculoskeletal disorders and enhance safety [19];
- *Rapid Entire Body Assessment (REBA):* Evaluates whole-body postures, including the neck, trunk, upper limbs, and lower limbs, and considers postural angles, forceful exertions, and the nature of movements [20];
- *Loading on the Upper Body Assessment (LUBA):* Evaluate the load and posture of the upper body during work tasks, focusing on the arms, shoulders, neck, and back to identify and mitigate potential risks [21];
- *Upper Limb Risk Assessment (ULRA):* Evaluate the upper limbs by assessing factors such as repetitive movements, force exertion, awkward postures, and duration of tasks [22];
- *Quick Exposure Check (QEC):* Identify ergonomic risks for musculoskeletal disorders by evaluating exposure to risk factors in specific work tasks [23];
- *Assessment of Repetitive Tasks (ART):* Evaluate the risk of upper limb disorders associated with repetitive work by analyzing factors such as repetition, force, awkward postures, and additional factors like vibration and breaks [24];
- *Agricultural Lower Limb Assessment (ALLA):* Evaluate the risk of musculoskeletal disorders in the lower limbs of agricultural workers by analyzing factors such as repetitive movements, force exertion, awkward postures, and duration of tasks [25];
- *Agricultural Upper Limb Assessment (AULA):* Evaluate the risk of musculoskeletal disorders in the upper limbs of agricultural workers by

assessing repetitive movements, force exertion, awkward postures, and the duration of tasks [26];
- *Hand Arm Risk Assessment Method (HARM):* Evaluate the risk of musculoskeletal disorders and other injuries to the hands and arms by analyzing factors such as repetitive motions, force exertion, posture, and vibration exposure [27];
- *Novel Ergonomic Postural Assessment (NERPA):* Assess work postures using a digital human model and 3D CAD tools to identify ergonomic risks and optimize workplace design [28];
- *Agricultural Whole-Body Assessment (AWBA):* Evaluate the risk of musculoskeletal disorders in agricultural workers by analyzing whole-body postures, repetitive movements, force exertion, and task duration [29];
- *Postural Ergonomic Risk Assessment (PERA*): Assesses cyclic work by considering posture, duration, and force across the entire work cycle, providing a comprehensive risk assessment [30].

Some researchers have conducted comparative studies of various postural assessment methods. Kee et al. calculated the maximum holding time in different body postures and compared it with OWAS, RULA, and REBA. The results indicate that RULA is the most effective posture assessment tool for postural load [31]. A similar study based on self-reported discomfort surveys yielded comparable results [32]. Choi et al. compared AULA with OWAS, RULA, and REBA across 196 tasks involved in various farming operations [33]. Another study was carried out among farm workers, evaluating 196 working postures using OWAS, RULA, and REBA [34]. Further research investigated various stages of timber harvesting, such as logging, skidding, and loading, comparing the postural assessments using OWAS and REBA [35]. Micheletti et al. assessed and compared the different postures of the operator during the manual feeding of a wood chipper using RULA and REBA [36]. Zare et al. presented self-report studies, observational methods, and direct measurement techniques in a truck assembly unit for upper limb and back assessments [37]. Chiasson et al. examined eight distinct assessment tools, including QEC, FIOH, RULA, REBA, JSI, HAL, OCRA, and EN 1005-3, while evaluating 567 tasks within the industrial sector [38].

The literature review shows that OWAS, RULA, and REBA are commonly used postural assessment tools [39]. The Postural Ergonomic Risk Assessment (PERA) is a newly developed posture assessment tool used to evaluate cyclic work [30]. Rubber tapping is a physically demanding activity that involves repetitive movements and sustained awkward postures. Each method focuses on different aspects of postural assessment, which can lead to variations in their output scores. For instance, the RULA method emphasizes the upper limbs, which can result in higher postural load scores if these body parts are predominantly involved in the task [40]. This paper aims to compare these methods in the context of rubber tapping to identify the most appropriate tool for assessing postural load and risk. Hence, the objectives of this research are as follows:

- Evaluate the risk factors among rubber-tapping workers through a self-reported questionnaire and observational methods in real practice;
- Compare the posture assessments of rubber-tapping workers to analyze the convergence of the OWAS, RULA, REBA, and PERA observational methods;
- Identify the suitability of various ergonomic assessment methods for identifying postural risks among rubber-tapping workers.

2. Methods

2.1. Study Population

A cross-sectional study was conducted among rubber-tapping workers in Kerala, a state in India, known as one of the world's leading natural rubber producers [1]. Fifty-one rubber-tapping workers were selected for the study after being informed about its objectives and the methods used for data collection. Participants provided their oral consent before data collection began. The criteria for participant selection included: (a) being a regular rubber tapper; (b) having at least one year of experience in rubber tapping; and (c) being at least eighteen years old. The study comprised 48 male and 3 female rubber tappers. Both demographic information and posture assessments covered the entire participant group, including male and female workers.

Various postures of fifty-one rubber tappers from videos captured during rubber tapping were examined, and 1,111 working postures were recommended for analysis. The detailed analysis of these 1,111 postures revealed that the majority (622 postures) were associated with the sub-task 'Incision on the Channel' suggesting this sub-task's high frequency and significance in the rubber tapping process. The distribution of the remaining postures among the other sub-tasks was as follows: 157 postures for 'Removal of Latex Cover from the Channel', 198 postures for 'Adjusting the Collecting Cup', and 134 postures for 'Moving to the Next Rubber Tree'. Most of the rubber tappers were male (48 males and 3 females), with a majority being middle-aged (46-60 years) and an average age of 51.78 (±10.94) years. The average body mass index (BMI) was 24.2 kg/m^2. Most workers (55%) were of normal weight, while a small percentage (5.8%) were underweight. Most workers had only a matriculation-level education, and many had over 30 years of experience in rubber tapping.

2.2. Data Collection Method

A questionnaire based on the Standard Nordic Questionnaire was developed for rubber-tapping workers, involving demographic details, work activity assessment, and physical and mental health assessment. Personal interviews were conducted with the rubber tappers to gather information about their work activity and demographic background. Additionally, participants were asked to assess the degree of pain or distress they experienced in various parts of their bodies during the tapping operation. To analyze the postures of rubber-tapping workers, conducted video recordings of the entire work cycle during typical rubber-tapping activities. The video recordings captured the complete range of activities performed by the rubber tappers, removing the latex cover, including making incisions, adjusting collection cups, and moving between trees. Each recording was segmented into individual frames to capture static postures at regular intervals, ensuring a comprehensive evaluation of the postural variations throughout the work cycle. From these segmented video frames, we selected 1,111 postures for detailed analysis based on criteria that included postures held for prolonged periods, involved significant force exertion, or were frequently repeated.

2.3. Observational Method

The posture assessments were conducted using various observational methods: OWAS, REBA, RULA, and PERA, by capturing frames from video recordings. Each of the four ergonomic assessment methods, this study uses distinct characteristics and application focuses. The action categories were grouped into four cluster levels to compare the results of different observational methods.

2.3.1. Ovako Working Posture Analysis System (OWAS)

OWAS, one of the oldest ergonomic assessment tools, was developed during the 1970s through collaboration between work-study engineers and Ovako Oy, a privately owned steel company in Finland [11]. It focuses on the discomfort caused by working postures to provide a framework for redesigning working conditions. OWAS primarily assesses back, arms, and leg postures without considering the duration of postures or the force exerted. The framework delineates seven limb postures, three arm postures, and four back postures and considers the weight being carried during the labor task. Video recordings of rubber-tapping tasks were captured, and specific postures were identified and segmented for analysis. Each identified posture was categorized according to the OWAS coding system, which includes back postures (straight, bent forward, twisted, or bent and twisted), arm postures (both arms below shoulder level, one arm at or above shoulder level, both arms at or above shoulder level), leg postures (standing on both legs, standing on one leg, standing with weight shifting, kneeling, or walking), and load handling (no load, handling a load less than 10 kg, handling a load more than 10 kg). OWAS divides the injury risk associated with a particular working posture into four distinct action categories:

- Cluster Level 1 (OWAS CL1): Action Category 1 – Except in a few instances, normal postures do not necessitate any particular attention;
- Cluster Level 2 (OWAS CL2): Action Category 2 – Future periodic assessments of working methods must consider postures; corrective actions will be required;
- Cluster Level 3 (OWAS CL3): Action Category 3 – In the near future, postures will require attention; corrective measures must be implemented immediately;
- Cluster Level 4 (OWAS CL4): Action Category 4 – Immediately correcting postures is required.

The OWAS method was used to categorize the postures of rubber tappers into predefined classifications according to their back, arms, and leg positions. During the observation of subtasks, the frequency and duration of each posture were recorded.

Each posture was then assigned a risk category (Action Category 1 to 4) based on the OWAS coding system. For example, bending while making incisions on the rubber tree was classified under higher risk levels due to sustained and awkward back posture.

2.3.2. Rapid Upper Limb Assessment (RULA)

RULA was developed for the rapid evaluation of body posture *during* upper extremity tasks, concentrating extensively on the upper limbs, neck, and trunk, *which makes* it especially sensitive to tasks that *involve* significant upper limb activity [14]. Conducting a postural analysis *with* RULA *entail*s assessing the angles of the wrist, lower arm, upper arm, neck, trunk, and legs, typically determined through the observation of the task, load, nature of work, and duration in the field. *The outcome* of the RULA assessment tool is the RULA Score, a sing*ular* number ranging from 1 to 7 that indicates the degree of musculoskeletal disorder (MSD) risk associated with the job task under examination. Video recordings of the rubber tapping tasks were analyzed to capture detailed upper limb postures, each of which was scored according to the RULA criteria. The scores were aggregated to determine risk levels and categorized into action levels that indicate the urgency of intervention, providing a targeted analysis of postural risks specific to upper limb activities in rubber tapping. The final scores are grouped into four cluster levels:

- Cluster Level 1 (RULA CL1): Score 1 and 2 - Minimal risk; No action is recommended;
- Cluster Level 2 (RULA CL2): Score 3 and 4 - Low risk, Change may be recommended;
- Cluster Level 3 (RULA CL3): Score 5 and 6 - Medium risk, Immediate change may be required;
- Cluster Level 4 (RULA CL4): Score 7 and more - High risk, Immediately Change required.

RULA was specifically employed to assess postures involving significant upper limb activity, which is prevalent in rubber tapping. During the subtasks, postures were analyzed in static and dynamic states, with a particular focus on the "incision" activity. Scores for arm, wrist, and neck positions were assigned based on angular measurements and load requirements. Additional adjustments were made for muscle use and static postures. The final scores categorized the risk levels, highlighting areas requiring immediate ergonomic intervention.

2.3.3. Rapid Entire Body Assessment (REBA)

REBA was developed to assess the posture of individual workers regarding MSDs and the risks associated with various tasks, evaluating the entire body, including the neck, trunk, and limbs, though it is not as comprehensive in upper limb assessment as RULA [20]. The method takes into account both upper and lower extremity postural angles, forceful exertions, the nature of movements or actions, and repetition in its analysis.

The REBA Score, which ranges from 1 to 11, indicates the degree of MSD risk linked to the job task being evaluated. In the context of rubber tapping, video recordings of the tasks were analyzed to capture a comprehensive array of postures. Each posture was scored based on REBA's criteria, which involve assessing body segment angles, the force exerted, and the nature of movements. The aggregated REBA scores offered a clear indication of overall postural risks, categorized into action levels to inform necessary interventions. This thorough application of REBA facilitated the identification of high-risk postures in rubber tapping, ensuring that suitable ergonomic measures could be implemented to reduce these risks. The final scores are grouped into four cluster levels:

- Cluster Level 1 (REBA CL1): Score 1 and 3 – Negligible risk or Low risk, No change or change may be required;
- Cluster Level 2 (REBA CL2): Score 4 and 7 – Medium risk, Change may be required soon;
- Cluster Level 3 (REBA CL3): Score 8 and 10 – High risk, Change required;
- Cluster Level 4 (REBA CL4): Score 11 and more – Very High-risk Immediate Change required.

The REBA tool was utilized to analyze whole-body movements specific to the subtasks of rubber tapping. For instance, during the "incision" subtask, detailed evaluations of trunk flexion, shoulder elevation, neck posture, and wrist deviations were performed. These observations were combined with load and coupling factors to generate a comprehensive risk score for each task. The overall risk level was calculated by summing individual scores and correlating them with predefined risk categories in the REBA framework.

2.3.4. Postural Ergonomic Risk Assessment (PERA)

PERA evaluates cyclic work by assessing the necessary force, duration of each task, and the physical posture of the workers [30]. The entire work cycle of rubber tapping is broken down into smaller tasks to swiftly identify high-risk activities and provide an overall averaged score along with recommendations for ergonomic intervention. In the context of rubber tapping, video recordings of the complete work cycle were analyzed to decompose the process into distinct tasks, such as making incisions on the channel, adjusting collection cups, and moving between trees. Each task was assessed for the exerted force, duration, and the posture adopted by the workers. The PERA method calculates an overall average score, ranging from 1 to 27, which is regarded as the final PERA score and categorized into low, medium, and high risks. The final scores are organized into four cluster levels:

- Cluster Level 1 (PERA CL1): Score 1 and 4 – Negligible risk or Low risk, No change or change may be required;
- Cluster Level 2 (PERA CL2): Score 4 and 7 – Medium risk, Change may be required soon;
- Cluster Level 3 (PERA CL3): Score 7 and 12 – High risk, Change required;
- Cluster Level 4 (PERA CL4): Score 13 and more – Very High-risk Immediate Change required.

PERA was adapted to evaluate cumulative ergonomic risks in the rubber tapping context, which differs from its traditional industrial applications. Its principles were adapted to assess the unique work dynamics of rubber tapping, which involves repetitive tasks with cyclical patterns. Work cycles were defined as the sequential execution of subtasks (e.g., removing the latex cover, making incisions on the channel, adjusting collection cups, and moving between trees). Each cycle was broken down into discrete postures, with duration and repetition recorded.

2.4. Comparison of Assessment Methods

The posture assessments were conducted using four observational methods—OWAS, REBA, RULA, and PERA— by analyzing frames captured from video recordings during the self-reported study. A two-stage evaluation process was employed to ensure the reliability and validity of these assessments. In the first stage, three experienced ergonomists independently assessed the postures using the specified methods, minimizing bias and capturing a diverse range of observations. In the second stage, three ergonomists re-evaluated the postures to verify the initial assessments. This secondary evaluation ensured consistency and accuracy in the findings. A high level of consensus (95% agreement) was observed between the two groups of ergonomists, with discrepancies being minimal and primarily related to subjective interpretations of intermediate postures. These discrepancies were resolved through discussions, ensuring that all assessments were thoroughly reviewed and agreed upon.

The final scores from the four observational techniques were categorized into four cluster levels for effective comparison. Postures were classified based on work type and tapping level, as tapping level significantly influences the incidence of musculoskeletal disorders (MSDs) [41]. The tapping levels were divided into three groups: (i) below waist level (BW), (ii) below shoulder level (BS), and (iii) above shoulder level (AS). Additionally, the entire rubber tapping process was segmented into four sub-tasks to enhance the accuracy of the posture assessment.

- Removal of Latex Cover from the Channel (Rc): This task involves carefully removing the latex cover from the tapping channel without damaging the tree bark. It requires precision and care to avoid disrupting the latex flow. Due to the precision needed to avoid bark damage and disruption of latex flow, it involved moderate levels of force. Its repetitive nature across multiple trees added to cumulative strain. The high frequency of this task within a tapping cycle made it a significant contributor to repetitive motion strain.
- Incision on the Channel (Ic): This critical task entails making precise cuts on the tapping channel to extract latex. It requires considerable skill and accuracy, as improper incisions can decrease latex yield and harm the tree. It necessitates high levels of force during precise cuts. Observations indicated increased muscular effort in the dominant arm, shoulder, and wrist. This sub-task also demands sustained accuracy postures, which contribute to muscular fatigue over time. The moderate repetition of multiple incisions per tree further exacerbates cumulative strain.
- Adjusting the Collecting Cup (Ac): This task involves positioning or adjusting the collection cups to ensure that the latex flows into them effectively. The height and placement of the cups need to be modified according to the latex flow. Depending on the amount of cup lump, it requires low to moderate force. Workers often maintained bent or squatting postures for brief periods, contributing to static loading on the lower back and knees. The high frequency of this task across several trees heightened the ergonomic risks linked to static postures.
- Moving to the Next Rubber Tree (Mt): This involves the transition of rubber tappers from one tree to another, often across uneven terrain. It requires minimal force, except when workers carry tools and exert force during transitions across uneven terrain. Although brief, the repetitive nature of this activity throughout the workday contributes to fatigue in the lower extremities due to consistent movements.

2.5. Statistical Analysis

The study evaluating the postures of rubber-tapping workers employed four observational methods: OWAS, REBA, RULA, and PERA, which assessed workers' postures during tasks. To evaluate the effectiveness of these methods, bar charts were created to compare postural loads. A thorough statistical analysis indicated that the postural assessment scores showed a skewness value of -0.239, suggesting a non-normal distribution. Therefore, non-parametric tests were utilized instead of standard parametric tests.

The primary statistical analysis utilized was the Wilcoxon signed-rank test, which is suitable for non-parametric data commonly found in posture assessment. This test evaluated statistically significant differences in mean ranks of risk levels from the four methods. By pairing the four assessment methods (a total of six pairs), the mean risk levels were compared to identify any significant differences, facilitating direct comparisons of risk levels. The Wilcoxon test's independence from the normal distribution assumption made it particularly fitting for this analysis.

3. Results and Discussion

3.1. Work Activity Assessment

Many workers view rubber tapping as a secondary job. As a result, they start this work early in the morning before heading to their primary employment. These primary roles include physically demanding tasks such as agriculture, loading and unloading, and masonry, as well as less strenuous activities like office work, running a business, and driving. Nearly half of the workforce participates in physically demanding jobs for 5 to 8 hours daily. All workers are right-handed except for one person. About half of the rubber tappers manage 200 to 300 trees in a single shift; most work more than five days a week. Rubber tappers operate in lowland and highland areas, with highland locations being more common. Another factor that influences posture is the age of the trees; 60% of rubber tappers tap trees between 9 and 12 years old.

3.2. Posture Assessment Based on the Work Type

The 'Work Type' involved in rubber tapping is divided into four categories: (i) Removal of Latex Cover from the Channel, (ii) Incision on the Channel, (iii) Adjusting the Collecting Cup, and (iv) Moving to the Next Rubber Tree. Most postures belong to 'Incision on the Channel' (56.16%), as shown in Figure 1.

This finding emphasizes the various and delicate movements required for this particular task. Conversely, the work type 'Moving to the Next Rubber Tree' exhibits a substantially lower number of postures. The research highlights the significance of identifying specific types of work and corresponding body postures to tackle potential ergonomic issues and improve workers' overall health and comfort. The prevalence of postures in 'Incision on the Channel' underscores the necessity for customized interventions targeting ergonomic issues related to rubber tapping.

3.3. Posture Assessment Based on the Level of Tapping

The results in Figure 2 provide valuable insights into the distribution of recommended postures among rubber tappers based on different levels of tapping. The tapping levels are categorized into three groups: Below Waist Level (BW), Below Shoulder Level (BS), and Above Shoulder Level (AS). Notably, more than half of the postures (65.34%) fall within the 'Below Shoulder Level' category because regular tapping of rubber trees begins when the trunk attains a girth of 50 cm around a tree height of 100 cm from the ground. This finding underscores the significance of the mid-level range in ergonomic considerations for rubber tapping activities. The high prevalence of postures in the 'Below Shoulder Level' category indicates that most of the recommended movements required for effective rubber tapping are situated between the waist and shoulder height. This critical observation informs ergonomic interventions, suggesting a focus on addressing challenges and optimizing conditions in the mid-level range to enhance the overall working experience and health of rubber tappers.

3.4. Comparison Based on Risk Levels

3.4.1. RULA vs OWAS

The OWAS cluster levels are shown in Figure 3(a). Out of 1,111 postures, RULA and OWAS cluster levels matched for 245 positions (27 in level 2, 61 in level 3, and 157 in level 4), while 866 postures demonstrated differing levels. The agreement degree between OWAS and RULA was approximately 22.05%. Among the 866 postures lacking consensus, OWAS overestimated 53 and underestimated 813 compared to RULA. Table 1 shows that 438 postures had a one-level difference, 289 had a two-level difference, and 139 had a three-level difference. Statistical tests confirm that OWAS tends to underestimate; the Wilcoxon signed-rank test indicates RULA scores for postural load are significantly higher than OWAS ($p < 0.01$).

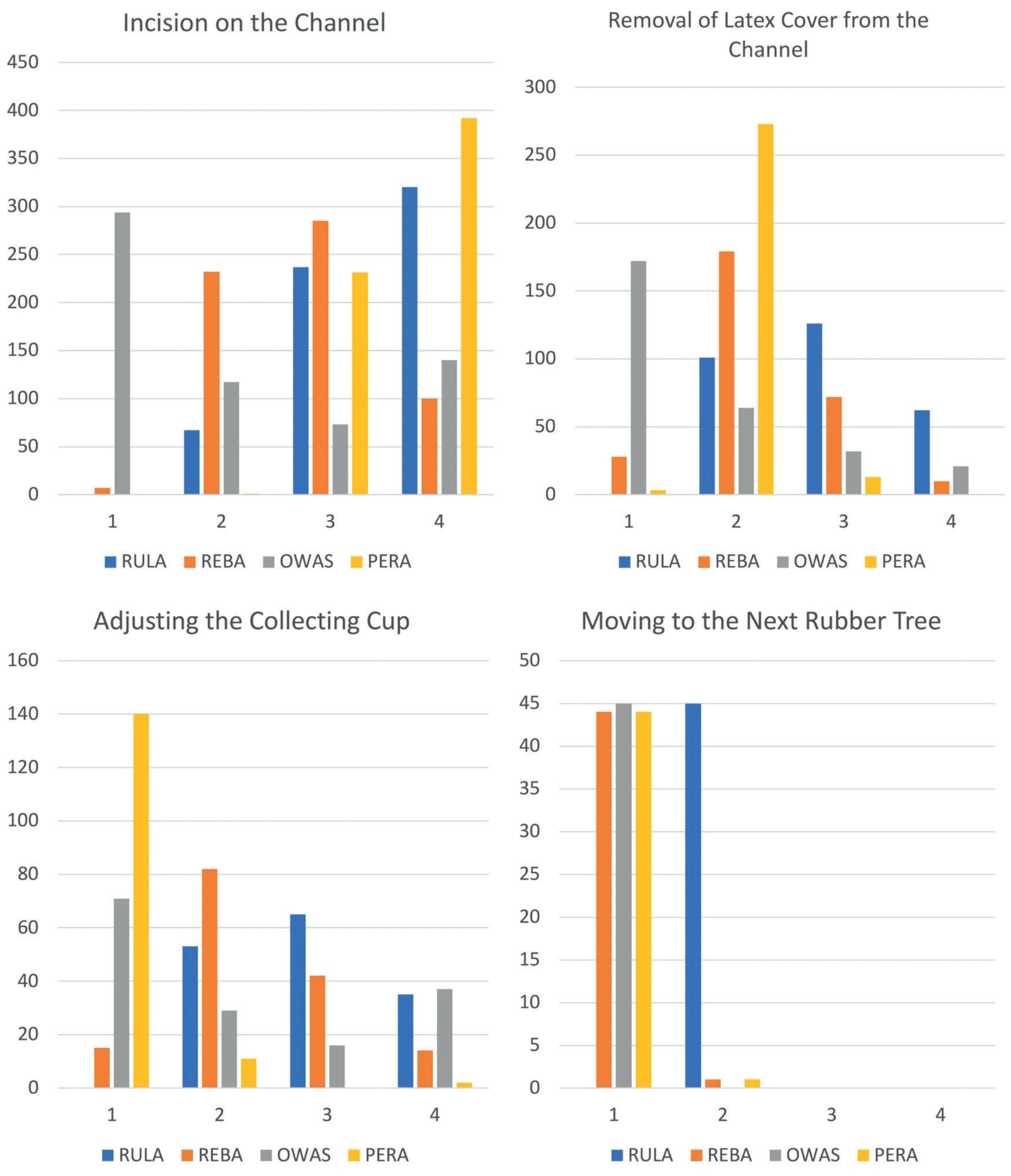

Figure 1. Cluster Level Distribution Based on Work Type.

3.4.2. RULA vs REBA

The relationship between REBA and RULA cluster levels is depicted in Figure 3(b). Of 1,111 postures, 432 had identical cluster levels (174 in level 2, 136 in level 3, and 122 in level 4), while 679 showed distinct levels. The concurrence level was around 38.88%. Among the 679 differing postures, REBA underestimated 674 and overestimated 5 compared to RULA. Table 1 indicates 639 postures differed by one risk level, and 40 by two levels. The Wilcoxon signed-rank test results confirm REBA's underestimation; RULA scores are statistically higher ($p < 0.01$).

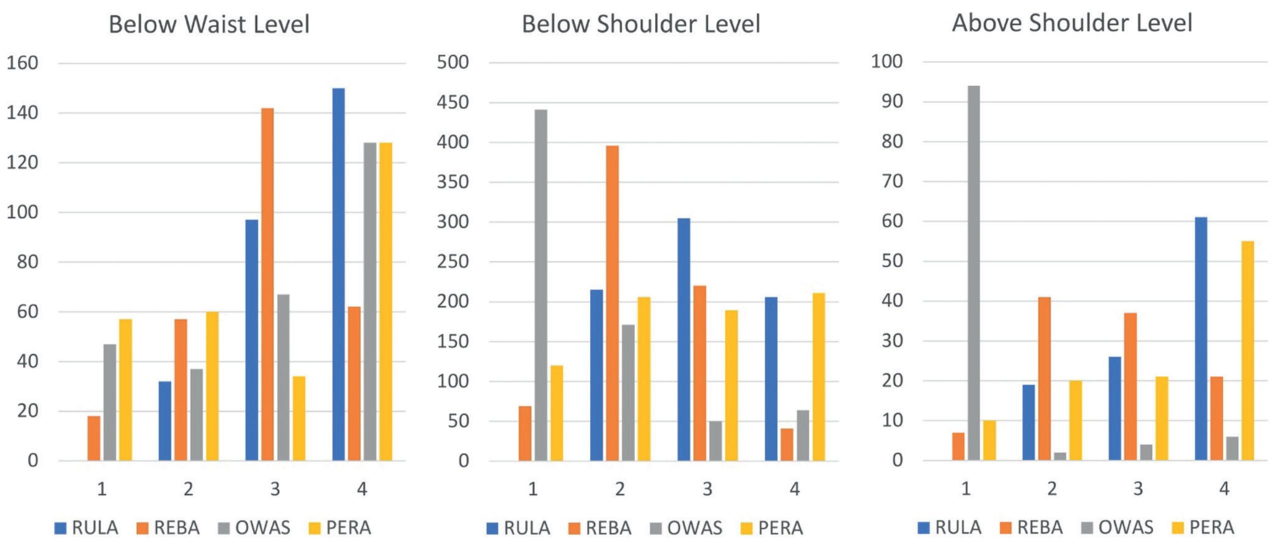

Figure 2. Cluster Level Distribution Based on Level of Tapping.

3.4.3. RULA vs PERA

Figure 3(c) illustrates the relationship between PERA and RULA cluster levels. About 543 postures had matching cluster levels (100 in level 2, 148 in level 3, and 295 in level 4), while 568 had distinct levels. The concurrence level between RULA and PERA was 48.88%. Among the 568 differing postures, PERA overestimated 164 and underestimated 404 compared to RULA. According to Table 1, 416 postures had a one-level difference, 119 had a two-level difference, and 33 had a three-level difference. The Wilcoxon signed-rank test results show that RULA scores for postural load are statistically higher than PERA ($p < 0.01$).

3.4.4. REBA vs OWAS

Figure 4(a) compares cluster levels of OWAS and REBA. Out of 1,111 postures, 355 had matching cluster levels (89 in level 1, 111 in level 2, 77 in level 3, and 78 in level 4), while 756 showed distinct levels, yielding an agreement of about 31.95%. OWAS underestimated 589 postures and overestimated 167 among the 756 misaligned cases. Differences were noted, with one risk level in 582 postures, two in 148, and three in 26 (see Table 1). Statistical analyses confirm OWAS's tendency to underestimate, as the Wilcoxon signed-rank test demonstrated significantly higher REBA scores for postural load ($p < 0.01$).

3.4.5. REBA vs PERA

Figure 4(b) illustrates the relationship between REBA and PERA. Among 1,111 postures, 379 matched levels (56 in level 1, 177 in level 2, 46 in level 3, and 100 in level 4), resulting in approximately 34.11% agreement. REBA overestimated 209 and underestimated 523 postures compared to PERA. Table 1 shows risk levels: 622 differed by one level, 94 by two, and 16 by three. Statistical tests confirm REBA's tendency to underestimate, with the Wilcoxon signed-rank test indicating significantly higher PERA scores ($p < 0.01$).

3.4.6. PERA vs OWAS

Figure 4(c) illustrates the OWAS and PERA cluster-level relationship across 1,111 postures: 334 share identical cluster levels (111 in level 1, 64 in level 2, 24 in level 3, and 135 in level 4). The remaining 777 postures showed divergent cluster levels, resulting in a 30.06% agreement between the two methods. Of these 777, OWAS overestimated 129 postures and underestimated 648 compared to

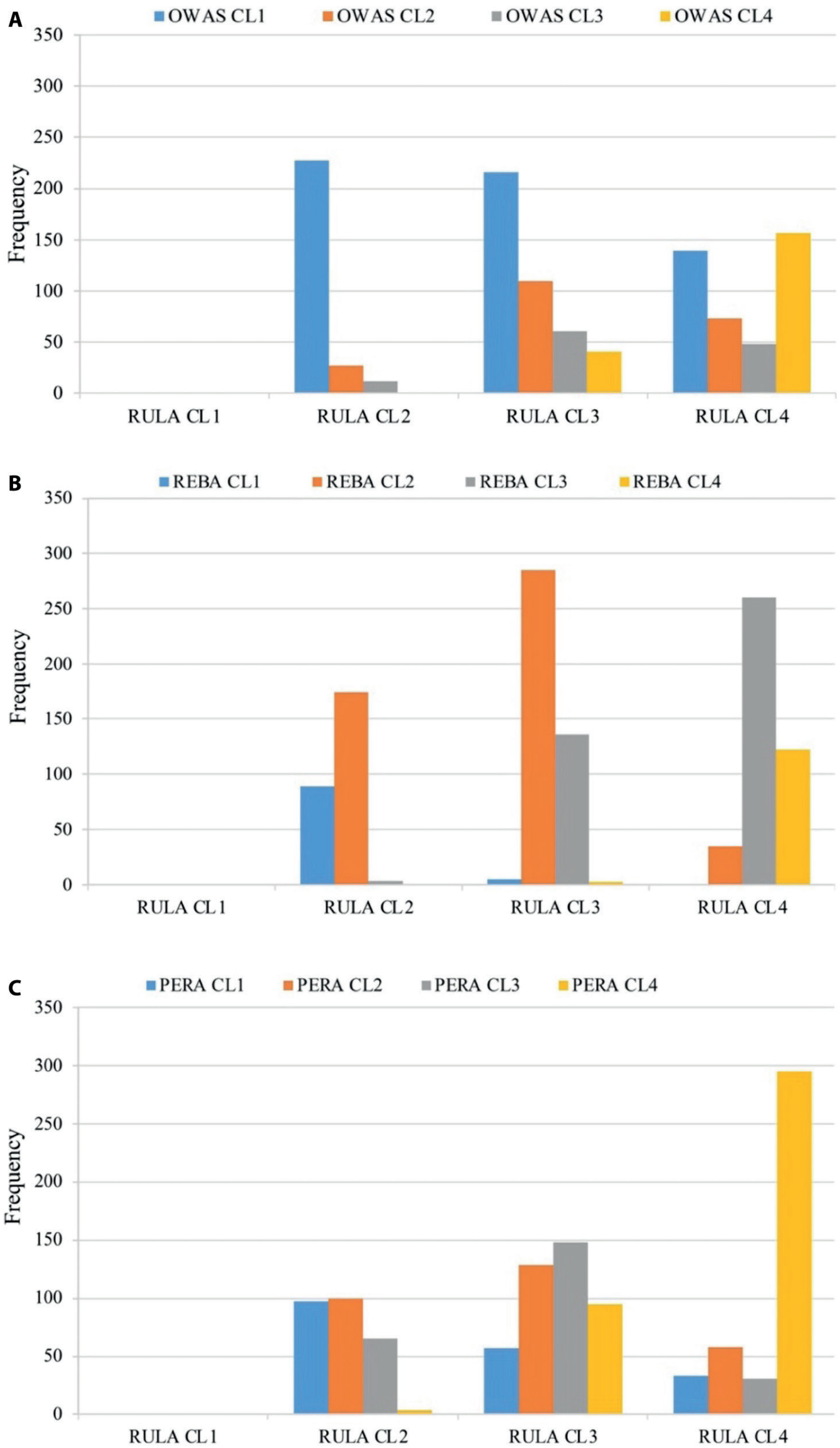

Figure 3. Frequency distribution of risk level (a) RULA vs OWAS (b) RULA vs REBA (c) RULA vs PERA

Table 1. Risk level differences and percentages (in brackets) between pairs of assessment methods.

Pair	0 level risk	1 level risk	2 level risk	3 level risk
RULA vs OWAS	245 (22.05)	438 (39.42)	289 (26.01)	139 (12.52)
RULA vs REBA	432 (38.88)	639 (57.52)	40 (3.6)	0 (0)
RULA vs PERA	543 (48.88)	416 (37.44)	119 (10.71)	33 (2.97)
REBA vs OWAS	355 (31.95)	582 (52.39)	148 (13.32)	26 (2.34)
PERA vs REBA	379 (34.11)	622 (55.99)	94 (8.46)	16 (1.44)
PERA vs OWAS	334 (30.06)	343 (30.88)	265 (23.85)	169 (15.21)

PERA. Table 1 presents the risk level differences: 343 postures had a one-level difference, 265 had a two-level difference, and 169 had a three-level difference. Statistical tests confirm that the OWAS method tends to underestimate; PERA scores for postural load are significantly higher than OWAS scores ($p < 0.01$), as per the Wilcoxon signed-rank test.

The results of the postural assessments revealed significant differences in the scores assigned by each method. The RULA method consistently indicated higher postural load scores than OWAS, REBA, and PERA. This can be attributed to its detailed focus on upper limb postures, which are heavily involved in rubber tapping [40]. In contrast, methods like OWAS and REBA take a more holistic approach by considering overall postural loads. OWAS effectively categorized overall postures during activities involving full-body movements. REBA included additional risk factors, such as trunk flexion and leg postures, providing a more balanced evaluation of tasks that involve bending and sustained positions.

PERA, originally developed for industrial environments, offered a unique perspective by evaluating cumulative ergonomic loads across the tapping work cycle. This approach highlighted the cyclical nature of rubber tapping tasks, particularly for repetitive actions like “Incision on the Channel”. While PERA does not emphasize individual postures as heavily as other methods, its ability to assess cumulative fatigue and exertion provided valuable insights into the long-term ergonomic implications for rubber tappers.

These findings underscore the importance of aligning ergonomic assessment methods with the specific demands of the work being analyzed. Tasks involving significant upper-limb engagement may be best assessed using RULA, while OWAS and REBA are more appropriate for evaluating whole-body postural demands. Similarly, PERA’s cumulative approach complements these methods by addressing repetitive strain and long-term workload in dynamic tasks.

3.5. Postural Criticalities and Method Application

In assessing ergonomic risks among rubber tappers, it is crucial to understand the specific postural criticalities that each method best captures and their respective scopes of application. Each method—OWAS, RULA, REBA, and PERA—has distinct strengths that make it particularly suitable for highlighting different aspects of postural risk in rubber tapping tasks.

OWAS effectively provides a broad overview of general postural risks associated with the back, arms, and legs. This method emphasizes static postural assessments without considering the duration or specific force exerted. OWAS is particularly useful for identifying high-risk postures that might occur sporadically but still pose significant ergonomic risks. Its application is well-suited for various segments of the workforce, providing a snapshot of postural strain across multiple body regions.

RULA is highly sensitive to upper limb activities, including the neck, trunk, and arms. This method is particularly effective at identifying risks associated with repetitive and intricate hand and arm movements, which are common in rubber tapping tasks. RULA’s detailed focus on the upper limbs makes it suitable for tasks requiring fine motor skills and precision, such as making incisions on rubber trees. This method captures the nuances of upper limb postural strain that may be overlooked by more generalized assessments.

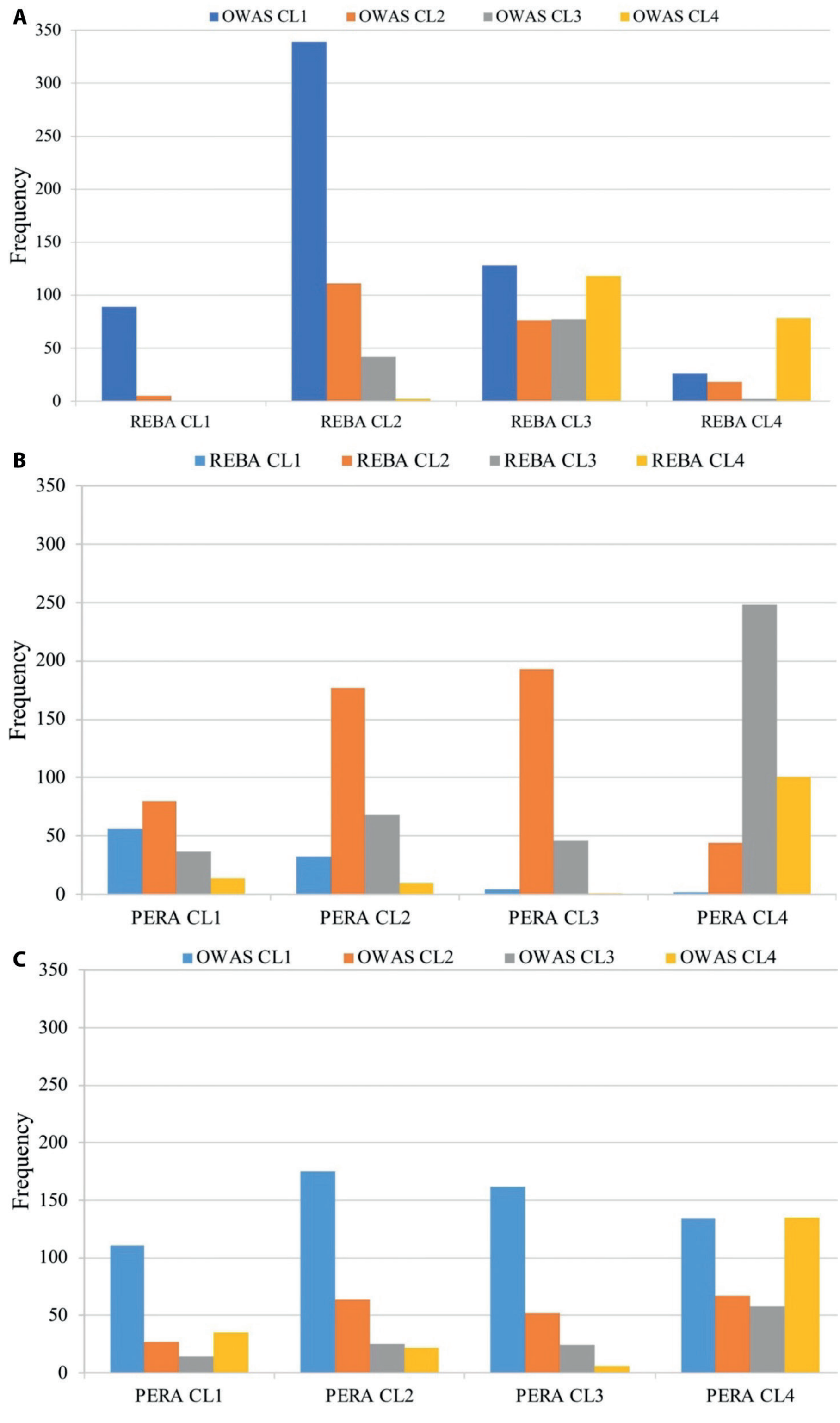

Figure 4. Frequency distribution of risk level: (a) REBA vs OWAS (b) PERA vs REBA (c) PERA vs OWAS.

REBA offers a thorough assessment of whole-body postures, taking into account factors such as postural angles, forceful exertions, and the nature of movements. This method captures the complete range of postures adopted during rubber tapping activities, making it ideal for tasks that require significant physical effort and varied body movements. REBA's capability to evaluate both upper and lower body postures renders it especially valuable for identifying ergonomic risks in activities that involve bending, twisting, and lifting.

PERA evaluates postural risks throughout the entire work cycle by considering posture, duration, and force. This method is particularly effective for assessing repetitive and cyclic tasks, providing a detailed analysis of high-risk activities over time. PERA's ability to account for the cumulative effects of duration and force makes it highly relevant to the continuous and repetitive nature of rubber tapping. This approach offers a comprehensive understanding of the long-term ergonomic risks associated with sustained and repetitive postural strain.

The application of these methods revealed significant variability in risk identification. RULA, focusing on upper limb activity, identified higher risk levels for postures involving precise and repetitive movements, such as those seen during the "incision" subtask. Conversely, OWAS and REBA provided broader risk assessments across the entire body, identifying trunk flexion and awkward leg postures as critical risk factors. PERA highlighted cumulative risks associated with repetitive tasks and prolonged durations, emphasizing the importance of evaluating work cycles holistically.

The results of this study align with those of Pramchoo et al. [42], particularly in acknowledging that awkward wrist postures significantly contribute to ergonomic risks in rubber tapping. However, this study builds on their conclusions by offering detailed cumulative load assessments using the PERA methodology. The correlation of REBA and OWAS scores with the identified risks in upper limb and back postures further emphasizes the necessity for task-specific ergonomic tools that incorporate total body and wrist-specific risk evaluations.

4. Conclusion

The implementation of OWAS, REBA, RULA, and PERA in ergonomic risk assessment for rubber tappers provided essential insights into workplace conditions and postural constraints. Most rubber tappers were middle-aged men with extensive expertise, and many viewed rubber tapping as a secondary occupation. The subtask 'Incision on the Channel' involved the most postures, many of which were inadequate due to their repetitive nature. The upper limbs and back experienced the greatest strain. Many postures were performed "below shoulder level" indicating that workers predominantly tap at this height.

The RULA method was deemed the most suitable for assessing upper limb postures in rubber tapping, highlighting the necessity of selecting ergonomic tools aligned with specific work activities. Each technique—OWAS, RULA, REBA, and PERA—has unique strengths: OWAS provides an overview, RULA focuses on upper limbs, REBA assesses the whole body, and PERA evaluates cyclic work with posture, duration, and force.

The key limitation is the sample size of 51 rubber tappers, which could affect the understanding of ergonomic risks across diverse demographics. Moreover, the assessment methods did not consider other factors, such as equipment design, environmental conditions, or psychosocial elements. Overall, the research calls for a comprehensive approach to assessing ergonomic risks in rubber tapping. It recommends multiple assessment methods with a preference for RULA due to its focus on upper limb engagement. Tailored ergonomic interventions should consider specific work tasks and tapping levels to enhance the well-being of rubber tappers, offering valuable guidance for policymakers and plantation owners aiming to improve working conditions in the industry.

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Ergonomic Criteria and Usability Testing of Cut-Resistant Protective Gloves: An Experimental Study

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Keywords: Hand Dexterity; Protective Clothing; Anti-Cut Gloves; Usability Testing; Ergonomics

Abstract
Background: *Although hand and arm injuries can be prevented with protective gloves, their use may reduce hand dexterity and muscle strength. This study examined the ergonomic criteria and usability of four cut-resistant protective gloves (CRPGs) types to identify the optimal glove choice.* **Methods:** *In this experimental study, 22 male participants were tested under five conditions: barehanded, wearing nitrile-coated gloves, gel-coated gloves, material-coated gloves, and foam nitrile-coated gloves. Dexterity was assessed using the Bennett and O'Connor tests; grip and pinch force were measured with a dynamometer, and a goniometer assessed the range of motion. The gloves' usability was evaluated through the System Usability Scale (SUS) questionnaire. At the same time, localized discomfort in different areas of the hand was assessed using the Local Perceived Discomfort (LPD) questionnaire. Finally, glove comparisons were made using appropriate statistical tests analyzed with SPSS version 24 software.* **Results:** *All examined CRPGs significantly lowered finger dexterity scores ($p < 0.001$). However, the effects of different gloves on hand dexterity varied. Wearing all four gloves reduced grip force, but statistically significant differences in grip force were noted only between the barehanded condition and Glove B ($p = 0.004$). Using all four gloves increased pinch force, though this increase was statistically significant only between the barehanded condition and Glove D ($p = 0.005$). Wearing all gloves caused a statistically significant reduction in wrist, palm, and finger range of motion compared to the barehanded condition ($p < 0.005$). Lastly, there was a significant statistical difference between the gloves regarding usability ($p = 0.001$) and LPD ($p = 0.001$).* **Conclusions:** *CRPGs can greatly influence hand skills. Glove D, featuring a foam nitrile coating, exhibited the highest finger dexterity compared to the other gloves studied. Considering aspects like sweat resistance and anatomical design, this foam nitrile-coated glove is appropriate for cutting-resistant tasks within various industries.*

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1. Introduction

Occupational activities involving sharp objects such as knives, glass, sheet metal, and similar materials pose cuts and hand injury risks, particularly in food processing plants, plastics, textiles, metalworking, glassmaking, and other industries where these tools are utilized [1, 2]. Sharp objects, including knives and metal parts, account for approximately 30% of lost work time and 80% of hand injuries [3]. Studies indicate that hand injuries are among the most common workplace injuries and the second most frequent work-related musculoskeletal disorder [4, 5]. According to statistics provided by the U.S. Bureau of Labor Statistics, nearly 20% of all work-related injuries affect workers' hands. Annually, there are 110,000 cases of time lost due to hand injuries, and 1 million workers seek treatment in emergency rooms due to hand injuries [6].

Human hands have unique physical and sensory capabilities that enable a wide range of delicate and rapid movements, high gripping forces, and repetitive motions with great precision [7]. Therefore, protecting hands in the workplace from mechanical, thermal, radiation, chemical, bloodborne pathogen transmission, electrical, and vibration hazards is crucial for reducing various hand injuries. Consequently, focusing on this body part and preventing injuries is imperative [8].

Personal Protective Equipment (PPE) and protective clothing serve as barriers between hazardous environments and workers' bodies, acting as critical protective measures [9]. In recent years, considerable research has focused on the role of ergonomics in designing and manufacturing protective equipment. Some studies have examined the specific considerations necessary for designing and producing protective footwear for firefighters [10, 11]. Other studies have aimed to develop tools for evaluating medical gloves [12, 13]. Among these, gloves are one of the PPE items frequently used across many professions to safeguard hands against potential hazards [9].

While wearing gloves offers protection and safety, it may also reduce gripping force, decrease skill, and diminish tactile sensitivity, leading to lower performance in manual tasks [14-16]. Manual skill refers to the motor skills involved in the arm, hand, and the range of motion available for the fingers during manual tasks [17]. Factors affecting manual skill include movement restrictions, reduced ability to bend fingers, weak contact between the hand and the target object due to glove thickness or poor fit, and inappropriate gloves [17, 18]. Previous studies have reported that wearing gloves decreases manual dexterity [19]. Other studies have shown a significant correlation between glove type and manual skill [20].

Among the gloves commonly used in various industries based on the type and nature of work, CRPGs stand out. CRPGs are a category of protective equipment designed to shield individuals from potential injuries. All workers handling sharp objects and tools require these types of gloves. However, some employees believe that using protective gloves can hinder their control over hand tools and affect their task performance, possibly increasing the risk of personal injury [21, 22]. As a result, some individuals prefer to avoid wearing gloves when faced with the risk of hand injury, leading to reduced control over tools and diminished task mastery [23]. Recent studies have also indicated that gloves with poor ergonomic features may raise workplace accident rates due to decreased precision, comfort, tactility, gripping force, and skill [9, 14]. Nevertheless, using thin gloves of the correct size, which have good muscle force to grip conversion capabilities, and ensuring proper sizing can significantly enhance worker protection while simultaneously increasing productivity and reducing upper limb muscle fatigue, thereby preventing potential injuries [24, 25]. Therefore, utilizing CRPGs with appropriate ergonomic features is an effective and cost-efficient safety measure [26].

Given the extensive use of hands and the importance of hand protection for daily tasks, addressing the potential hazards posed by non-ergonomic CRPGs is essential, making the proper selection of this protective equipment crucial to prevent possible injuries [27]. To date, numerous studies have investigated optimal glove selection for professions such as firefighting, healthcare, and other occupations. However, research specifically focusing on CRPGs from the standpoint of ergonomic and usability criteria remains relatively limited. Thus, the current study was designed and conducted to explore the ergonomic and usability requirements of CRPGs.

2. Methods

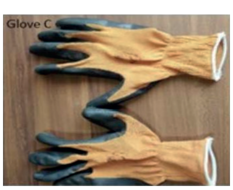
2.1. Participants

This experimental study involved 22 male volunteers. All participants were male, as men typically perform heavy-duty activities that require the use of CRPGs in Iran. The sample size was calculated using an effect size of 0.63 based on the study by Irzmanska et al. (2016) [19] with G*Power software. The inclusion criteria were as follows: an age range of 20 to 40 years, good health, right-handedness, no musculoskeletal disorders in the hand area, no prior experience with CRPGs to eliminate the experience effect, and individuals with average hand size according to the EN420 standard to eliminate the impact of anthropometric dimensions. Participants' health and absence of musculoskeletal disorders in the hand area were self-reported. Additionally, individuals with a hand circumference of 203-209 mm and a hand length of 182-192 mm, corresponding to the size eight standard according to EN420, were selected as having average hand size [28]. Participants were tested under two conditions, with and without gloves, based on objective and subjective criteria, and the results were compared. This study received approval from the Ethics Committee of Isfahan University of Medical Sciences (Ethics code: IR.MUI.RESEARCH.REC.1401.268). All volunteers read and signed an informed consent form to participate in the study and could withdraw anytime.

2.2. Cut-Resistant Protective Gloves

In this study, four samples of commonly used CRPGs in Iran, including gloves with materials like palm-cut-resistant, nitrile-coated, foam-nitrile-coated, and gel gloves in medium size typically used in various industries, were selected based on input from sellers and experts in this field. The picture and characteristics of these gloves are presented in Table 1.

Table 1. Characteristics of CRPGs used in the study.

Glove	Picture	Main materials	Special characteristic	Application
Glove A		high density polyester covered by nitrile	Resistant to oil, grease, solvent and combustible materials, it has grooved texture for better grip	assembly work, oil and petrochemical industries, home appliance production, printing and packaging, transportation
Glove B		Polyester and polyvinyl chloride	—	Construction, service works, gardening, agriculture and transportation
Glove C		Polyester, latex in the fingers and palm regions	high grip even for smooth and polished work tools	Can be used for working with construction materials, concrete, bricks, metalworking, machinery, storage, automotive industry, transportation
Glove D		Polyester, nitrile foam in the fingers and palm regions	With breathable fibers	Automotive industry, maintenance, oil and gas industries, facilities, production industries, assembly work, storage, transportation

2.3. Study Procedure

Initially, all participants received detailed explanations regarding the experimental procedures and objectives. Subsequently, the examiner provided practical demonstrations on how to perform the tests. Participants were informed of their right to withdraw from the study at any experiment stage. Each participant required approximately 2.5 hours to complete all test procedures. The dexterity tests were arranged on one table, while the dynamometer and goniometer were set up on another. Each participant initially performed the tests with bare hands and subsequently with each of the four aforementioned gloves. A rest period of 3 to 4 minutes was allocated between tests. Subjective assessments were conducted immediately following the completion of each test. All experiments were conducted between 8:00 AM and 3:30 PM in a laboratory with normal ambient temperature and relative humidity conditions. Participants were seated on adjustable chairs during the tasks, with the flexibility to adjust the chair height for optimal manipulation of objects on the table. The tests performed in this study were:

- Whole hand dexterity test;
- Finger dexterity test;
- Grip force test;
- Pinch force test;
- Range of motion measurement;
- LPD measurement;
- Usability evaluation.

2.3.1. Dexterity Tests

2.3.1.1 Whole Hand Dexterity Test

Whole-hand dexterity refers to manipulating relatively large objects [29]. The Bennett test assesses whole-hand dexterity while utilizing standard mechanical and assembly tools, including gloves. This test involves assembling three different sizes of bolt, nut, and washer combinations onto a vertical wooden board [30]. Each participant was seated in an adjustable chair facing the workbench where the wooden board was positioned. Participants adjusted their seat height to achieve a comfortable working posture. The test included the following steps:

- Loosening bolts using a wrench;
- Unscrewing and completely removing bolts and washers by hand;
- Placing bolts and washers back into the holes;
- Firmly fastening bolts using a wrench.

The process of loosening and unscrewing bolts and washers began at the top row of holes on the left, while the fastening process started at the bottom row of holes on the right. The time taken to complete these four steps demonstrated dexterity [31].

2.3.1.2. Finger Dexterity Test

Tests for finger dexterity are often employed to evaluate performance changes connected to wearing gloves. The O'Connor Finger Dexterity test has proven effective in predicting the rapid manipulation of small objects, particularly in assembly line tasks. This test consists of a plate with multiple holes, where participants must use their fingers to insert three pins into each hole. Dexterity in the O'Connor test is assessed based on the time taken to place three pins into a single hole [32].

2.3.2. Hand Power Tests

2.3.2.1. Grip Force Test

Hand grip entails holding objects with the thumb, fingers, and palm [33]. This study assessed hand grip strength using the standardized test position endorsed by the American Society of Hand Therapists, employing the Saehan hydraulic hand dynamometer. As per the protocol, participants were seated in a height-adjustable chair with their feet flat on the ground. Their shoulders rested in a neutral position without elbow support, and their elbows were maintained at a 90-degree angle. Participants executed the maximum voluntary contraction three times, and the highest recorded score was noted as their hand grip force [34].

2.3.2.2. Pinch Force Test

Pinch grip involves using one or more fingers to manipulate objects and thumb movements without engaging the palm. The strength of the pinch grip was assessed according to the American Society of Hand Therapists protocol [33] and with the Saehan Hydraulic Pinch Gauge. Similar to the grip force test, participants sat in a height-adjustable chair with their feet flat on the ground, shoulders relaxed, and elbows bent at a 90-degree angle. They exerted maximum voluntary contraction three times, and the highest score recorded was considered their pinch grip force [35].

2.3.3. Hand Range of Motion Measurement

A goniometer was used to assess the range of motion of various hand joints [36]. Precisely, the range of motion of the metacarpophalangeal joints in the fingers, the thumb, and wrist flexion was measured under different conditions: bare hand and while wearing gloves A through D. The results from these measurements were then compared to analyze how wearing different gloves impacts hand joint flexibility and mobility.

2.3.4. Subjective Evaluation

2.3.4.1. Usability Evaluation

Usability, defined as the suitability of an artifact for a specific purpose, was assessed using the SUS questionnaire. The SUS is a ten-item scale that offers a comprehensive view of subjective usability evaluations. Respondents were asked to answer each question right after reading it without overthinking their answers. Each item's score ranged from 0 to 4. One point was deducted from all odd-numbered questions and five points from all even-numbered questions to compute the final score. We then combined the results of the even and odd questions and multiplied by 2.5. The final score ranged from 0 (very poor usability) to 100 (very high usability) [37]. The validity of the SUS questionnaire in evaluating usability has been supported by studies conducted by John Brooke (1996) [37] and Bangor et al. (2008) [38].

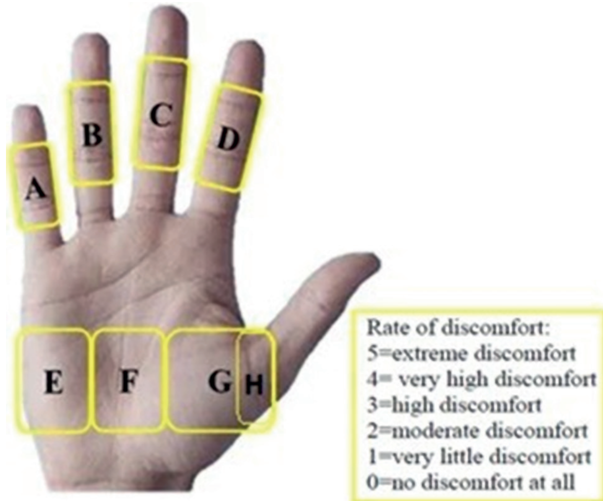


Figure 1. Local perceived Discomfort (LPD) scale.

2.3.4.2 Local Perceived Discomfort Measurement

The LPD questionnaire, a quantitative scale, was employed to evaluate local discomfort. After completing the tests, respondents were asked to report any discomfort experienced in specific areas shown in Figure 1, using a 5-point scale ranging from 0 (no problem) to 5 (extremely uncomfortable) [39]. Previous studies have established the validity and reliability of the LPD scale, with a Cronbach's alpha coefficient of 0.92 indicating high reliability [40].

2.4. Statistical Analyses

Statistical analysis was conducted using SPSS version 24 statistical software. The following steps were taken:

- Normality Assessment: The Shapiro-Wilk test was used to assess the data normality.

Comparison of Quantitative Variables:

- The ANOVA test with rank transform procedure was employed to compare the means of

- quantitative variables among the four gloves studied (A, B, C, D).
- Pairwise comparisons among the variables were performed using the Post hoc Bonferroni test.

Comparison of Specific Measures:

The Wilcoxon signed-rank test (2-related sample test) was used to compare the following measures between the use of gloves (A, B, C, D) and bare hands:

- Whole hand dexterity;
- Finger dexterity;
- Grip force;
- Pinch force;
- Range of motion.

Statistical Significance:

- A confidence level of 95% (α=0.05) was considered for all statistical tests to determine the significance of the findings.

These statistical methods were used to analyze the data and evaluate differences in performance and usability among the various glove types and between gloved and bare-hand conditions.

3. Results

All participants were male. The average age of participants was 23.05 ± 3.44 years (range = 20-36), and the average body mass index (BMI) was 22.88 ± 3.79 (range = 15.57-28.63). The descriptive and comparative results of hand power tests, hand dexterity tests, and wrist, forearm, and finger range of motion during the use of various gloves and with bare hands are presented in Table 2.

Measurements of overall hand dexterity indicated that the highest dexterity was observed with glove D, while glove A showed the lowest. Gloves C and D led to a shorter completion time for the Bennett test than bare hands, and their use enhanced overall hand dexterity. In contrast, gloves A and B decreased overall hand dexterity concerning the bare-hand condition. However, this difference was statistically significant only with glove D compared to the bare-hand condition. No statistically significant difference was noted in mean overall hand dexterity when using gloves A, B, and C compared to the bare-hand condition (p-value > 0.05).

The highest level of finger dexterity was observed in the bare-hand condition. In contrast, the lowest level of finger dexterity was recorded with glove A. Pairwise comparisons of mean finger dexterity for each glove, compared to the bare-hand condition, showed that all gloves led to a statistically significant decrease in finger dexterity concerning the bare-hand condition.

The highest grip force was recorded in the bare-hand condition (mean: 47.105 kg). The use of any of the four types of gloves resulted in a reduction in grip force. Glove A had the highest mean grip force (mean: 45.69 kg), while glove B showed the lowest (mean: 43.8 kg). Statistical analysis revealed that grip force varied significantly only between the bare-hand condition and glove B. No statistically significant difference in grip force was found between the bare-hand condition and gloves A, C, and D.

The measurements of pinch force indicated that the highest pinch force was associated with glove D (mean: 12.03 kg), while the lowest was observed in the bare-hand condition (mean: 11.06 kg). The results demonstrated that using any gloves increased pinch force compared to the bare-hand condition. Statistical analysis revealed a significant difference in pinch force only between the bare-hand condition and glove D. No statistically significant differences were found when comparing the bare-hand condition with gloves A, B, and C. All four types of gloves reduced the range of motion in the wrist, forearm, and finger joints. Glove C was associated with the lowest range of motion in the wrist, while glove D had the highest. The lowest range of motion in the forearm was noted with glove B, and the highest was observed with glove D. For the fingers, glove D was linked to the lowest range of motion, whereas glove A reflected the highest. Statistical analysis indicated significant wrist, forearm, and finger joint range of motion variations between all gloves and the bare-hand condition.

Table 3 presents the comparative results of overall hand dexterity, finger dexterity, grip strength, pinch

Table 2. The results of dexterity tests, hands power tests, and range of motion of wrists, thumbs, and fingers.

	Bare hand		Glove A			Glove B			Glove C			Glove D		
	Mean	**SD**	**Mean**	**SD**	**p**	**Mean**	**SD**	**p**	**Mean**	**SD**	**p**	**Mean**	**SD**	**p**
Grip force (kg)	47.1	8.2	45.7	8.1	0.204	43.8	7.8	0.004	45.5	7.6	0.100	45.3	8.6	0.113
Pinch force (Kg)	11.1	3.0	11.7	3.6	0.119	11.5	3.3	0.154	11.7	3.7	0.144	12.0	3.4	0.005
Finger dexterity (s)	134.3	36.3	178.8	71.5	<0.001	172.5	6.3	<0.001	174.7	57.8	0.001	163.7	48.3	<0.001
Hand dexterity (s)	472.9	113.9	492.1	169.8	0.661	475.9	139.7	0.910	449.5	137.2	0.055	426.7	116.5	0.024
Wrist range motion	81.0	6.7	78.1	7.5	0.002	77.8	7.0	0.002	76.7	7.5	0.001	78.6	6.3	0.005
Thumb range motion	70.3	12.4	65.2	14.0	<0.001	64.4	13.8	<0.001	65.3	14.1	<0.001	65.4	14.5	<0.001
Fingers range motion	118.5	7.2	113.5	7.6	<0.001	108.6	7.2	<0.001	112.1	7.3	<0.001	107.7	9.6	<0.001

**Wilcoxon 2-related sample test wit barehand.*

Table 3. Comparative results of dexterity tests, hand power tests, and range of motion of wrists, thumbs, and fingers between the studied gloves.

		SS	DF	MS	F	p value
Grip force	Between groups	121.8	4	30.5	0.470	0.76
	Within groups	6806.1	105	64.8		
Pinch force	Between groups	10.9	4	2.7	0.236	0.92
	Within groups	1215.5	105	11.6		
Finger dexterity	Between groups	2680.6	3	893.5	0.248	0.86
	Within groups	302762.9	84	3604.3		
Whole hand dexterity within groups	Between groups	67663.1	3	22554.4	1.090	0.36
	Within groups	1737666.8	84	20686.5		
Range motion of the wrist	Between groups	40.9	3	13.6	0.271	0.85
	Within groups	4231.0	84	50.4		
Range motion of the thumb	Between groups	13.4	3	4.5	0.022	0.99
	Within groups	16695.0	84	198.8		
Range motion of the fingers	Between groups	520.2	3	173.4	2.724	0.051
	Within groups	5347.8	84	63.7		

Table 4. The results of examining subjective criteria at CRPGs.

	Glove A			Glove B			Glove C			Glove D		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
SUS	69.9	16.2	42.5-92.5	55.0	20.8	20.0-97.5	77.2	15.0	30.0-100	73.8	18.8	27.5-100
LPD	0.5	0.5	0-1.6	1.0	0.8	0-3.0	0.4	0.3	0-1.0	0.4	0.4	0-1.25

strength, and the range of motion for the wrist, forearm, and finger joints among the analyzed gloves. Statistical analysis using One-Way ANOVA indicated no statistically significant differences among the gloves concerning grip strength, pinch strength, finger dexterity, hand dexterity, wrist range of motion, thumb range of motion, and the range of motion for four fingers.

Table 4 shows the descriptive results of subjective measures, including usability assessments and localized discomfort, from the SUS and LPD questionnaires on CRPGs.

The findings reveal that glove C received the highest usability score of 77.16, while glove B had the lowest score of 55. Glove B also reported the highest LPD score, averaging 0.954, whereas glove C recorded the lowest LPD score, averaging 0.352. Statistical analysis using One-Way ANOVA indicated a significant difference between the various gloves regarding usability and LPD.

A post hoc Bonferroni test analyzed the statistical differences between pairs of glove groups in usability and LPD. Significant differences in usability were found between gloves A and B, gloves B and C, and gloves B and D. Additionally, significant differences in LPD were found between gloves A and B, gloves B and C, and gloves B and D. These findings emphasize specific pairwise differences in usability and LPD.

4. Discussion

This study aimed to achieve several objectives. Four well-known CRPGs, commonly employed in major industries, were analyzed and compared using objective and subjective criteria. The different gloves produced varying effects on several manual dexterity tests.

According to the results, all four types of gloves led to a significant decrease in finger dexterity, which is consistent with the findings of Irzeminska et al. (2017) and Ghasemi et al. (2021) [20, 29]. Berger et al. (2009) [32] also reached similar conclusions in their study. The results of finger dexterity assessments indicated that gloves D, B, C, and A had the least negative impact on finger dexterity, respectively. Gloves A and B specifically reduced overall hand dexterity, aligning with Ghasemi et al.'s findings (2021) [29]. However, contrary to expectations, gloves C and D positively affected overall hand dexterity, inconsistent with Ghasemi et al.'s findings (2021) [29]. Glove C is made from polyester with a latex coating, providing enhanced friction and performance for the user. Similarly, glove D possesses an appropriate coefficient of friction. Participant feedback also supported this observation.

Furthermore, based on these gloves' catalogs and technical specifications, glove C is characterized by slip resistance and high flexibility. In contrast, glove D is known for its comfort and ergonomic design to prevent fatigue, comprising breathable and sweat-resistant fibers. These factors enable participants to control tools easily while wearing these gloves without experiencing sweating, slipping, pain, or fatigue. This contrasted with conditions without gloves, where some participants encountered sweating in their palms and fingers, which led to the French wrench slipping and longer test completion times.

The evaluation of pinch and grip force was conducted according to the standardized testing protocol approved by the American Society of Hand Therapists, utilizing the Saehan Hydraulic Hand Dynamometer. Grip force varied depending on the type of glove worn and the specific test administered. All glove types resulted in a reduction in grip force, consistent with findings from studies by Wimer et al. (2010) [22], Ramadan et al. (2017) [15], Annie Yu et al. (2022) [23], and Ghasemi et al. (2021) [29]. In that order, gloves A, C, D, and B had the least negative impact on grip force. The results indicated that wearing gloves increased pinch force, which aligns with Annie Yu et al.'s findings (2022) [23]. According to participant feedback, this effect could be attributed to increased friction between the glove and the dynamometer, resulting in improved grip performance and control over the dynamometer. Glove D had the most positive effect on pinch force, while glove B exhibited the least positive effect.

The SUS questionnaire was employed to assess usability. This questionnaire is a reliable and cost-effective scale that can be used globally to evaluate the usability of various systems [37]. Based on the results of the subjective tests, gloves C and D achieved the highest usability scores, while gloves B garnered the lowest. Correspondingly, the level of LPD caused by the gloves was lowest with gloves C and D and highest with gloves B. As observed, gloves C and D induced less discomfort and consequently demonstrated better usability for the participants. Furthermore, they did not negatively impact overall hand dexterity.

This study had certain limitations that need to be acknowledged. We examined four types of gloves with varying materials and thicknesses. The material of the gloves determines characteristics such as surface friction, hardness, and flexibility [41, 42]. Due to time constraints, we could not evaluate these parameters, including glove thickness, in this study. Additionally, the usage scenarios for the gloves studied were diverse. It is recommended that future studies employ gloves with consistent usage scenarios to ensure comparability and reliability in findings. In this study, only 22 men participated. The small sample size may reduce the generalizability of the data. Larger sample sizes and a more diverse participant pool would provide more robust data and improve the generalizability of the results. One of the strengths of this study is the concurrent investigation of different manual skills alongside the usability of various gloves. Furthermore, given that learning effects are a common challenge in such studies, we attempted to mitigate this issue by randomizing the sequence of experiments. This approach aimed to minimize potential biases associated with the order of tasks and the learning curve [43].

Designers and manufacturers of CRPGs primarily focus on safety issues to enhance usability and manual skills. Therefore, it is recommended that ergonomic considerations be more integrated into new designs. Manufacturers should avoid producing gloves with unnecessary thickness. Indeed, a balance between safety and individual performance should always be maintained. In this regard, the use of developed nano-materials that provide a high level of protection with minimal thickness is recommended [44]. The current study's findings will assist product designers in cultivating ergonomic protective gloves that meet the needs of workers.

5. Conclusion

CRPGs can have an impact on manual skills. In this study, using CRPGs resulted in decreased hand dexterity, range of motion, and grip force but had no adverse effect on pinch force. The best performance during hand and finger force tests was associated with gloves A and D, respectively. Hand and finger dexterity was best in glove D. Cognitive tests also indicated that gloves C and D exhibited the best usability and least LPD among individuals. Consequently, glove A, made of polyester and nitrile material for power activities, showed better performance and had the least interference in the motion of four fingers. However, due to its low usability and LPD in the hand, its use is not recommended.

In contrast, glove D with nitrile foam coating exhibited the best finger dexterity compared to other gloves studied. This glove had the least negative impact on wrist and hand motion range. Additionally, it increased hand dexterity and pinch force without negatively affecting these skills while wearing and strengthening them. Subjective tests also indicated the high usability of this glove, with the least LPD among individuals. Considering this glove's descriptions and features, such as its sweat-resistant properties and anatomical design, it can be suitable for performing cut-resistant activities in the industry. This is because attention has been paid not only to safety but also to its ergonomic characteristics.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved as a research project by the research ethics committees of Isfahan University of Medical Sciences under the ethics code IR.MUI.RESEARCH.REC.1401.268. All participants filled out and signed the informed consent forms. The researchers only had access to unidentified data.

Informed Consent Statement: Written consent forms were prepared and provided to the participants before the study. All participants completed and signed the informed consent forms.

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Occupational Rhizarthrosis Treated Surgically: Effects on Work Performance

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Keywords: Osteoarthritis of the Trapeziometacarpal Joint; Rhizarthrosis; Occupational Medicine; Occupational Hazards; Eaton and Littler Scale; Surgical Treatment

Abstract

Background: *Osteoarthritis of the trapeziometacarpal joint (rhizarthrosis) is one of the most frequent causes of hand dysfunction. Its significant impact on daily activities and work tasks is evident. This clinical condition is more commonly associated with older age, predominantly affects females, and is often linked to repetitive movements and heavy manual labor. Therefore, it is crucial to focus on the prevention and early intervention of this pathology to minimize its impact not only on worker's health but also on their professional performance. This article aims to critically examine the association between rhizarthrosis, namely the pain with these conditions and its influence on work capacity.* **Methods:** *An epidemiological survey was conducted on active workers diagnosed with symptomatic rhizarthrosis who underwent surgical treatment. Data collected included gender, age, dominant hand, labor intensity scale, radiological classification of rhizarthrosis, patient-reported pain classification, and work capacity before and after surgical intervention.* **Results:** *In this study, there was a higher prevalence among females and older individuals. More advanced radiological classifications of rhizarthrosis did not correlate with more advanced pain classifications; however, statistically significant differences were found in higher work disability. Jobs requiring higher labor intensity and greater hand use were significantly associated with higher pain levels, increased work disability, and elevated radiological classifications of rhizarthrosis according to the Eaton and Littler scale.* **Conclusions:** *Patients with rhizarthrosis surgically treated showed a statistically significant reduction in reported pain on the analog scale, as well as greater work capacity after surgical intervention, thus contributing to better professional performance.*

1. Introduction

Trapeziometacarpal joint osteoarthritis, commonly known as rhizarthrosis, is one of the most prevalent, painful, and disabling forms of hand osteoarthritis [1-6]. However, not all patients seek medical care for diagnosis and treatment, especially in the milder forms of the disease [2, 7]. Studies indicate that the symptoms experienced by patients and limitations in joint movement of the hand do not directly correlate with the radiographic severity observed. Therefore, clinical evaluation and objective examination are crucial for monitoring and treating this pathology [2, 8-10].

In the current occupational context, rhizarthrosis has emerged as a significant concern. It is frequently

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associated with aging, repetitive movements, heavy manual labor, and inadequate postures during professional activities [3, 11, 12]. This condition can lead to a loss of hand functionality and substantial worker discomfort, thereby compromising their work capacity and increasing costs related to reduced productivity [3, 12-14].

Given the rising ergonomic, biomechanical, and psychosocial demands in today's workplaces, it is imperative to understand the potential consequences of rhizarthrosis in occupational settings [3, 15]. The existing literature emphasizes the importance of prevention and early intervention to mitigate the impact of this condition, aiming not only on the worker's health but also at the effectiveness and efficiency within the work environment [1, 11, 12, 14, 15].

Treatment begins with conservative approaches, including temporary rest or immobilization of the affected thumb using orthoses, therapy with non-steroidal anti-inflammatory drugs (NSAIDs) or intra-articular corticosteroid injections, strengthening and range-of-motion exercises, patient education on symptom control techniques, provision of a home exercise program, and physical or occupational rehabilitation [1, 4, 14, 16-19]. Conservative treatment is described in the literature as a practical first-line approach for thumb basal joint arthritis, demonstrating significant improvements in pain reduction, increased strength, and pinch capacity without notable differences compared to pharmacological therapy or joint immobilization with orthoses [14, 16, 18]. Physical rehabilitation, including physiotherapy, has also proven effective in treating this condition, either as a standalone therapy or as an adjunct to pharmacological or more invasive treatments [14, 18]. The application of unilateral passive accessory mobilization targeting the symptomatic thumb carpometacarpal joint induced an increase in pressure pain thresholds, though with limited clinical value [20]. Another option described in the literature is the neurodynamic mobilization of the median nerve in patients with secondary thumb carpometacarpal osteoarthritis, which has shown decreased pain and increased grip strength in the affected thumb [21].

In cases resistant to these methods, surgical intervention should be considered. Surgical options include techniques such as arthrodesis, trapeziometacarpal joint arthroplasty with or without implants, trapeziectomy with or without tendon interposition, or stabilization ligamentoplasty [1, 4, 14, 22].

The efficacy of surgical intervention for trapeziometacarpal joint osteoarthritis is well-documented in various literature reviews, providing significant evidence of its impact on pain reduction and long-term functional capacity improvement [1, 4, 5, 9, 23].

In summary, understanding rhizarthrosis within the occupational context is essential not only for the physical health and well-being of patients but also for optimizing professional performance and fostering healthier and more productive work environments [12, 15].

This article aims to advance knowledge in this area and promote more effective practices in managing this clinical condition. The study will consider demographic factors such as sex and age, along with preoperative determinants, including the disease's radiographic stage, the patient's dominant hand, the intensity of hand use in their occupation, reported pain levels, and work capacity. Additionally, the study evaluates postoperative determinants, specifically the degree of pain relief and improvement in work capacity, aiming to implement effective strategies for prevention and intervention in this clinical condition. Thus, we intend to determine whether the surgical intervention is beneficial for recovering the patient's functionality, particularly regarding work capacity.

2. Methods

2.1. Sample Description

This study is a prospective, cross-sectional observational study with intervention, conducted through the epidemiological survey of active workers diagnosed with rhizarthrosis who, after the failure of conservative treatment, underwent surgical treatment at a Portuguese tertiary hospital from January 1, 2017, to December 31, 2022. The following inclusion criteria were also considered: a primary diagnosis of rhizarthrosis; patients who underwent surgery after failure of conservative treatment; at least 15 years of continuous work activity before surgery and 6 months of work activity to assess the degree of recovery.

Additionally, the following exclusion criteria were applied: patients who were retired at the time of surgical intervention; workers with fewer than 15 years of continuous employment prior to the surgical intervention; patients with secondary causes of rhizarthrosis, such as rheumatoid arthritis or trauma; and patients with other comorbidities affecting the joints, like systemic arthritis or hyperuricemia.

2.2. Variables

This analysis considers demographic factors such as sex and age. Additionally, it evaluates preoperative determinants, including the radiographic stage of the disease, the patient's dominant hand, the intensity of hand use in their profession, reported pain levels, and work capacity. The postoperative determinants analyzed include the degree of pain recovery and the improvement in work capacity.

2.3. Data Collection

Data were extracted from the clinical database records maintained by the Orthopedics Service of the institution under study and outlined in the flowchart (Figure 1), following ethics committee approval and informed patient consent. Participant anonymity was ensured.

The following data were collected: age and sex of the affected patients, date of intervention, professional category, workplace, and hand radiographs

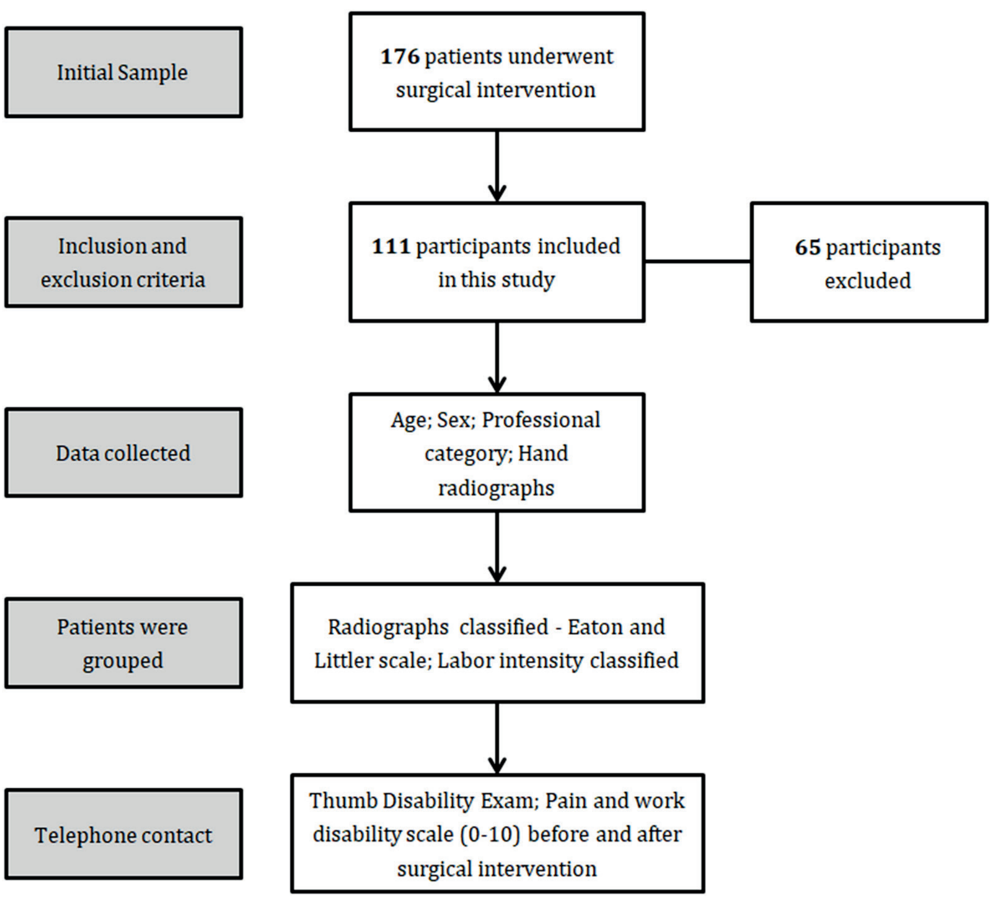

Figure 1. The flowchart represents the data collection scheme, patient selection, and subsequent analysis steps.

with a rhizarthrosis diagnosis classified according to the Eaton and Littler scale [24]. This classification describes four stages of osteoarthritis based on an X-ray of the trapeziometacarpal joint of the thumb, considering joint space narrowing, joint destruction, and the presence and size of osteophytes. Patients were subsequently grouped according to their profession on an analog scale (1-3) of labor intensity regarding hand use into the following three categories: light manual work (repetitive thumb movements <10 actions/minute), moderate manual work (repetitive thumb movements 10-20 actions/minute), and heavy manual work (repetitive thumb movements>20 actions/minute), adapted from the scale for risk assessment of repetitive tasks of the upper limbs (the ART tool) [2, 25].

Through telephone contact, the Thumb Disability Exam (TDX) scale [26, 28], which has been approved and translated into Portuguese [26], was utilized to classify the pain, work capacity impairment, and quality of life reported by the patient prior to surgical intervention. This scale evaluates the activities performed by the patient through 20 questions, scored from 1 to 5, organized into three sections that respectively assess function, pain level, and satisfaction with thumb mobility before surgery [26].

To objectively measure pain levels and work disability before and after surgical intervention, a numerical scale from 0 to 10 was utilized, where 0 indicates no pain or work disability, and 10 represents the maximum possible pain or total work disability [28, 29]. The degree of pain improvement and recovery of work capacity was subsequently assessed by comparing the averages obtained from the aforementioned scales before and after surgical intervention.

2.4. Statistical Analysis

Sample characterization and statistical analysis were conducted using SPSS version 27.0 – PASW (SPSS Inc., Chicago, IL, USA), along with descriptive statistics from this program. The Kolmogorov-Smirnov test assessed whether the variables followed a normal distribution. Numerical variables exhibiting a normal distribution are described using mean ± standard deviation (SD), while those without a normal distribution are represented by the median (range of values). For the analysis of normally distributed variables, the t-test for independent samples was applied. Conversely, the Mann-Whitney U test was utilized for analyzing non-normally distributed variables. Contingency tables and Chi-square tests were performed to examine relationships between relevant variables, and Spearman's correlation test was applied to assess the relationships among variables. A p-value of <0.05 was regarded as statistically significant for all tests conducted in this study.

3. RESULTS

3.1. Demographic and Clinical Characteristics

The studied population comprised 176 patients who underwent surgical interventions for trapeziometacarpal joint osteoarthritis. After applying the inclusion and exclusion criteria, a total of 111 participants were included in this study. Detailed demographic and clinical characteristics are presented in Table 1. Among these patients, 99 were female (89.2%) and 12 were male (10.8%), with a mean age of 59.64 ± 6.58 years. It was noted that the dominant hand was affected in 92 patients (82.9%).

The average years of work experience in the study population was 24.55 ± 3.76 years. The profession most commonly impacted by the pathology was textile workers (18.0%), followed by administrative personnel (15.3%) and construction workers (12.6%).

The distribution of the radiographic stage, according to the Eaton and Littler classification, is also illustrated in Table 1, indicating that most participants were in grade IV with 52 cases (46.8%), followed by grade III with 31 cases (27.9%). Regarding the intensity of hand usage categorized by the patients' professional activities, as shown in Table 1, out of the total study population, 71 patients (64.0%) were engaged in occupations requiring heavy manual labor. Additionally, 15 patients (13.5%) participated in moderate manual labor, and 25 patients (22.5%) in light manual labor.

Table 1. Demographic and Clinical Characteristics of Patients Undergoing Surgical Treatment for Rhizarthrosis.

Variable	Study Sample (n=111)	
	No. or mean ± SD	**%**
Age (years)	59.64 ± 6.58	
Sex: *Female*	99	89.2%
Male	12	10.8%
Hand: *Dominant*	92	82.9%
Non-Dominant	19	17.1%
Years of actívity activity (years)	24.55 ± 3.76	
Work activity: *Textile workers*	20	18.0%
Administrative personnel	17	15.3%
Construction workers	14	12.6%
Automotive industry workers	10	9.0%
Footwear production workers	9	8.1%
Senior technicians	9	8.1%
Metalworker	7	6.3%
Canning industry workers	5	4.5%
Farmers	4	3.6%
Kitchen staff	4	3.6%
Cleaning staff	3	2.7%
Other activities	9	8.1%
Radiographic Classification – Eaton & Littler scale:		
Grade 1	6	5.5%
Grade 2	22	19.8%
Grade 3	31	27.9%
Grade 4	52	46.8%
Manual Work Intensity (1-3): *Light (<10 actions/min)*	25	22.5%
Moderate (10-20 actions/min)	15	13.5%
Heavy (>20 actions/min)	71	64.0%
TDX Classification (1 to 5)	4.10 ± 0.62	
Analog Pain Scale (0 to 10)	8.27 ± 1.29	
Work Disability (0 to 10)	8.23 ± 1.38	

3.2. Pre-Operative Determinants

Regarding the Eaton and Littler scale, radiographs classified as grade 3 or higher were associated with an older average age and a higher proportion of males, both statistically significant (p<0.001 and p=0.002, respectively). The dominance of the affected hand did not significantly influence on the more or less advanced stage of rhizarthrosis, according to the radiographic scale (p=0.813).

Moreover, higher manual work intensities (p<0.001) and greater work disability (p=0.023) were associated with Eaton and Littler scores of 3 or higher. Conversely, TDX classification (p=0.082) and analog pain scale scores (p=0.104) did not show statistically significant differences, as detailed in Table 2.

When evaluating the intensity of manual work performed by the patients, it was found that heavy manual work was predominantly associated with male patients (p=0.007), higher Eaton and Littler scores (p<0.001), higher TDX classifications (p=0.034), higher analog pain scale scores (p=0.033), and lower work capacity (p<0.001). All these differences were statistically significant, as detailed in Table 3. In contrast, age and dominant hand status were not statistically significant concerning the type of manual work intensity (p=0.356 and p=0.538, respectively).

Table 2. Clinical Characteristics and Radiographic Classification: Comparison between Eaton and Littler grades below and above 3.

Variable	Total Sample (n= 111)	Eaton and Littler Scale <3 (n=28)	Eaton and Littler Scale ≥3 (n=83)	p-value
Age (years)	59.64 ± 6.58	55.46 ± 5.48	61.05 ± 6.34	<0.001
Female (n)	99	28	71	0.002
Dominant hand (n)	92	24	68	0.813
Manual Work Intensity	2.41 ± 0.83	1.11 ± 0.32	2.86 ± 0.35	<0.001
TDX Classification	4.10 ± 0.62	3.92 ± 0.44	4.16 ± 0.66	0.082
Analog Pain Scale	8.27 ± 1.29	7.93 ± 0.86	8.39 ± 1.39	0.104
Work Disability	8.23 ± 1.38	7.71 ± 1.63	8.40 ± 1.25	0.023

Table 3. Clinical Characteristics and comparison between light or moderate and heavy manual work intensity

Variable	Total Sample (n= 111)	Light or Moderate Work Intensity (n=40)	Heavy Work Intensity (n=71)	p-value
Age (years)	59.64 ± 6.58	57.48 ± 6.36	57.86 ± 6.43	0.356
Female (n)	99	40	59	0.007
Dominant hand (n)	92	31	61	0.538
Eaton and Littler Scale	3.16 ± 0.93	2.17 ± 0.71	3.72 ± 0,45	<0.001
TDX Classification	4.10 ± 0.62	3.93 ± 0.44	4.19 ± 0.69	0.034
Analog Pain Scale	8.27 ± 1.29	7.93 ± 0.86	8.46 ± 1.44	0.033
Work Disability	8.23 ± 1.38	7.45 ± 1.65	8.66 ± 0.97	<0.001

3.3. Post-Operative Determinants

All patients in the sample initially received conservative treatment, which included pharmacological therapy. In 72 cases, rehabilitation therapy (physiotherapy) was also attempted. After the failure of conservative treatment, surgical intervention was recommended for these patients. The main surgical techniques performed on the observed patients included arthrodesis, arthroplasty, and trapeziectomy with tendon interposition, revealing no significant differences in surgical outcomes or results. Analysis of the analog pain scale before and after surgery showed a statistically significant decrease ($p<0.001$), as did work disability ($p<0.001$), with reported values being significantly lower compared to the pre-operative work disability levels. This information is detailed in Table 4.

Table 4. Work Intensity and Pain Classification: Comparison before and after surgical intervention

Variable	Pre-Surgery Classification	Post-Surgery Classification	p-value
Analog Pain Scale	8,27 ± 1,29	2,87 ± 1,75	<0.001
Work Disability	8,23 ± 1,38	2,34 ± 1,39	<0.001

It should also be noted that data were collected six months after the total return to work to assess pain recovery and work capacity, as described in the methods. Additionally, it is essential to highlight that two patients reported post-surgical complications; however, they also showed significant improvements in pain recovery scores and work capacity during data collection.

4. Discussion

Given that trapeziometacarpal osteoarthritis is one of the leading causes of functional disability in the thumb, it significantly impacts the ability to perform daily activities as well as work tasks [5, 6, 16]. In this study, a higher prevalence of female patients was observed, consistent with the literature, along with older participants, which correlated with more advanced stages of rhizarthrosis [31]. The occurrence of rhizarthrosis in the dominant hand did not demonstrate statistical significance; this could be explained by the bilateral nature of the disease in many cases, with no clear preference for one side. Moreover, many tasks are performed with both hands, contributing to the bilateral manifestation of the disease.

Higher Eaton and Littler scale classifications did not correlate with higher pain scales and TDX classification levels, which is expected and has been previously described in the literature [4]. Thus, there is no clear association between increased patient-reported pain and a more advanced stage of rhizarthrosis on the radiographic scale. This underscores the importance of quantifying pain when deciding to proceed with surgery rather than relying solely on the radiographic classification presented by the patient after conservative treatment has failed.

When evaluating the parameter of labor intensity, specifically jobs with more significant hand use—such as textile workers, construction workers, automotive industry workers, footwear production workers, and metalworkers—significant statistical differences were found. These included higher work disability and elevated Eaton and Littler classifications. Therefore, it can be concluded that the intensity and work disability experienced by the patient should also be considered when proposing surgical treatment for these workers to provide greater comfort and productivity after conservative treatment has failed.

This study also showed that older male employees typically engaged in jobs with more intense hand usage, which is expected considering that heavy manual labor, particularly among construction workers or in metallurgy, is predominantly performed by males. Moreover, it was statistically significant that changes in the dominant hand were unaffected by the worker's higher labor intensity. However, jobs with greater manual intensity were associated with higher Eaton and Littler radiological classifications, higher pain scales, TDX classifications, and increased work disability.

From these data, it can be inferred that evaluating a worker's work is significant when examining rhizarthrosis. More intense work was generally associated with a more significant impact on patient-reported pain and a stronger connection with reduced work capacity at the time of rhizarthrosis diagnosis.

Finally, it is essential to emphasize the significance of conservative treatment as the first approach for thumb basal joint arthritis, with high efficacy in improving pain, strength, and pinch capacity, as extensively described in the literature [14, 17, 18, 31]. Surgical intervention should be considered a practical approach in cases refractory to this first line of treatment. This was confirmed in the present study, highlighting the substantial improvement workers experienced in pain scores and work capacity after surgical intervention and full reintegration into the workplace. This demonstrates the therapeutic efficacy not only in reducing patient-reported pain, as described in other studies [23], but also in increasing the worker's capacity post-surgical treatment of rhizarthrosis, thereby enabling better professional performance. This is the main difference in this study article.

5. Conclusions

This study demonstrates that jobs requiring higher manual intensity are associated with greater pain and work disability in patients diagnosed with rhizarthrosis. Radiological classification did not correlate with pain but correlated with labor intensity. A key strength of the study is its emphasis on the importance of assessing work intensity as a determinant for surgical indication. This approach has proven beneficial in providing better pain control and increasing work capacity, suggesting that surgical intervention positively impacts the professional performance of workers following the failure of conservative treatment.

The main weakness and limitation of the study, considering future research, is that the evaluated cases were only those who received surgical indications during a hospital consultation after conservative treatment failed, which likely introduces a bias towards cases with greater clinical severity and more advanced radiographic stages. Therefore, it is important for future research within primary healthcare to assess the recovery of work capacity using conservative treatments and to determine which of these treatments is most effective in improving work performance, either as a standalone treatment or as an adjunct to surgery.

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Assessing Work Addiction: Validity of the Italian Version of the Work Addiction Risk Test

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Keywords: Work Addiction; WART; Scale Validation

Abstract

Background: *Work addiction is a contemporary addiction affecting 8.3% to 22% of individuals in Europe, leading to detrimental effects on relationships, work-family balance, and overall well-being. Given its prevalence and impact, standardized assessment tools are crucial for distinguishing between work addiction and healthy work engagement.* **Methods:** *This study evaluated the psychometric properties of the Italian version of the Work Addiction Risk Test (WART). A convenience sample of 700 workers from Northeastern and Southern Italy completed the Italian version of the WART along with other well-being at work and personality measures.* **Results:** *Exploratory factor analysis revealed a five-factor structure of the WART, partially overlapping with the original version. Despite some weaknesses in the factor structure, the WART demonstrated satisfactory psychometric properties, including internal consistency and associations with organizational and personality correlates of work addiction.* **Conclusions:** *The Italian version of the WART is a reliable tool for assessing work addiction risk among Italian workers. This tool can aid in identifying individuals at risk and facilitating early intervention and support. Future research should focus on further validating the factor structure and exploring the utility of the WART in different cultural and occupational contexts.*

1. Introduction

Work addiction (WA) is one of the so-called new addictions, which raises particular concerns for public health due to its high prevalence, estimated to be between 8.3% [1] and 22% [2] in European countries. According to current definitions, WA manifests as an "obsessive, irresistible inner drive to work excessively hard" [3] (p. 219). The most evident behavioral symptom of work addiction is spending more time on work than necessary, according to explicit and implicit norms [4, 5]. Obsessive and ceaseless work-related thoughts represent a further distinctive component of WA, leading to compulsive working. Work addicts are characterized by uncontrollable concerns for work, feeling compelled to work hard even when they dislike it, and experiencing guilt when taking breaks [2].

Given that time is a limited resource, several studies have shown that WA has negative effects on marital relationships [6], family relationships, work-family balance [7], and life satisfaction [8]. WA also has negative effects on individuals' mental and physical health. Work addicts are at higher risk for

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depression, insomnia, and burnout [9], and report a higher prevalence of physical disorders, including metabolic syndrome [10] and increased systolic blood pressure [11], compared to non-addicts.

Regarding the etiology of WA, research has mainly focused on two risk factors: personality traits and organizational factors [4]. Specifically, personality characteristics oriented towards goal achievement, such as perfectionism and Type A personality, are strongly associated with WA [12]; higher-order dispositional variables such as conscientiousness, neuroticism, and narcissism are at higher risk of WA as well [13]. Individuals with high scores on perfectionism have difficulty delegating tasks to others at work [5] and generally set very high standards; as a result, they perceive their current performance as far from ideal and thereby invest more time and energy on work compared to non-perfectionists [12]. Type A personality is characterized by aggressiveness, competitiveness, ambition, impatience, and a persistent pursuit of personal goals, with an overall drive to work that goes beyond workplace or financial requirements [14]. Conscientious individuals are meticulous and take their obligations towards others seriously, being systematic and strongly committed to work, sometimes to an excessive or even compulsive extent [15]. Individuals with higher levels of neuroticism tend to be ineffective in their emotional regulation, feel insecure and anxious, and experience persistent concerns about both daily life management and work commitments [16]. Lastly, narcissistic individuals, with their typical self-importance and pursuit of power, may become obsessed with work success and spend excessive hours working at the expense of other life activities [17].

Regarding organizational factors, following the Job Demands-Resources model [18], empirical research has revealed that antecedents of WA include high demands, such as excessive workload and role conflicts, and lack of support from colleagues and managers [12]. Work addicts tend to overburden themselves and complicate their work unnecessarily, being reluctant to delegate and seek help [19]. Job satisfaction seems to be preserved in work addicts [4], whereas the impairment of work-family balance weakens their life satisfaction [8].

WA assessment and diagnosis are challenging because the most distinctive indicator of WA, namely working a lot, is usually socially desirable and common also among non-work addicts. Non-addicts may invest a lot of time in work for strategic purposes, such as seeking promotions or due to high engagement in their work [3]. However, unlike transient excessive work investment, work addiction leads to negative consequences with clinical relevance for mental health and well-being. Standardized assessment tools are essential for validly discriminating between work-addicted individuals and those healthily engaged in their work.

1.1. The Work Addiction Risk Test

The Work Addiction Risk Test (WART), developed by Robinson [20], is a widely used tool that assesses the diagnostic core symptoms of WA, such as a tendency towards perfectionism, feelings of guilt when not working, and impairment of personal relationships. The questionnaire consists of 25 items, with responses on a 4-point Likert scale (ranging from 1 = never true to 4 = always true). Traditionally, the WART is used as a unidimensional scale, with an overall WA risk score calculated by summing responses to all items, yielding a score between 25 and 100. Scores from 67 to 100 indicate a high risk of WA; scores from 57 to 66 indicate a moderate risk; and scores below 57 indicate negligible WA levels [20].

Several studies have demonstrated satisfactory psychometric properties for the WART. Reliability, as measured by Cronbach's alpha, ranges from 0.85 to 0.90 [2, 21], and test-retest reliability has been reported as r = 0.83 [22]. In terms of external validity, WART scores have been shown to correlate with lower psychological well-being [23], as well as higher work-related stress [2], anxiety disorders [20], and personality variables such as neuroticism, negative affectivity, narcissism, perfectionism, and Type A behaviors [12, 20]. In addition to the expected unidimensional structure, a five-factor structure of the WART has also been proposed, including Compulsive Tendencies, Control, Impaired communication/Self-absorption, Inability to delegate, and Self-worth [24]. However, the factors of Inability to delegate and Self-worth were psychometrically weak, being loaded by only one and two items, respectively, and were not effective in distinguishing work addicts from a control group [24]. Furthermore, this five-factor structure has not been replicated in subsequent studies [2, 17, 25, 26], raising questions about the utility of subscale scores compared to an overall score [13].

Despite the instability of its multi-dimensional factor structure, the WART remains a widely used tool for assessing WA, mainly due to its ease of application and scoring. This enables a proper WA risk assessment by considering both the dysfunctional components related to addiction (Compulsive Tendencies and Impairment of social and work functioning) and personality dimensions associated with WA, such as control and self-esteem [2]. Although an Italian version of the WART has been used in work settings [27, 28], it has not been validated systematically. Moreover, other translations in the grey literature lack adherence to established translation and cultural adaptation guidelines, such as professional translation and back-translation procedures. To address these limitations and provide a reliable tool for scholars and professionals, this study aims to validate a newly translated Italian version of the WART using a large sample of Italian workers.

2. Methods

2.1. Participants

A total of 700 adult workers, recruited as a convenience sample, participated in the study, with 264 participants from Northeastern Italy and 436 (62.3%) from Southern Italy. Table 1 provides an overview of the main descriptive characteristics of the sample, showing a balanced distribution in terms of gender, demographic, and occupational variables. The significant gender differences were in terms of working hours, with a higher rate of part-time employment among females, and type of employment, with a higher rate of self-employment among males. Additionally, 66 participants (34 men) completed the WART and other instruments for a second time 8 ± 1 weeks after the initial completion. When respondents from Northeastern and Southern Italy were compared based on their socio-demographic characteristics, the results indicated that they were statistically comparable in terms of gender, age, qualification, type of contract, type of employment, and working hours. Respondents from Southern Italy reported a higher prevalence of shift work compared to those from Northeastern Italy ($p < 0.001$).

2.2. Procedures and Measures

Participation was voluntary, and a snowball sampling procedure was employed. From November 2018 to May 2019, University students were invited to administer the paper-and-pencil questionnaire to two male and two female workers of different ages and occupations. These respondents, in turn, could suggest additional voluntary participants. Eligibility criteria required participants to be 18 years old, fluent in Italian, and currently employed. Participants were informed about the purpose of data collection and data treatment and were assured of complete data anonymity and confidentiality. By returning the questionnaire, participants indicated their informed consent. The completed questionnaires were returned in sealed envelopes, which were collected by two co-authors who then prepared the raw data set.

In addition to demographic and work-related information, all participants completed the WART. To minimize questionnaire length and reduce respondent fatigue, thus limiting missing data, improving response rates, and enhancing the reliability of answers, different subsamples were invited to further report on one or more of the other instruments described below. The 25 items of the WART were translated and back-translated from the original English version. After resolving any discrepancies in meaning, the final version reported in Supplementary Material (Table S1) was developed. This study was reported following the STROBE guidelines to ensure comprehensive and transparent reporting.

2.2.1. Well-Being at Work Measures

Maslach Burnout Inventory (MBI). This self-report questionnaire comprises 22 items rated on a 6-point Likert scale (1 = never, 6 = always) and

Table 1. Descriptive characteristics of the study sample.

		Full sample	Men	Women	Statistical Test (df)
N		700	338	361	
Age ± SD		43.05±13.97	43.13±14.77	43.00±13.20	$0.21_{(1, 696)}$
Geographical area	North-Est	264	134	130	$0.98_{(1)}$
	South	435	204	231	
Qualification	Vocational school or lower	93	50	43	
	High school	246	121	125	
	Bachelor's degree (1st level)	104	41	63	
	Master's degree or single-cycle degree (2nd level)	150	74	76	
	Postgraduate degrees	48	19	29	
Type of contract	Fixed term	223	106	117	$0.05_{(1)}$
	Permanent	471	228	243	
Working hours	Full-time	563	294	269	$17.31^{*}_{(1)}$
	Part-time	136	44	92	
Shift work	Yes	290	129	161	$2.98_{(1)}$
	No	409	209	200	
Type of employment	Employee / Subordinate	524	227	294	$21.92^{*}_{(1)}$
	Self-employed	174	111	63	
Work seniority	0-1	79	33	46	$19.43_{(5)}$
	2-5	123	63	60	
	6-10	76	41	35	
	11-20	109	43	66	
	21-30	132	52	80	
	30 or more	176	105	71	

Note. F-test for comparison between men and women for age, $\chi 2$ for the remaining qualitative variables.
** $p \leq 0.001$*

assesses burnout along three dimensions according to Maslach's theory [29]: Emotional Exhaustion, Depersonalization, and reduced Personal Accomplishment. In this study, 160 participants completed this instrument. Cronbach's alpha coefficients were 0.87 for the Emotional Exhaustion scale, 0.77 for the reduced Personal Accomplishment scale, and 0.53 for the Depersonalization scale, which was not considered in subsequent analyses due to its low internal consistency. Participants who completed the MBI were generally older ($p < 0.001$) and showed a higher prevalence of female gender, full-time contracts, and permanent work contracts ($p < 0.001$) compared to the remaining sample. However, the effect sizes for these differences were marginal (i.e., Pearson's r and Cramer's V < 0.16).

Health and Safety Executive Management Standards Indicator Tool (HSE-MS IT) evaluates exposure to seven organizational stressors: Demands, Control, Roles, Relationships, Managers' support, Peer Support, and Change. Responses are reported on a 5-point Likert scale (1 = never, 5 = always) [30]. Higher scores indicate effective management of these areas, while lower scores signify inadequate management, which exposes workers to the risk of work-related stress. In this study, four additional organizational stressors were included [30]: Physical work environment (3 items, e.g., "The climate control in the environment is comfortable"), Workload distribution (3 items, e.g., "The amount of work is evenly distributed among all my colleagues"), Relationship with users/clients (6 items, e.g., "Users behave inappropriately or incomprehensibly in their requests"), and Tools (2 items, e.g., "Work tools are adequate for their frequency of use"). This extended version of the HSE-MS IT was administered to 238 participants. Cronbach's alpha coefficients ranged from 0.57 (Workload distribution) to 0.91 (Managers' support). Respondents who completed the HSE-MS IT reported a slightly higher prevalence of permanent job contracts ($p = 0.008$) compared to those who did not complete this instrument.

Perceived Occupational Stress Scale (POS). This 4-item scale measures the perception of stress at work on a 5-point Likert scale (1 = not at all, 5 = very much) [31]. It complements scales measuring exposure to stressors at work, as, according to the transactional stress model, the relationship between stressors and strain is mediated by the perception of being stressed [32]. The POS scale was completed by 632 participants. Cronbach's alpha coefficient was 0.83. No differences ($p \leq 0.01$) were found in the sample composition between those who completed the POS and those who did not.

2.2.2. Personality and Personal Well-Being Measures

Satisfaction with Life Scale (SWLS). Proposed by Diener and colleagues [33], this five-item scale assesses subjective well-being in terms of overall life satisfaction, with responses measured on a five-point Likert scale (1 = not at all, 5 = very much). In the present study, 572 participants completed this scale. Cronbach's alpha coefficient was 0.78. No differences ($p \leq 0.01$) were found in the sample composition between those who completed the SWLS and those who did not.

Rosenberg Self-esteem Scale (RSES). Developed by Rosenberg [34], this 10-item self-report scale is widely used in research to assess global self-esteem in terms of self-satisfaction and self-acceptance. In this study, 161 participants completed this scale. The Cronbach's alpha coefficient was 0.79. Respondents who completed the HEXACO-PI generally reported a higher percentage of full-time employment and permanent job contracts than the remaining participants ($p < 0.001$, Cramer's $V < 0.20$).

HEXACO Personality Inventory. In its abbreviated form, the instrument consists of 60 items, 10 for each of the following personality dimensions evaluated according to the model developed by Ashton and Lee [35]: Honesty-Humility (sincerity, loyalty, and modesty), Emotionality (emotional fragility, sentimentality, and dependence on others), Extroversion (self-esteem, sociability, and social boldness), Agreeableness (kindness, helpfulness, and patience), Conscientiousness (organization, prudence, orderliness), and Openness to Experience (creativity, unconventionality, curiosity). Responses are provided on a 5-point Likert scale (1 = completely disagree, 5 = completely agree). In the present study, 343 participants completed the self-report questionnaire. Cronbach's alpha levels range from 0.66 (Honesty-Humility) to 0.73 (Conscientiousness). Respondents who completed the HEXACO-PI generally reported a higher percentage of full-time jobs and permanent job contracts compared to the other participants ($p < 0.001$, Cramer's $V < 0.20$).

Self-rating Anxiety Scale (SAS) and Self-rating Depression Scale (SDS). Developed by Zung [36, 37], these two diagnostic screening tools each consist of 20 items that assess symptomatic markers of anxiety and depression, respectively. Responses are provided on a 4-point scale (1 = rarely, 4 = very often). Participants (N = 124) reported their prevailing emotional states over the last three months. Cronbach's alpha levels were 0.79 for SAS and 0.76 for SDS in the present sample. No differences ($p \leq 0.01$) were found in the sample composition between those who completed the SAS and SDS and those who did not.

Short Dark Triad (SD3). Developed by Jones and Paulhus as part of the dark triad personality model [38], this self-report instrument consists of 27 items, with nine items for each of the three scales: Machiavellianism, Narcissism, and Psychopathy. The SD3 questionnaire was administered to a subsample of respondents (N = 124), consistent with recent studies that show a relationship between the dark triad personality traits and addictive behaviors [39], as well as counterproductive behaviors in the workplace [40]. For the present dataset, Cronbach's alphas ranged from 0.62 (Narcissism) to 0.74 (Machiavellianism). No significant differences ($p \leq 0.01$) were found in the sample composition between those who completed the SD3 and those who did not.

2.3. Statistical Analyses

A priori power analysis indicated that a sample size of 150 would be sufficient to detect true correlations ≥ 0.25 (alpha = 0.05, beta = 0.80), reflecting modest concurrent associations between WART and external criteria. We established a minimum sample size ten times larger than the number of WART items. To ensure rigorous testing of the structural invariance of the WART items, we doubled the sample size. Data were not inspected before the overall data collection was concluded.

The factor structure of the WART was examined using exploratory factor analysis (minimum residuals method, Varimax rotation) and multigroup confirmatory factor analysis to assess measurement invariance across different participant groups. The Root Mean Square Error of Approximation (RMSEA) and Tucker-Lewis Index (TLI) served as quantitative fit indices of the factor structure, with 0.05 < RMSEA ≤ 0.08 representing an acceptable fit, RMSEA ≤ 0.05 indicating an excellent fit, and TLI ≥ 0.90 indicating a satisfactory fit.

Pearson correlation analysis, regression analysis, and factor analysis were conducted to explore the external validity of the overall WART scores. Additionally, factor scores of the WART subcomponents or facets and the scale scores of the external correlates were analyzed. Reliability was assessed using Cronbach's alpha for internal consistency and Pearson correlation for test-retest reliability. Differences between participant groups were examined using t-tests and analysis of variance (ANOVA). Listwise deletion of cases was applied.

All statistical analyses have been conducted using IBM SPSS Statistics 23 and IBM AMOS 23 (IBM Corporation, USA).

3. Results

3.1. Factor Structure of the WART

Preliminary inspection showed that the missing values for the WART items (< 0.01%) occurred randomly. Little's MCAR test was statistically nonsignificant, confirming that the missing values were missing completely at random.

An exploratory factor analysis was conducted to identify the sub-components of the WART. Parallel analysis suggested seven factors, but two were hyper-specific, each loaded by only two items. The same limitation was observed with the six-factor solution. Therefore, a five-factor solution was explored and favored over other solutions due to its clear interpretability and satisfactory fit index values: RMSEA = 0.04 (90% CI 0.033-0.044) and TLI = 0.89. Solutions with a lower number of factors, ranging from a single general factor to four varimax-rotated dimensions, yielded adequate but less robust RMSEA fit indices (0.05 ≤ RMSEA ≤ 0.07) and inadequate TLI indices (0.68 ≤ TLI ≤ 0.85), with significant model fit change indices ($\Delta\chi^2_{(90)} > 135$, $p \leq 0.001$) demonstrating they were weaker solutions compared to the five-factor solution. The five-factor solution (after varimax rotation, reported in Supplementary Material Table S2) accounts for 30.3% of the total variance. It presents the following factors: 1) Compulsive Tendencies (accounting for 8.4% of the total variance), loaded by items reflecting an intense need to work and a low tolerance for mistakes; 2) Impatience (5.9% of the total variance), with items expressing a need to accomplish tasks quickly and low tolerance for interferences or obstacles; 3) Internal Drive/Urging (5.8% of the total variance) collecting statements indicating a constant tension towards future outcomes; 4) Egocentrism (5.5% of the total variance) reflecting how individuals prioritize work over social relationships; 5) Overworking (4.7% of the total variance) representing individuals who simultaneously engage in multiple projects and endure burdensome workloads.

Table 2. Fit indices and model comparisons for invariance based on gender, geographic origin, and shift work.

Model	χ2(gdl)	RMSEA	TLI
Invariance by gender (M *vs.* F)			
1. Structural invariance	857.95 (504)	0.03	0.86
2. Metric invariance	884.38 (528)	0.03	0.87
Difference 2 vs. 1	26.43 (24), P = 0.33		
3. Scalar invariance	905.63 (543)	0.03	0.87
Difference 3 vs. 2	47.68 (39), P = 0.16		
Invariance by geographic areas			
1. Structural invariance	916.15 (504)	0.03	0.84
2. Metric invariance	949.44 (528)	0.03	0.84
Difference 2 vs. 1	33.29 (24), P = 0.10		
3. Scalar invariance	968.90 (543)	0.03	0.85
Difference 3 vs. 2	52.75 (39), P = 0.07		
Invariance by shift work (yes *vs.* no)			
1. Structural invariance	899.71 (504)	0.03	0.85
2. Metric invariance	922.48 (528)	0.03	0.85
Difference 2 vs. 1	22.78 (24), P = 0.53		
3. Scalar invariance	933.95 (543)	0.03	0.86
Difference 3 vs. 2	34.24 (39), P = 0.69		

Additionally, we assessed the invariance of the WART across gender, geographic area (Northeastern vs. Southern Italy), and the presence/absence of shift work. Table 2 presents fit indices for the different main invariance models (structural, metric, and scalar invariances) we tested. The fit indices were statistically comparable, with $\Delta\chi^2$ indicating no significant differences between structural/metric or metric/invariance models. Therefore, the factorial structure of the WART is robust across gender, geographic areas, and the presence/absence of shift work.

3.1.1. External Concurrent Correlates of the WART.

No substantial associations were found between demographic and descriptive variables of work conditions and the overall WART scores. Regarding its facet scales, Egocentrism scores were higher in older individuals ($r = 0.15$, $p \leq 0.001$), in respondents working fixed hours (vs. shift work, $t_{(678)} = -3.65$, Cohen's $d = -0.30$) and with full-time jobs (vs. part-time jobs, $t_{(679)} = 3.87$, Cohen's $d = 0.38$). Moreover, self-employed workers scored higher on the Internal drive/Urging component than employees ($t_{(678)} = 3.52$, Cohen's $d = 0.31$).

Table 3 presents simple correlations between the overall WART and facet scores and the study variables assessing work-related risk and personality. Higher levels of the overall WART correlated with higher perceived stress at work (POS), higher Emotional Exhaustion and lower Personal Accomplishment (MBI), and higher risk in the organizational areas of Demand, Peer Support, Relationships with colleagues, and Relationships with users/customers. Perceived stress at work and the Demand risk factor were associated with each WART facet.

Regarding individual personality differences, respondents with higher overall WART scores reported lower self-esteem (RSES) and life satisfaction (SWLS), as well as increased levels of anxiety (SAS) and depression (SDS). They exhibited higher withdrawal and hostility in interpersonal relationships, evidenced by lower HEXACO Extroversion

Table 3. Observed simple correlations between WART (overall score and factor scores at facet level) and work context and personality variables.

Study variables (number of participants in brackets)	WART facets					
	Compulsive Tendencies	Impatience	Internal drive/Urging	Egocentrism	Over-working	WART Overall score
Age (680)	-.05	-.01	-.12*	.15**	.05	-.02
Work context variables						
MBI EE (160)	.18 (.19)	.24* (.24*)	.01 (.05)	.19 (-.17)	.00 (-.03)	.21* (.21*)
MBI PA (159)	-.12 (-.12)	-.22* (-.22*)	-.31** (-.28**)	-.17 (-.20)	.18 (.15)	-.24* (-.24*)
POS (621)	.17** (.21*)	.19** (.20**)	.20** (.23**)	.26** (.23*)	.13** (.11**)	.34** (-.36**)
HSE D (235)	-.17* (-.18)	-.24** (-.26**)	-.24** (-.22**)	-.32** (-.28**)	-.28** (-.26**)	-.44** (-.43**)
HSE C (236)	-.05 (-.05)	.08 (.04)	-.02 (-.01)	-.08 (-.11)	.07 (.09)	.01 (-.01)
HSE PS (235)	-.03 (-.03)	-.21** (-.20*)	-.15 (-.15)	-.18* (-.18)	.10 (.10)	-.18* (-.17*)
HSE MS (231)	-.05 (-.05)	-.18* (-.18)	-.02 (-.03)	-.16 (-.16)	.11 (.11)	-.11 (-.12)
HSE RE(236)	-.17* (-.20*)	-.13 (-.17*)	-.16 (-.15)	-.28** (-.23**)	-.09 (-.06)	-.30** (-.29**)
HSE RO(236)	-.03 (-.04)	.08 (.03)	-.27** (-.23*)	.01 (-.02)	.22** (.21**)	-.02 (-.02)
HSE CH(232)	-.07 (-.07)	-.08 (-.09)	-.15 (-.15)	-.13 (-.13)	.06 (.06)	-.13 (-.14)
HSE PWE (236)	-.04 (-.06)	-.02 (-.07)	-.09 (-.06)	-.16 (-.11)	.06 (.07)	-.09 (-.07)
HSE UC (237)	-.14 (-.15)	-.17* (-.21*)	-.13 (.12)	-.13 (-.09)	-.06 (-.04)	-.23** (-.22**)
HSE WD (235)	.03 (.02)	-.06 (-.08)	-.13 (-.12)	-.20* (-.16)	-.13 (-.10)	-.17* (-.16)
HSE T (234)	-.06 (-.07)	-.01 (-.05)	-.16 (-.14)	-.03 (.02)	.07 (.10)	-.08 (-.06)
Personality variables						
HEXACO-PI H (335)	-.10 (-.09)	-.22** (-.22**)	-.33** (-.31**)	-.03 (-.03)	.05 (.02)	-.25** (-.24**)
HEXACO-PI E (334)	.29** (.32**)	.07 (.10)	.06 (.11)	-.11 (-.04)	.12 (.06)	.16* (.21**)
HEXACO-PI X (335)	-.17* (-.15)	-.12 (-.12)	-.22** (-.21**)	-.36** (-.34**)	.16* (.14)	-.25** (-.24**)
HEXACO-PI A (333)	-.31** (-.30**)	-.33** (-.31**)	-.07 (-.04)	-.09 (-.08)	-.02 (-.04)	-.29** (-.28**)
HEXACO-PI C (335)	-.12 (-.12)	-.02 (-.05)	-.43** (-.42**)	-.03 (-.06)	.19** (.18**)	-.17* (-.17*)
HEXACO-PI O (334)	-.01 (-.01)	-.07 (-.06)	-.09 (-.08)	-.02 (-.01)	.18** (.17*)	-.02 (-.01)
RSES (158)	-.34** (-.31**)	-.05 (-.08)	-.39** (-.36**)	.03 (-.06)	.11 (.10)	-.30** (-.32**)
SWLS (554)	-.21** (-.20*)	-.10 (.11)	-.22** (-.21**)	-.21** (-.24**)	.00 (.00)	-.28** (-.28**)
SAS (124)	.37** (.34**)	.26* (.27**)	.26* (.29**)	.05 (.06)	.14 (.15)	.47** (.47**)
SDS (124)	.37** (.34**)	.12 (.14)	.25* (.31**)	.09 (.10)	-.06 (-.07)	.36** (.36**)
SD3-M (124)	.24* (.25**)	.27* (.27**)	.27* (.19)	.18 (.21)	-.02 (.05)	.41** (.41**)
SD3-N (124)	.12 (.14)	.26* (.26**)	.06 (-.02)	-.02 (.00)	.12 (.18)	.23* (.23)
SD3-P (124)	.07 (.10)	.28* (.28**)	.32** (.25*)	-.03 (-.02)	.09 (.14)	.32** (.32**)

Note. The sample size varies: N = 680 for age; N = 160 for MBI; N = 621 for POS; N = 231-237 for HSE; N = 333-335 for HEXACO; N = 158 for RSE; N = 554 for SWLS; N = 124 for SAS, SDS, SD3. Semi-partial correlations are presented in parentheses, after controlling for differences in gender, age, type of contract, and working hours.
*Legend: MBI EE = Emotional exhaustion, PA = Personal Accomplishment; POS = Perceived Occupational Stress; HSE D = Demand, C = Control, PS = Peer Support, MS = Managers' Support, RE = Relationships, RO = Role, CH = Change, PWE = Physical Work Environment, UC = Users/Clients, WD = Workload Distribution, T = Tools; HEXACO H = Honesty- Humility, E = Emotionality, X = Extroversion, A = Agreeableness, C = Conscientiousness, O = Openness to Experience; RSES = Rosenberg Self-esteem Scale; SWLS = Satisfaction with Life Scale; SAS = Self-rating Anxiety Scale; SDS = Self- rating Depression Scale; SD3 M = Machiavellism, N = Narcissism, P = Psychopathy. * $p \leq 0.01$ ** $p \leq 0.001$.*

and Agreeableness scores. Additionally, they scored significantly higher in areas indicating a tendency to view others as tools to achieve their goals at any cost, reflected in elevated scores on SD3 Machiavellianism, Narcissism, and Psychopathy, coupled with lower scores on HEXACO Honesty and Humility.

The associations between the WART and personality and work context variables were investigated using multiple regression analysis (critical p value equal to 0.001) and factor analysis. Firstly, the HEXACO-PI dimensions, along with SWLS, were entered as independent variables, controlling for working fixed hours vs. shift, which was the only significant estimator ($\beta = -0.17$, $p \leq 0.001$) among the demographic and work condition variables in this study ($n = 332$). The results showed that higher overall WART scores are uniquely associated with lower scores in HEXACO Agreeableness ($\beta = -0.21$, $p \leq 0.001$) and Honesty-Humility ($\beta = 0.21$, $p \leq 0.001$) and life satisfaction ($\beta = -0.18$, $p \leq 0.001$). These four estimators account for 18% of the total WART variance ($R^2_{ADJ} = 0.18$, $p \leq 0.001$). When examining how SAS Anxiety, SDS Depression, and SD3 scales predicted overall WART scores ($n = 124$), the results reveal that individuals at higher risk of work addiction also report higher levels of anxiety ($\beta = 0.44$, $P \leq 0.001$) and SD3 Machiavellianism ($\beta = 0.38$, $P \leq 0.001$), accounting for $R^2_{ADJ} = 0.35$ ($P \leq 0.001$). No demographic and work condition variables accounted for additional variance. Among the work context variables (i.e., POS, HSE, and MBI), regression analysis showed that individual differences in work addiction are associated with job stress (POS, $\beta = 0.48$, $P \leq 0.001$, $n = 157$) and working fixed hours vs. shift ($\beta = -0.24$, $P \leq 0.001$), with a $R^2_{ADJ} = 0.27$ ($P \leq 0.001$). Since the respondents varied across the instruments, we also examined the associations between WART scores and predictors, controlling for differences in gender, age, type of contract, and working hours. The results in Table 3 (semi-partial correlations) show that the associations remained substantially invariant.

Regarding factor analysis, factor scores for the five sub-components of the WART were simultaneously entered along with personality variables and, separately, work environment variables. Table 4 presents results from factor analyses (principal axis method), using the Kaiser criterion to determine the number of factors to extract and rotate (Varimax). When the WART facets were factor analyzed together with the MBI, HSE and POS scales, the eigenvalues indicated a 4- factor solution (56.8% of accounted variance). The results showed that the WART components of Impatience, Egocentrism, Compulsive Tendencies, and Internal drive/Urging (Factor 3) are primarily associated with work conditions characterized by higher perceived work-related stress (POS) and emotional exhaustion (MBI), and lower relationships with colleagues and users/clients (HSE), and personal achievement (MBI). Conversely, the WART facet of Over-working (Factor 4) is associated with lower personal achievement (MBI) and higher perceived role (HSE).

When the WART facets were factor analyzed along with personality variables, 4 factors emerged (56.3% of explained variance). The results suggest that WART Internal drive/Urging is more prevalent among less organized and conscientious individuals (Factor 1); WART Impatience and Compulsive Tendencies are especially reported by less cooperative, honest, and modest workers (Factor 2).

WART Egocentrism is generally reported by introverted individuals and those less satisfied with their lives (Factor 3). Higher WART Over-working and Compulsive Tendencies are generally associated with higher emotionality and openness to experience (Factor 4).

3.2. Descriptive Statistics and Reliability Coefficients

The mean values of the WART and its five facets were compared across geographical area, gender, shift work, type of contract (permanent vs. fixed term), and working hours (part-time vs. full-time). ANOVA revealed marginal differences (effect sizes $\eta^2 \leq 0.02$) when subgroup differences were statistically significant ($p \leq 0.001$). Regarding geographical area, a significant difference emerged for the WART Internal Drive/Urging facet, with higher mean values in Southern Italy ($M = 11.8$) compared to Northeastern Italy ($M = 11.2$, $F_{(1,694)} = 7.34$, $\eta^2 = 0.01$). Full-time workers reported higher mean levels for WART Egocentrism ($M = 6.16$ vs. $M = 5.58$ for

Table 4. Factorial solutions including WART sub-components and personality and work context variables.

	Factor 1	Factor 2	Factor 3	Factor 4
		Work context variables		
HSE PS	**0.77**	0.14	-0.08	0.19
HSE MS	**0.66**	0.17	-0.07	0.17
HSE C	**0.55**	0.23	0.03	0.16
HSE CH	**0.50**	**0.38**	-0.03	**0.31**
HSE RE	**0.50**	0.26	**-0.37**	-0.16
HSE PWE	0.19	**0.75**	-0.04	0.19
HSE T	**0.33**	**0.71**	0.11	0.16
HSE WD	**0.46**	**0.50**	-0.16	-0.08
MBI EE	-0.21	**-0.48**	**0.47**	-0.01
HSE UC	0.23	**0.43**	**-0.36**	-0.10
POS	-0.24	**-0.42**	**0.73**	0.25
WART I	-0.05	-0.03	**0.48**	0.00
WART E	-0.01	-0.04	**0.47**	0.03
WART TC	0.01	0.05	**0.45**	-0.11
WART SI	-0.02	0.02	**0.33**	-0.32
HSE RO	**0.36**	0.21	0.00	**0.66**
MBI PA	0.09	0.21	**-0.35**	**0.51**
WART OW	0.12	-0.05	0.22	**0.43**
		Personality variables		
HEXACO-PI C	**0.75**	-0.02	-0.09	-0.01
WART ID	**-0.50**	-0.16	0.23	0.11
HEXACO-PI A	0.00	**0.64**	-0.10	-0.02
WART I	-0.03	**-0.49**	0.12	0.16
HEXACO-PI H	**0.34**	**0.46**	-0.03	0.18
WART E	0.03	-0.05	**0.81**	0.00
HEXACO-PI X	**0.37**	0.19	**-0.45**	0.09
SWLS	0.19	0.15	**-0.36**	-0.13
HEXACO-PI E	-0.10	-0.05	-0.07	**0.51**
WART CT	-0.13	**-0.41**	0.21	**0.46**
HEXACO-PI O	0.29	0.22	0.01	**0.34**
WART OW	0.25	-0.06	0.12	**0.32**

Note. For the WART components, factorial scores calculated based on the solution presented in Table 2 are included in the factorial analysis. For work-related risk variables, N = 157; for personality variables, N = 330.

Legend: MBI EE = Emotional exhaustion, PA = Personal Accomplishment; POS = Perceived Occupational Stress; HSE D = Demand, C = Control, PS = Peer Support, MS = Managers' Support, RE = Relationships, RO = Role, CH = Change, PWE = Physical Work Environment, UC = Users/Clients, WD = Workload Distribution, T = Tools; HEXACO H = Honesty-Humility, E = Emotionality, X = Extroversion, A = Agreeableness, C = Conscientiousness, O = Openness to Experience; WART I = Impatience, E = Egocentrism, CT = Compulsive Tendencies, ID = Internal drive/Urging, OW = Over-working.

part-time workers, $F_{(1,695)}$ = 7.74, η^2 = 0.01) and WART Over-working (M = 11.32 vs. M = 10.67 for part-time workers, $F_{(1,692)}$ = 10.12, η^2 = 0.01). No differences emerged based on working fixed hours vs. shift work or on permanent vs. fixed-term contracts. Women reported higher levels of both Egocentrism (M =6.38 vs. M = 5.74 for men, $F_{(1,694)}$ = 15.15, η^2 = 0.02) and Internal drive/Urging (M = 12.00 vs. M = 11.30 for men, $F_{(1,692)}$ = 7.39, η^2 = 0.01). Although the differences are negligible, Table 5 presents the descriptive values and the corresponding points for potentially critical levels for the total WART and subscales, separately for men and women. Conversion tables from raw scores to T scores can be requested from the authors.

Table 5 also presents reliability levels as internal consistency (Cronbach's alpha, overall sample) and as test-retest reliability, observed from a subset of participants (n = 66) who completed the WART again 8 ± 1 weeks after the initial administration. The values indicate adequate internal consistency for the overall WART (α = 0.83) and weaker internal consistency for the facets, ranging from α = 0.45 for WART Over-working to α = 0.74 for WART Compulsive Tendencies, each scale comprising 3 to 7 items only. Test-retest reliability is high for both the overall WART (r = 0.79) and its facets (r = 0.67 for WART Egocentrism to r = 0.89 for WART Compulsive Tendencies).

A final analysis was conducted on the test-retest data. In addition to the WART, participants also completed the RSES, SWLS, and POS scales at retest. Cross-lagged regression analysis showed that initial levels of work-related stress (POS) do not predict changes in WA risk levels a few weeks later when controlling for initial levels of addiction. However, changes in the two variables are correlated, with a partial correlation of pr = 0.71 (p ≤ 0.01) between POS and WART at the second measurement occasion when controlling for initial levels of both scales. This indicates that increases in work-related stress are associated with increases in WA risk levels.

4. Discussion

The present research aims to test the psychometric properties of the Work Addiction Risk Test, one of the most widely used tools for assessing work addiction in both applied and research settings. Exploratory factor analysis revealed a five-factor structure consistent with the theoretical components of the higher-order work addiction construct, although it only partially aligns with those originally reported by Flowers and Robinson [24]. Nevertheless, the WART was initially developed as a unidimensional measurement tool and is generally utilized as such, while a set of WART subscales was identified later, but their adequacy and clinical utility remain subjects of debate. Indeed, numerous studies have failed to replicate the original multidimensional structure [2, 17, 25, 26], which is somewhat weak, including a factor with just two items, a factor with a single item, and an item that did not load on any factor. Apart from potential cultural and linguistic differences, a possible reason for the instability in the WART's factor structure is that several studies, including the original by Flowers and Robinson [24], collected data from samples with large percentages of students to psychometrically investigate a construct that, by definition, applies only to individuals predominantly engaged in work activities. In the current study, we involved only adult workers and successfully tested the structural invariance of the WART across gender, geographical area, and working shifts or fixed hours. In addition to the current assessment of structural validity, several additional psychometric properties of the WART were found to be more than adequate. These include internal consistency and test-retest reliability for the overall WART scores. Moreover, the WART scores at higher-order and middle-order (facet) levels showed meaningful associations with external organizational and personality-related criteria, which we investigated as theoretically relevant for work addiction risk [2, 10, 12, 13, 20, 22]. Consistent with previous studies on work addiction, assessed using the WART [23] or other instruments [1], we found no significant differences across gender or work conditions (type of contract, working hours, and presence of shifts).

While the overall WART score demonstrated stronger correlations with related criteria than the subscales, which exhibited weaker associations, both the total score and the subscales ought to be

Table 5. Descriptive statistics, percentile ranks, and reliability for WART (overall and facets).

	Reliability			Men				Women			
					Percentiles				Pecentiles		
	Alpha (n)	**Test-retest**	**Range**	**Mean (SD)**	**85**	**90**	**95**	**Mean (SD)**	**85**	**90**	**95**
WART Overall	0.83 (25)	0.79	25-100	58.14 (10.87)	69	72	76	57.02 (9.92)	66	68	73
Compulsive Tendencies	0.74 (7)	0.89	7-28	15.78 (4.25)		21	23	16.00 (4.15)	20	21	24
Impatience	0.62 (5)	0.72	5-20	12.91 (3.19)		17	18	12.55 (2.84)		16	17
Internal Drive /Urging	0.60 (6)	0.87	6 - 24	11.97 (3.38)		16	18	11.31 (2.98)		15	17
Egocentrism	0.62 (3)	0.67	3-12	6.38 (2.22)	9		10	5.74 (2.13)	8	9	10
Over-working	0.45 (4)	0.83	4-16	11.05 (2.18)		14	15	11.33 (2.14)		14	15

Note. (n) Number of items; N = 66 for test-retest; PR = percentile rank (reported for the subscales where possible); N= 327-337 for men, N = 335 – 361 for women.

considered. The total score provides a comprehensive measure of the severity of work addiction risk, while the subscales can reveal the specific components underlying work addiction. For instance, two individuals with the same overall score might show distinct profiles when their subscales are analyzed: one might score higher in Overwork and Urging, while another could score higher in Egocentrism and Compulsive tendencies, highlighting entirely different types of issues. Therefore, examining the subscales alongside the total score is valuable for obtaining a more detailed understanding of work addiction, allowing for more tailored assessments and interventions.

The strengths of this study include the involvement of a large sample of workers from both Northeastern and Southern Italy. This study is also the first to link the WART with multidimensional tools for assessing organizational well-being (HSE-MS IT) and personality (HEXACO-Personality Inventory and SD3). Specifically, it was observed that, in addition to narcissism, a dimension already known in the literature to predispose individuals to work addiction [17], the other two components of the dark triad of personality (Machiavellianism and psychopathy) were also significantly associated with work addiction risk, consistent with studies linking these personality dimensions to addictive behaviors regarding work [39, 40]. Furthermore, the use of cross-lagged regression analysis allowed for a dynamic assessment of the relationship between work-related stress and work addiction over time. This analysis revealed a significant partial correlation between changes in perceived work-related stress and work addiction risk, highlighting the reciprocal relationship between these variables and underscoring the importance of considering temporal changes in work-related stress when assessing the risk of work addiction.

One limitation of this study is that only an exploratory factor analysis was conducted on the collected sample without a subsequent confirmatory factor analysis. Although we demonstrated the invariance of the structure concerning some demographic and work-related variables, further studies are needed to assess the robustness of the identified factorial structure. Another limitation is the sampling method, which utilized a snowball procedure. While this allows reaching many participants, it does not guarantee complete control over the sampling process. Additionally, using a convenience sample limits the generalizability of the findings, as the sample may not fully represent the broader population of Italian workers.

5. Conclusion

In conclusion, the WART proves to be an agile and reliable tool for assessing the risk of WA, even in the Italian context. The robustness of its factorial structure remains open and should be addressed in further studies. A better understanding of its components would allow for a more in-depth investigation of this construct. Highlighting the compulsive component, for example, could be particularly useful for discriminating between WA and work engagement, constructs that share the component of excessive work but with entirely different clinical and organizational implications [3]. Additionally, exploring the role of various personality traits and work-related stressors in predicting WA over time could provide valuable insights for developing targeted interventions to mitigate the risk of work addiction and promote healthier work environments.

Supplementary Materials: The following are available online: Table S1: Work Addiction Risk Test – Italian version, Table S2: Exploratory factor analysis of WART items.

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Institutional Review Board Statement: The study was conducted in accordance with the guidelines of the Declaration of Helsinki and the ethical code of the Italian Association of Psychology (AIP). Ethics committee approval was not required, as the study posed no risks to participants. All data were collected anonymously, ensuring participant confidentiality. Data were handled in compliance with privacy laws and following European Union Regulation 679/2016 (GDPR).

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Declaration on the use of AI: None.

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Supplementary Files

Table S1: Work Addiction Risk Test – Italian version

Valuti il grado di accordo con le seguenti affermazioni riferite a come si è sentito/a riguardo il Suo lavoro nell'ultimo mese, utilizzando la scala fornita.					
1	Preferisco fare quasi tutto da solo/a piuttosto che chiedere aiuto	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
2	Divento impaziente quando devo aspettare qualcuno o quando qualcosa richiede troppo tempo	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
3	Mi sembra di essere sempre di fretta e in corsa contro il tempo	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
4	Mi irrito quando vengo interrotto/a mentre sto facendo qualcosa	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
5	Mi mantengo impegnato/a e metto molta carne sul fuoco	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
6	Mi ritrovo a fare due o tre cose contemporaneamente, come mangiare e prendere appunti mentre sono al telefono	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
7	Mi sovraccarico perché prendo più impegni di quanti posso realisticamente gestire	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
8	Mi sento in colpa quando non lavoro	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
9	E' importante che io veda i risultati concreti di quello che faccio	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
10	Sono più interessato/a ai risultati finali del mio lavoro che al processo con cui li raggiungo	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
11	Le cose non mi sembrano mai andare o concludersi abbastanza velocemente per me	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
12	Perdo la pazienza quando le cose non vanno come dico io o non funzionano per me	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
13	Faccio di nuovo la stessa domanda, senza rendermene conto, dopo che mi è già stata data la risposta	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
14	Passo molto tempo a pianificare e a pensare al futuro, dimenticandomi del presente	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
15	Mi ritrovo a continuare a lavorare dopo che i miei colleghi hanno smesso	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
16	Mi arrabbio quando le persone non soddisfano i miei ideali di perfezione	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
17	Mi arrabbio quando mi trovo in situazioni in cui non riesco ad avere il controllo	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
18	Mi tengo sotto pressione con scadenze autoimposte quando lavoro	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
19	Trovo difficile rilassarmi quando non sto lavorando	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐
20	Passo più tempo a lavorare piuttosto che a socializzare con gli amici, a svolgere attività ricreative o hobbies	per niente ☐	parzialmente ☐	abbastanza ☐	molto ☐

21	Mi tuffo nei progetti per partire in vantaggio prima ancora che tutte le fasi siano state definite	per niente ◻	parzialmente ◻	abbastanza ◻	molto ◻
22	Mi arrabbio con me stesso per aver fatto anche il più piccolo errore	per niente ◻	parzialmente ◻	abbastanza ◻	molto ◻
23	Metto più impegno, tempo ed energia nel mio lavoro che nelle mie relazioni con gli amici e i miei cari	per niente ◻	parzialmente ◻	abbastanza ◻	molto ◻
24	Dimentico, ignoro o sminuisco compleanni, incontri, anniversari o vacanze	per niente ◻	parzialmente ◻	abbastanza ◻	molto ◻
25	Prendo decisioni importanti prima di avere tutte le informazioni e di avere la possibilità di pensarci approfonditamente	per niente ◻	parzialmente ◻	abbastanza ◻	molto ◻

Table S2: Exploratory Factor Analysis of Wart Items

WART items	1	2	3	4	5
17. Mi arrabbio quando mi trovo in situazioni in cui non riesco ad avere il controllo	0.58				
22. Mi arrabbio con me stesso per aver fatto anche il più piccolo errore	0.56				
16. Mi arrabbio quando le persone non soddisfano i miei ideali di perfezione	0.50	0.32			
12. Perdo la pazienza quando le cose non vanno come dico io o non funzionano per me	0.49	0.34			
18. Mi tengo sotto pressione con scadenze autoimposte quando lavoro	0.44				0.36
19. Trovo difficile rilassarmi quando non sto lavorando	0.33			0.30	
8. Mi sento in colpa quando non lavoro	0.32				0.27
2. Divento impaziente quando devo aspettare qualcuno o quando qualcosa richiede troppo tempo		0.59			
4. Mi irrito quando vengo interrotto/a mentre sto facendo qualcosa	0.32	0.53			
3. Mi sembra di essere sempre di fretta e in corsa contro il tempo		0.47			
11. Le cose non mi sembrano mai andare o concludersi abbastanza velocemente per me		0.33	0.30		
1. Preferisco fare quasi tutto da solo/a piuttosto che chiedere aiuto		0.28			
25. Prendo decisioni importanti prima di avere tutte le informazioni e di avere la possibilità di pensarci approfonditamente			0.53		
14. Passo molto tempo a pianificare e a pensare al futuro, dimenticandomi del presente	0.33		0.40		
13. Faccio di nuovo la stessa domanda, senza rendermene conto, dopo che mi è già stata data la risposta	0.31		0.38		

21. Mi tuffo nei progetti per partire in vantaggio prima ancora che tutte le fasi siano state definite	0.36		
7. Mi sovraccarico perché prendo più impegni di quanti posso realisticamente gestire	0.35		
10. Sono più interessato/a ai risultati finali del mio lavoro che al processo con cui li raggiungo	0.29		
20. Passo più tempo a lavorare piuttosto che a socializzare con gli amici, a svolgere attività ricreative o hobbies		0.71	
23. Metto più impegno, tempo ed energia nel mio lavoro che nelle mie relazioni con gli amici e i miei cari		0.67	
24. Dimentico, ignoro o sminuisco compleanni, incontri, anniversari o vacanze	0.30	0.34	
5. Mi mantengo impegnato/a e metto “molta carne sul fuoco”			0.53
6. Mi ritrovo a fare due o tre cose contemporaneamente, come mangiare e prendere appunti mentre sono al telefono			0.43
9. E’ importante che io veda i risultati concreti di quello che faccio			0.39
15. Mi ritrovo a continuare a lavorare dopo che i miei colleghi hanno smesso			0.32