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EDITORIAL

REVIEWS, COMMENTARIES, PERSPECTIVES

ORIGINAL ARTICLES

SHORT COMMUNICATIONS

LETTER TO THE EDITOR

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La Medicina del Lavoro

Editorial

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Pride and Concern for Bibliometric Achievements: Deserved Results or Result of Cites Inflation?

We are delighted to announce the publication of the latest bibliometric scores by Clarivate's Journal Citation Reports (JCR) and Scopus. The official journal impact factor (JIF) for 2022 is 2.7, the corresponding Cite Score being 3.1, thus reflecting the growing impact and success of our journal and validating our efforts to publish high-quality research. Such a positive trend is corroborated by other metrics, such as the immediacy index, and has been achieved in a few years by a small, independently managed, and fully open-access journal not applying, so far, any article processing charge. Thanks to the Italian Society of Occupational Medicine's sponsorship of its official journal, only scientific merit makes us decide whether to accept or decline submissions. The decision to publish research articles in English has been crucial in widening the readership and increasing the journal's international visibility, particularly in countries where Occupational Medicine is still growing.

We want to thank all authors who have entrusted us with their original research, our dedicated editorial staff, and our reviewers for helping us maintain the highest standards of academic rigor as a reliable source of knowledge dissemination. A concerning trend tempering our enthusiasm for recent bibliometric achievements has emerged in recent years, a phenomenon I would call 'citeflation'1. Citeflation can be described as the inflationary growth in the number of citations in academic literature. It refers to excessively citing papers, not necessarily for their intellectual merit or contribution to a particular study but for boosting one's visibility and impact metrics. This phenomenon distorts scholarly work's value and undermines scientific research's integrity and reliability.

The pressure to publish frequently and gain recognition has intensified with academic institutions placing increased emphasis on researchers' publication records. As a result, scholars are under immense pressure to produce an impressive number of publications while maintaining a high citation count. Some researchers resort to excessive self-citation or manipulative citation practices in this hypercompetitive environment.

One major consequence of citeflation is the distortion it creates in perceived research impact. Inflated citation counts can give an illusion of significant influence within a field, leading to biased assessments in hiring decisions, promotions, grant allocations, and tenure evaluations. As scholars strive for greater prestige and recognition through artificial means, the true quality and novelty of their contributions may be overshadowed by inflated metrics.

Moreover, citeflation hampers scientific progress in two fundamental ways. First, it perpetuates echo chambers within academia by reinforcing existing beliefs instead of encouraging critical thinking and diverse perspectives. Researchers repeatedly cite well-known papers within their subfields while overlooking potentially valuable contributions from lesser-known authors or interdisciplinary studies. Second, it erodes the credibility of academic publishing. Scientific progress is built on the foundation of rigorous peer review and meticulous validation of research findings. However, when citations become a currency for reputation and career advancement, the integrity of the peer review process can be compromised. Researchers may feel compelled to cite influential authors excessively or exchange citations as a form of academic favoritism.

To address Citeflation, several steps can be taken. Academic institutions must prioritize quality over quantity and foster an environment where originality, creativity, and sound research methodology are valued

[1] Note: The term "Citeflation" and the concept of excessive citation practices have not gained widespread recognition in the academic community. It is proposed in this editorial serves as a speculative piece to highlight the potential negative consequences of such practices, i.e., the devaluation of scholarly impact and the need for vigilance in maintaining academic integrity.

above citation counts alone. Peer reviewers should be wary of manipulative citation patterns during the evaluation process and emphasize the importance of intellectual contribution rather than sheer quantity.

Although excellent scientists lend, in most cases free of charge, their prestige, their commitment, and their hard work to publishers, and maintain their high standard of scientific rigor, predatory and mega journals born in the last few decades often have less stringent criteria for acceptance than traditional subject-specific journals, particularly in special issues, which means more papers can be published, potentially leading to more citations. Scholars publishing in such special issues may benefit from increased visibility and citation counts. However, this emphasis on quantity can result in a lower average quality of published papers. With a flood of articles being released, the thoroughness of peer review processes may be compromised.

We adopt strict guidelines for citation practices, discouraging excessive self-citation and encouraging reference diversity. Additionally, technological advancements in citation analysis tools could be utilized to identify potential cases of citeflation and flag suspicious patterns.

Quantity or Quality in Academic Promotion?

Even leaving aside malpractice or misconduct cases, it is time for scientists, especially the junior ones, to ask themselves: is my bibliometric record well deserved or rather a consequence of citeflation? Similarly, mentors should ask themselves whether encouragement and support they give to their pupils is going far beyond their mission and duty.

Bibliometric criteria were introduced to avoid competition among mentors when acting as commissioners with the responsibility for assigning academic positions and to base their decisions on a transparent and possibly objective assessment of scientific merit. After two decades, we are back to the problem: how can we assess the individual scientific productivity, and how can we separate the candidate's contribution from the overall activity of the team?

Combating citeflation requires collective efforts from researchers, institutions, funding agencies, and publishers. It demands a cultural shift within academia whereby scholars prioritize genuine impact over superficial metrics. By valuing intellectual rigor, collaboration, and integrity in research practices, we can restore the true essence of scholarly pursuit - advancing knowledge for the betterment of society.

As stakeholders in academia strive for excellence and impact, they must guard against this malpractice by promoting genuine scholarship and reevaluating current assessment metrics. Perhaps through a transition phase, we can only ensure that academic pursuits focus on meaningful contributions to human knowledge rather than inflated numbers on a page.

Finally, the primary academic job is teaching, and while scientific achievements are important, they alone do not justify a tenure track position.

Antonio Mutti

La Medicina del Lavoro

Reviews, commentaries, perspectives

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Shoulder Tendinopathies and Occupational Biomechanical Overload: A Critical Appraisal of Available Evidence

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Keywords: Shoulder Tendinopathy; Musculoskeletal Diseases; Occupational Exposure; Occupational Health; Occupational Disease; Systematic Review; Upper Extremity

Abstract

Background: *The aim of this study is to evaluate the association between occupational exposure to biomechanical risk factors and shoulder tendinopathies.* **Methods:** *We updated recent systematic reviews about specific shoulder disorders and work-related risk factors. MEDLINE was searched up to September 2022. Studies satisfying the following criteria were included: i) the diagnosis was based on physical examination plus imaging data (when available), and ii) the exposure assessment was based on video analysis and/or directly measured.* **Results:** *Five studies met the inclusion criteria: three cross-sectional studies identified from published systematic reviews and two cohort studies retrieved from the update. Two studies investigated shoulder tendinitis, one supraspinatus tendinitis, and the other two rotator cuff syndrome. The diagnosis was based on physical examination, not supported by imaging techniques for all the included studies. In four out of five studies, the exposure was assessed by experienced ergonomists with the support of video recordings. In two studies, the exposure assessment was further supplemented by force gauge measurements or direct measurements of upper arm elevation. Only the combined exposure of working with arms above shoulder level with forceful hand exertion appears to be associated with rotator cuff syndrome: i) a cohort study reported an HR=1.11 (95%CI 1.01-1.22) for each unit increase in forceful repetition rate when the upper arm is flexed ≥45° for ≥29% of the working time; and ii) a cross-sectional study showed an OR=2.43 (95%CI 1.04-5.68) for the combination of upper arm flexion ≥45° for more than 15% of the time with a duty cycle of forceful exertions more than 9% of the time.* **Conclusions:** *There is moderate evidence of a causal association between shoulder tendinopathy and combined exposures of working above shoulder level with forceful hand exertion. The evidence is insufficient for any single biomechanical exposure on its own. High-quality cohort studies with direct exposure measures and objective diagnostic criteria are needed. The occupational origin of shoulder tendinopathies is still an open question that must be properly answered.*

1. Introduction

Shoulder disorders are prevalent among men and women of the general population (7% and 9.1% in England and 6.8% and 9.0% in France, respectively) [1, 2]. However, the prevalence of shoulder pain varied considerably across studies and case definitions [3]. Rotator cuff syndrome is one of the

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most frequently reported shoulder disorders among the working population in both men and women, with an incidence of more than 2/100 person-years among subjects older than 44 years [4].

Rotator cuff disorders encompass a broad spectrum of conditions affecting tendons of rotator cuff muscles ranging from inflammation to tears or rupture [5]. There is no universally accepted way to label or define shoulder tendinopathies [6]. Shoulder disorders have been described in the literature under a variety of names including, but not limited to, rotator cuff disease, rotator cuff syndrome, rotator cuff tendinitis/tendinosis, subacromial impingement syndrome, subacromial shoulder disorders, subacromial bursitis, supraspinatus tendinitis/tendinosis, infraspinatus tendinitis/tendinosis, and bicipital tendinopathy.

The international classification of diseases 10th revision (ICD-10) covers the following shoulder lesions: M75.0 (adhesive capsulitis of shoulder), M75.1 (rotator cuff syndrome), M75.2 (bicipital tendinitis), M75.3 (calcific tendinitis of the shoulder), M75.4 (impingement syndrome of the shoulder), M75.5 (bursitis of the shoulder), M75.8 (other shoulder lesions), and M75.9 (shoulder lesion, unspecified). However, no international consensus has been reached about the diagnosis of "subacromial pain syndrome" suitable for epidemiological studies: only 34% of the panellists agreed that a case definition for epidemiological research could be based on symptoms only [7].

Biomechanical risk factors for shoulder disorders include repetitive upper arm movements, working above shoulder height, and shoulder efforts; non-occupational risk factors could be associated with shoulder pain among adults [4, 8].

We aimed to evaluate the association between shoulder tendinopathies and occupational exposure to biomechanical risk factors ranking the quality of evidence for establishing a causal relationship. However, to our knowledge, a critical appraisal focusing on objective criteria for both exposure assessment and diagnosis has yet to be performed.

2. Methods

For the present review, we included shoulder tendinopathies defined as the following: i) rotator cuff syndrome/disease; ii) tendinitis/tendinosis of the rotator cuff muscles; iii) bicipital tendinitis/tendinopathy; iv) calcific tendinitis; and v) impingement syndrome. These diagnoses correspond to M75.1-M75.4 codes of ICD-10.

At first, we re-evaluated the studies already included in published systematic reviews about specific shoulder disorders and work-related risk factors [9-11]. These three systematic reviews are based on the same methodological approach, and each, in turn, constitutes an update of the previous one. We retrieved the list of included studies, and two authors (SC and SM) independently extracted the following data: first author, year of publication, systematic reviews identifying the included studies, study design, outcome assessment, and exposure assessment. For each included study, data about diagnosis and exposure assessment were retrieved and categorized according to predefined criteria [12]. Each combination of diagnosis and exposure was ranked for case definition and exposure assessment. The hypothetical combinations of case definition and exposure assessment and their evidence quality are reported in Supplementary Table 1.

The minimum criteria to be qualified as potentially eligible for the present study are as follows: i) the diagnosis is based on physical examination (symptoms plus clinical signs), and ii) the exposure assessment is based on video analysis or video-based observations. The best scenario is represented by studies whose case definition is based on physical examination plus imaging (e.g., Magnetic Resonance Imaging, MRI). Exposure is assessed using quantitative measures of biomechanical exposure like inclinometer measurements. Studies based on self-reported symptoms (e.g., shoulder pain) and/or an indirect assessment of biomechanical exposure (e.g., job titles, job exposure matrix, self-reports, or expert ratings) did not qualify for inclusion but were retained for descriptive purposes. Studies about a wide spectrum of shoulder pathologies were poorly rated and reported non-standardized and adequately described diagnostic criteria and/or exposure assessment. Of note, studies using imaging alone (without physical examination) do not allow a standardized medical diagnosis, precluding any ratings. Occupational exposure to vibration and psychosocial risk factors were not included as well.

In addition, we updated the search of the literature included in MEDLINE (through PubMed) from November 1, 2018, up to September 25, 2022. The search strategy is reported in Supplementary Table 2. Briefly, search terms related to shoulder tendinopathies were combined with the "more specific" PubMed search filter for occupational determinants of diseases [13], along with terms related to biomechanical risk factors. Such a search strategy was validated against the reference set of 34 citations included in the three selected systematic reviews [9-11]. The reference lists of included studies and other reviews about the topic of interest (if any) were checked for additional citations (including grey literature reports). No language restriction was applied. Case reports and case series were excluded.

Two authors (SC and SM) independently screened titles and abstracts to identify potentially relevant studies. The same two authors assessed whether each full article met the inclusion criteria. Disagreements were resolved by a third author (FSV). Multiple publications were detected, and valuable information was retained as appropriate. Two authors (SC and SM) independently extracted data from each eligible study. We collected information on the first author, year of publication, study design, outcome assessment, and exposure assessment. Data about diagnosis and exposure were then classified according to the quality of evidence [12].

The quality of included studies was evaluated according to predefined criteria [12]. Two authors (SC and SM) independently performed the quality assessment. Disagreements were resolved by consensus. The quality assessment covered the following topics: i) study design; ii) study population; iii) outcome assessment; iv) exposure assessment; and v) data analysis. The overall quality score ranges from 3 to 17. According to tertile distribution, studies were classified into three categories, namely: low-quality (3-7), medium-quality (8-12), and high-quality studies (13-17). To evaluate the causal relationship between shoulder tendinopathies and occupational exposure to biomechanical risk factors, a slightly modified version of the criteria developed by The Scientific Committee of the Danish Society of Occupational and Environmental Medicine was used [12, 14].

3. Results

The three published systematic reviews on specific shoulder disorders and work-related risk factors included 34 studies (excluding duplications) [9-11]. Of these, three studies met the inclusion criteria for the present study [15-17]. The update of the electronic search in MEDLINE retrieved 696 potentially relevant references, of which 20 were assessed in full text. Of these, one met the inclusion criteria [18]. Eight additional references were identified through other sources [19-21] and one study qualified for inclusion [22]. Overall, five studies were included in qualitative synthesis. The flow diagram is summarised in Figure 1.

Table 1 reported the list of studies included in three published systematic reviews classified according to quality of evidence. Overall, 34 studies were listed including 19 cross-sectional studies, 3 case-control studies and 12 cohort studies.

Most of these applied a case definition based on physical examination but performed an indirect assessment of biomechanical exposure. In one case, ultrasonography further supported the clinical diagnosis [23]. Of note, three other studies did not meet the minimum diagnostic requirements (i.e., imaging - MRI or ultrasonography - without physical examination was used) [24-26]. On the contrary, none of the studies was detected using a case definition based on self-reports and direct exposure measurements. In addition, 13 studies were poorly ranked according to case definition and exposure assessment criteria. The ranking for outcome/exposure combination by study design is reported in Table 2.

Altogether, five studies met the inclusion criteria for the present review: three cross-sectional studies were identified from the selected systematic reviews [15-17], and two cohort studies were retrieved from the update [18, 22] (Table 1). The main characteristics of the included studies are reported in Table 3.

Two studies investigated shoulder tendinitis [15, 22], another one supraspinatus tendinitis [16], and the last two rotator cuff syndromes [17, 18]. The case definition was based on physical examination

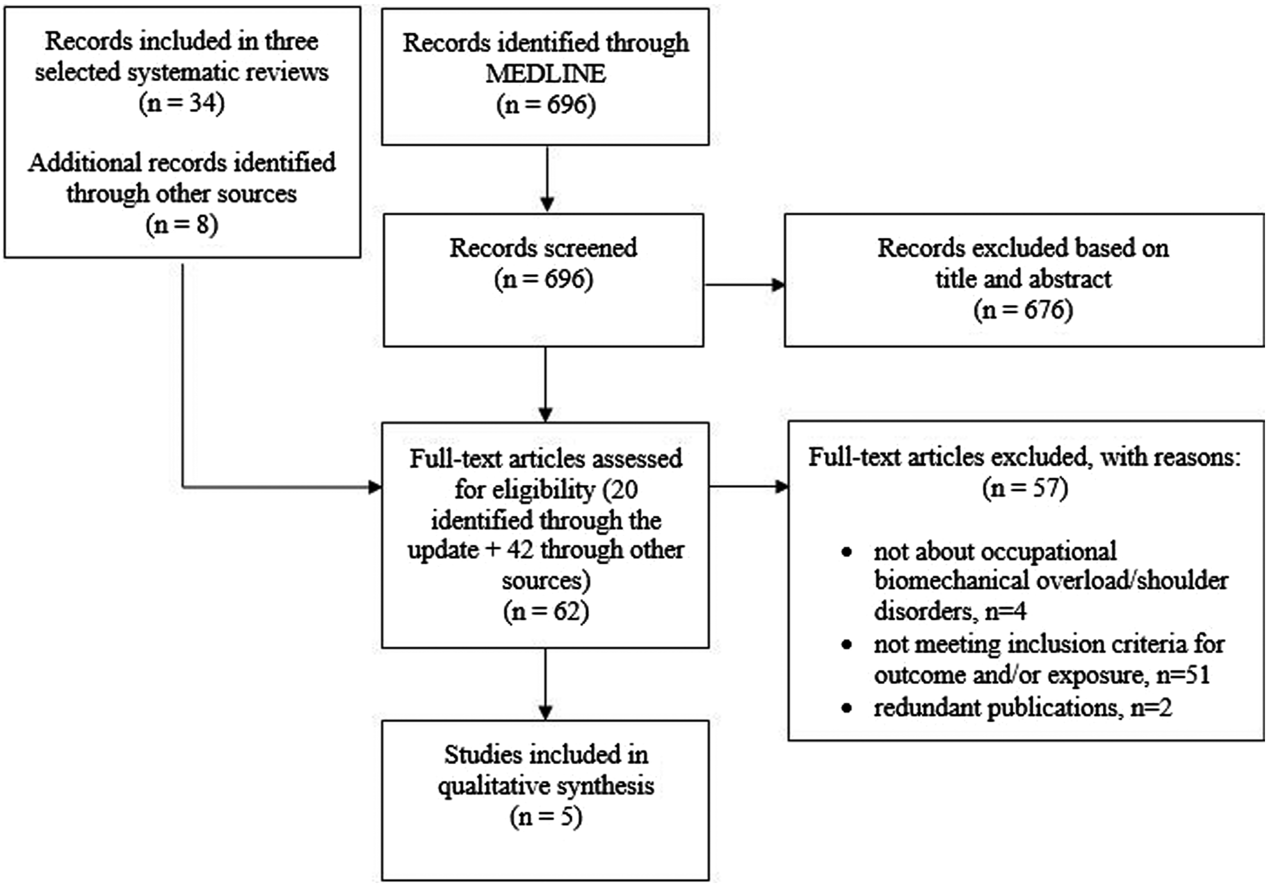

Figure 1. Flow-chart of included studies.

for all the included studies. In four out of five studies, the exposure was assessed by experienced ergonomists with video recordings combined with plant walkthrough and self-reported task distribution [15, 18, 22] or work history [17]. In one study, the exposure assessment was further supplemented by force gauge measurements of objects' weights and push/pull forces [17]. The other study was based on direct measurements of upper arm elevation above 30°, 60°, and 90° using an inclinometer which consisted of a sensor on each upper arm and a torque index combining posture and force along with the collection of individual occupational history [16].

In the study by Frost and colleagues, the risk of shoulder tendinitis was three times higher for workers performing repetitive tasks (adjusted Odds Ratio [OR] 3.12, 95% Confidence Interval [95%CI] 1.33-7.34) [15]. In particular, the high frequency of shoulder movements (i.e., 15-36 movements/min) was associated with an adjusted OR of 3.29 (95%CI 1.34-8.11) compared to non-repetitive work. The risk for high force demands (i.e., ≥10% of maximal voluntary contraction) was more than fourfold (adjusted OR 4.21, 95%CI 1.71-10.40) compared to the reference group, whereas performing 80% of cycle time without pauses reported an OR of 3.33 (95%CI 1.37-8.13). Combined exposures were found to be at risk as well [15]. Svendsen and colleagues reported that supraspinatus tendinitis was associated with current upper arm elevation above 90° for 6–9% of working hours (OR 4.70, 95%CI 2.07-10.68); however, no association was found for lifetime upper arm elevation above 90°, for both dominant and non-dominant shoulder [16]. The cohort study by Werner and colleagues did not report an association between shoulder tendonitis and abnormal hand activity threshold limit value (42.3% of incident cases vs. 40.6% of referent subjects, p=0.87

Table 1. List of studies included in published systematic reviews on specific disorders of the shoulder and work-related risk factors along with those included in the update categorised by quality of evidence.

Authors	Systematic reviews: van Rijn 2009	Systematic reviews: van der Molen 2017	Systematic reviews: Seidler 2020	Critical appraisal/update	Study Design	Outcome assessment	Exposure assessment	Ranking outcome/ exposure
Luopajärvi 1979	X	X			Cross-sectional	Humeral tendinitis: self-reported symptoms plus physical examination	Job title (assembly-line packers vs shop assistants)	+/-
Herberts 1981	X				Cross-sectional	Supraspinatus tendinitis: self-reported symptoms plus physical examination	Job title (welders vs office clerks)	+/-
Park 1992	X	X			Nested case-control	Rotator cuff syndrome: medical insurance claims	Work history	-/-
Andersen 1993	X				Cross-sectional	Rotator cuff syndrome: self-reported symptoms plus physical examination	Job title (sewing machine operators vs control group) and years of employment as sewing machine operators	+/-
Ohlsson 1994	X				Cross-sectional	Supraspinatus tendinitis, infraspinatus tendinitis, bicipital tendinitis: self-reported symptoms plus physical examination	Job title (fish processing factories vs control group)	+/-
Frost 1999	X	X			Cross-sectional	Shoulder impingement syndrome: self-reported symptoms plus physical examination	Years of employment as slaughterhouse work	+/-
Nordander 1999	X	X			Cross-sectional	Supraspinatus tendinitis, infraspinatus tendinitis, bicipital tendinitis: self-reported symptoms plus physical examination	Job title (fish processing factories vs control group)	+/-
Kaergaard 2000	X	X			Cross-sectional	Rotator cuff tendinitis: self-reported symptoms plus physical examination	Duration of exposure as sewing machine operators	+/-
Frost 2002	X	X	X	X	Cross-sectional	Shoulder tendinitis: self-reported symptoms plus physical examination	Observations by plant walk-through, video recordings, and self-reported task distribution	+/+

(Continued)

Table 1. List of studies included in published systematic reviews on specific disorders of the shoulder and work-related risk factors along with those included in the update categorised by quality of evidence. (Continues)

Authors	Systematic reviews			Critical appraisal/update	Study Design	Outcome assessment	Exposure assessment	Ranking outcome/ exposure
	van Rijn 2009	van der Molen 2017	Seidler 2020					
Svendsen 2004a	X	X	X	X	Cross-sectional	Supraspinatus tendinitis: self-reported symptoms plus physical examination	Inclinometer measurements, torque index, and job title	+/++
Svendsen 2004b	X	X	X		Cross-sectional	Supraspinatus tendinopathy: MRI without physical examination	Inclinometer measurements, torque index, and job title	NA/++
Miranda 2005	X	X	X		Cross-sectional	Chronic rotator cuff tendinitis: self-reported symptoms plus physical examination	Cumulative exposure based on self-reported work-related physical loading	+/-
Wang 2005	X	X			Cross-sectional	Shoulder impingement syndrome: self-reported symptoms plus physical examination, and ultrasonography	Job title (culler group vs non-culler group)	++/-
Werner 2005				X	Cohort	Shoulder tendinitis: self-reported symptoms plus physical examination	Jobs rated according to the American Congress of Governmental Industrial Hygienists' (ACGIH) TLV® for hand activity and peak force	+/++
Melchior 2006	X	X			Cross-sectional	Rotator cuff syndrome: self-reported symptoms plus physical examination	Manual work and self-reported physical work exposure	+/-
Sutinen 2006	X	X	X		Cohort	Rotator cuff syndrome: self-reported symptoms plus physical examination	Lifetime vibration dose in chain saw use	+/++ (*)
Kaerlev 2008	X	X			Cohort	Rotator cuff syndrome: hospital register (ICD-10: M75.1)	Job title (fishermen vs seamen)	-/-

Silverstein 2008	X	X	X	X	Cross-sectional	Rotator cuff syndrome: self-reported symptoms plus physical examination	Observations by workplace walkthrough, video recordings, force gauges measurements, and work history	+/++
Nordander 2009		X			Cross-sectional (pooling 30 studies, including Ohlsson 1994 and Nordander 1999)	Supraspinatus, infraspinatus & bicipital tendinitis: self-reported symptoms plus examination (diagnostic criteria not standardized and adequately described)	Occupational groups (exposure assessment not standardized and adequately described)	-/-
Seidler 2011		X	X		Population-based case-control	Supraspinatus tendon lesions: MRI and self-reported symptoms	Job title and self-reported physical workload	NA/-
Bodin 2012		X	X		Cohort	Rotator cuff syndrome: self-reported symptoms plus physical examination	Work history and self-reported work-related factors	+/-
Grzywacz 2012		X			Cross-sectional	Rotator cuff syndrome: self-reported symptoms plus physical examination	Job title (poultry vs non-poultry manual workers) and self-reported work-related factors	+/-
Herin 2012		X	X		Cohort	Chronic shoulder pain: self-reported symptoms plus physical examination	Self-reported work-related factors	-/-
Bugajska 2013		X			Cohort	Rotator cuff tendinitis: self-reported symptoms plus physical examination	Self-reported physical working conditions	+/-
Chung 2013		X			Cohort	Rotator cuff syndrome: national health insurance database (ICD-9 CM code: 726.1)	Job title (nurses vs reference group)	-/-
Rosenbaum 2013		X			Cross-sectional	Rotator cuff syndrome: self-reported symptoms plus physical examination	Job title (poultry vs non-poultry manual workers) and self-reported work-related factors	+/-
Svendsen 2013		X			Cohort (including the population described by Svendsen 2004b)	Subacromial impingement syndrome: first-time surgery (medical register, ICD-10: M19, M75.1– M75.9)	Job exposure matrix, experts' ratings and self-reported occupational exposure	-/-
Dalbøge 2014		X	X		Cohort	Subacromial impingement syndrome: first-time surgery (medical register, ICD-10: M19, M75.1– M75.9)	Job exposure matrix, experts' ratings, and employment register	-/-

(Continued)

Table 1. List of studies included in published systematic reviews on specific disorders of the shoulder and work-related risk factors along with those included in the update categorised by quality of evidence. (Continues)

Authors	Systematic reviews			Critical appraisal/update	Study Design	Outcome assessment	Exposure assessment	Ranking outcome/ exposure
	van Rijn 2009	van der Molen 2017	Seidler 2020					
Møller 2018			X		Cohort (same population as Thygesen 2016)	Subacromial shoulder disorders: diagnosed or surgically treated (patient register, ICD-10: M75.1-M75.9)	Job title (baggage handlers vs unskilled workers), self-reported data on work tasks, and biomechanical modelling in experimental setting	-/-
Hsiao 2015		X			Cohort	Shoulder subacromial impingement: military medical register (ICD-9 CM code: 726.10)	Military rank and branch of military service (military register)	-/-
Sansone 2015		X			Cross-sectional	Calcific tendinopathy: self-reported symptoms and ultrasonography without physical examination	Job title (cashiers vs customers)	NA/-
Nordander 2016		X			Cross-sectional (pooling 16 studies, including Ohlsson 1994, Nordander 1999 and Nordander 2009)	Supraspinatus, infraspinatus, and bicipital tendinitis: self-reported symptoms plus physical examination (diagnostic criteria not standardized and adequately described)	Direct measurements of physical exposure (exposure assessment not standardized and adequately described)	-/-

Thygesen 2016	X		Cohort	Subacromial shoulder disorders: diagnosed or surgically treated (patient register, ICD-10: M75.1-M75.9)	Job title (baggage handlers vs unskilled workers) and cumulative years of employment	-/-
Dalbøge 2017	X		Case-control (nested within the cohort described by Dalbøge 2014)	Subacromial impingement syndrome: first-time surgery (medical register, ICD-10: M19, M75.1– M75.9)	Self-reported job title, job exposure matrix, and cumulative occupational mechanical exposure	-/-
Dalbøge 2018	X		Cohort (reanalysis of Dalbøge 2014)	Subacromial impingement syndrome: first-time surgery (medical register, ICD-10: M19, M75.1– M75.9)	Employment register, job exposure matrix, and cumulative occupational mechanical exposure	-/-
Meyers 2021		X	Cohort	Rotator cuff syndrome: self-reported symptoms plus physical examination	Task-level biomechanical exposure assessment including video recordings: repetition rates and duty cycle of total exertion and forceful exertions, vibration (yes/no), and upper arm postures	+/++

(*) Occupational exposure to vibration was excluded from the present study.
Notes: NA, not applicable. These studies did not meet minimum requirements for diagnosis. The references of excluded studies are reported in Supplementary Table 3.

Table 2. Ranking for outcome/exposure combination by study design.

	Ranking for outcome/exposure combination			
Study design	**Minimum criteria for eligibility from (+/+) to (++/++)**	**Objective diagnostic criteria and indirect exposure assessment from (+/-) to (++/-)**	**Case definition based on self-reported symptoms from (-/-) to (-/++)**	**Not meeting minimum requirements for diagnosis**
Cross-sectional	3	12	2	2
Case-control	0	0	2	1
Cohort	3 (*)	2	9	0
Overall	6 (*)	14	13	3

(*) Sutinen 2006 measured the cumulative exposure to hand-arm vibration (excluded from the present study).
Note: The ranking for outcome and exposure combination is reported in Supplementary Table 1.

Table 3. Summary characteristics of included studies by study design (chronological order).

Study design	Country	Participants	Outcome	Main results	Covariates
Cohort					
Meyers 2021	USA	485 workers from a cohort of manufacturing and healthcare workers were followed for two years	Rotator cuff syndrome	Multivariable analyses: i. no association between rotator cuff syndrome and any single biomechanical exposure; ii. HR 1.11 (95%CI 1.04-1.34) for each unit increase in total repetition rate when the upper arm is abducted 30° for 12-21% of the working time; iii. HR 1.18 (95%CI 1.04-1.34) for each unit increase in forceful repetition rate when the upper arm is abducted 30° for 12-21% of the working time; iv. HR 1.16 (95%CI 1.04-1.29) for each unit increase in forceful repetition rate when the upper arm is abducted ≥60° for 5% of the working time; v. HR 1.11 (95%CI 1.01-1.22) for each unit increase in forceful repetition rate when the upper arm is flexed ≥45° for ≥29% of the working time	Confounders controlled for in the analysis: age, gender, education, BMI, diabetes mellitus, biomechanical exposure, psychosocial factors Data on physical activities outside of work were recorded
Werner 2005	USA	501 workers from four industrial and three clerical work sites were followed for an average of 5.4 years	Shoulder tendinitis	Univariate analysis: The study did not report an association between shoulder tendinitis and abnormal hand activity TLV (42.3% of incident cases vs 40.6% of referent subjects, p=0.87) or hand peak force at the dominant side (2.96 in incident cases vs 2.96 in referent subjects, p=0.98)	Covariates explored in univariate analysis included: age, gender, BMI, smoking habits, exercise levels, medical history, biomechanical exposure, psychosocial factors

Cross-sectional					
Silverstein 2008	USA	733 workers from manufacturing and health care sites	Rotator cuff syndrome	Multivariable analyses: i. OR 2.02 (95%CI 1.01-4.07) for frequent forceful exertions (i.e., ≥5 times/min); ii. OR 1.01 (95%CI 0.43-2.38) for performing shoulder movements > 20 times/min; iii. OR 2.16 (95%CI 1.22-3.83) for upper arm flexion ≥45° maintained for more than 18% of the time; iv. Combination of upper arm flexion ≥45° for more than 15% of the time was associated with rotator cuff syndrome either with a duty cycle of forceful exertions more than 9% of the time (OR 2.43, 95%CI 1.04-5.68) or a forceful pinch more than 0% of the time (OR 2.66, 95%CI 1.26-5.59)	Confounders controlled for in the analysis: age, gender, BMI, and psychosocial factors (only for combined exposures) Hobbies or sports requiring: i. high hand force, or ii. high repetitive hand activities were recorded
Svendsen 2004a	Denmark	529 machinists, 599 car mechanics, 758 house painters from 29 machine shops, 110 garages for domestic cars, and 119 painters' workshops	Supraspinatus tendinitis	Multivariable analyses: The supraspinatus tendinitis was associated with current upper arm elevation above 90° for 6-9% of working hours (OR 4.70, 95%CI 2.07-10.68) No association was found for lifetime upper arm elevation above 90° for both dominant and non-dominant shoulder	Confounders controlled for in the analysis: age, smoking habits, psychosocial factors Shoulder intensive sports were recorded
Frost 2002	Denmark	2846 workers from: four food processing companies, three textile plants, four electronic plants, three cardboard industries, two postal sorting centers, one bank, and two supermarkets	Shoulder tendinitis	Multivariable analyses: i. OR 3.29 (95%CI 1.34-8.11) for high frequency of shoulder movements (i.e., 15-36 movements/min); ii. OR 4.21 (95%CI 1.71-10.40) for high force demands (i.e., ≥10% of maximal voluntary contraction); iii. OR 3.33 (95%CI 1.37-8.13) for performing 80% of cycle time without pause; iv. combined exposures were found to be at risk	Confounders controlled for in the analysis: age, gender, BMI, shoulder injury/surgery, physical activity during leisure time, overhead sport

Abbreviations: ACGIH=American Conference of Governmental Industrial Hygienists; CI=Confidence Interval; BMI=Body Mass Index; HR=Hazard Ratio; OR=Odds Ratio; TLV=Threshold Limit Value.

at the univariate analysis) or hand peak force at the dominant side (2.96 in incident cases vs. 2.96 in referent subjects, p=0.98 at the univariate analysis) [22].

The study by Silverstein and colleagues reported that frequent forceful exertions (i.e., ≥ five times/min) were associated with an increased risk of rotator cuff syndrome (adjusted OR 2.02, 95%CI 1.01-4.07); on the other hand, performing shoulder movements more than 20 times per minute was found not to be associated (adjusted OR 1.01, 95%CI 0.43-2.38) [17]. In addition, upper arm flexion ≥45° doubled the risk of rotator cuff syndrome when maintained for more than 18% of the time (adjusted OR 2.16, 95%CI 1.22-3.83). The combination of upper arm flexion ≥45° for more than 15% of the time was associated with rotator cuff syndrome either with a duty cycle of forceful exertions more than 9% of the time (OR 2.43, 95%CI 1.04-5.68) or a forceful pinch more than 0% of the time (OR 2.66, 95%CI 1.26-5.59) [17].

The cohort study by Meyers and colleagues failed to identify an association between rotator cuff syndrome and any single biomechanical exposure. However, it showed an increased risk of incident rotator cuff syndrome for interactions between forceful hand exertions and upper arm elevation. In particular, it was found i) an hazard ratio [HR] of 1.11 (95%CI 1.04-1.34) for each unit increase in total repetition rate when the upper arm is abducted 30° for 12%-21% of the working time; ii) an HR of 1.18 (95%CI 1.04-1.34) for each unit increase in forceful repetition rate when the upper arm is abducted 30° for 12%-21% of the working time; iii) an HR of 1.16 (95%CI 1.04-1.29) for each unit increase in forceful repetition rate when the upper arm is abducted ≥60° for 5% of the working time; iv) an HR of 1.11 (95%CI 1.01-1.22) for each unit increase in forceful repetition rate when the upper arm is flexed ≥45° for ≥29% of the working time [18].

The quality assessment of the five included studies is reported in Table 4.

Four studies were ranked with medium quality scores [15-18], and the other one was classified as low quality [22]. Four out of five studies controlled for confounding [15-18]; of these, only one adjusted for non-occupational biomechanical risk factors [15].

4. Discussion

This review showed limited evidence of a causal relationship between occupational exposure to biomechanical risk factors and shoulder tendinopathies.

We summarised the existing epidemiological evidence for the associations between shoulder tendinopathies and occupational exposure to biomechanical risk factors. This study has a specific focus on both outcome and exposure assessment; in particular, we included i) studies in which physical examination was part of the outcome definition with or without the support of imaging; and ii) the exposure assessment was based on direct measurements or estimated with video recordings. Studies that used as outcome shoulder pain or were based on MRI/US without physical examination [24-26] were not considered to provide evidence of any causation as well those reporting/using an indirect measure of the exposure.

US was reported to be as accurate as MRI for identifying and measuring the size of partial and full-thickness rotator cuff tears [27]. However, a high prevalence of rotator cuff tears in asymptomatic subjects was detected using MRI [28]. The study also revealed a relationship of rotator cuff tears with increasing age in subjects who had normal, painless shoulder function. This casts a shadow for those studies that used imaging alone to diagnose shoulder tendinopathy in the absence of positive physical findings, considering that the disease–exposure association might be underestimated and confounded by age.

Compared to MRI, US tends to be more operator dependent, less costly and more accessible [29]. However, imaging techniques are not routinely applied in large epidemiological studies and, as reported in a recent scoping review, some studies proposed the use of X-ray to assess shoulder degenerative changes, while others sustained the use of US, to exclude a rotator cuff rupture [30].

A range of methods have been developed for the assessment of exposure to risk factors for work-related musculoskeletal disorders. The choice between these methods depends upon the nature of the investigation and purposes of the study. Self-reports from workers can be used to collect data on

Table 4. Detailed assessment of study quality for each included study (minimum score of 3 and maximum of 17).

Items	Frost 2002	Svendsen 2004a	Werner 2005	Silverstein 2008	Meyers 2021
a. Study design (1-3)					
Cross-sectional (1)	1	1	-	1	-
Cohort with a follow-up≤1 year (2)	-	-	-	-	-
Cohort with a follow-up>1 year (3)	-	-	3	-	3
b. Study population (0-3), sum of:					
Adequate description of inclusion/exclusion criteria (1)	1	1	0	1	1
Participation rate ≥70% (1)	1	1	0	1	1
Sufficient description on completers vs withdrawals (1)	0	0	0	0	0
c. Outcome assessment (1-3)					
Physical examination (symptoms and clinical signs) (1)	1	1	1	1	1
Physical examination (symptoms and clinical signs) plus imaging techniques (2)	-	-	-	-	-
Blinding for exposure status (+1)	1	1	0	1	1
d. Exposure assessment (1-3)					
Observation and video analysis (1)	1	-	1	-	1
Quantitative measurements (2)	-	2	-	2	-
Blinding for outcome status (+1)	0	0	0	1	1
e. Data analysis (0-5)					
Confounders in descriptive tables only (1)	-	-	1	-	-
Control for confounding (age, gender) (2)	-	-	-	-	-
Control for confounding (age, gender, and others) (3)	3	3	-	3	3
Analysis adjusted for non-occupational biomechanical risk factors (e.g. sport, hobby) (+1)	1	0	0	0	0
Robustness of the results to missing data (+1)	0	0	0	0	0
Total quality score	10	10	6	11	12

workplace exposure by using, for instance, interviews or questionnaires. However, a major problem with these subjective methods is that worker perceptions of exposure have been found to be imprecise and unreliable. For example, having musculoskeletal complaints were found to increase the probability of workers reporting higher durations or frequencies of physical load in comparison with those workers without musculoskeletal complaints from the same occupational groups [31, 32]. On the contrary, direct measurement techniques can provide more reliable data than those based on subjective judgements only. For the purpose of the present study, we included studies that reported quantitative measures of the exposure (like force measurement or, at least, observations supported by video analysis). Direct measurements and video-based observation of exposure are more desirable considering that these methods are assumed to have a higher level of accuracy than subjective assessment and self-reports [31, 32].

With respect to high frequency shoulder movements, only a cross-sectional study was in favor of an association with shoulder tendinopathies [15], while a cohort study [18] and a cross-sectional study [17] did not support it. In addition, another cohort study did not report an association between repetitive hand movements and shoulder tendinopathies [22].

Two cross-sectional studies reported an association with rotator cuff syndrome or supraspinatus tendinopathy with upper arm elevation [16, 17]. Conversely, a cohort study did not support this association [18].

With respect to forceful exertions, two cross-sectional studies reported an association with rotator cuff syndrome [17] or with shoulder tendinopathy [15], while two cohort studies did not report this association [18, 22].

Regarding combined exposures, a cross-sectional study showed an association between upper arm flexion (≥45°) and frequent forceful exertions with rotator cuff syndrome [17]. The same study reported an association between upper arm flexion (≥45°) and forceful pinch as well [17]. Moreover, a cohort study found a weak association between rotator cuff syndrome and forceful hand exertions plus upper arm flexion or abduction [18]. Finally, a cross-sectional study found an association between high-force demands and a high frequency of shoulder movements with shoulder tendonitis [15].

Based on a cohort study and a cross-sectional study of medium quality, we found moderate evidence of a causal association between shoulder tendinopathy and combined exposures of working with arms above shoulder level with forceful hand exertion [17, 18]. On the other hand, the evidence is still insufficient for any single biomechanical exposure considered by itself.

These findings contrast with a recent systematic review with metanalysis that calculated a 21% risk increase (95%CI 4–41%) per 1000 h of work above the shoulder [11]. It should be noted that the studies included in this meta-analysis were heterogeneous in terms of study design, exposure assessment, and diagnosis [24, 25, 33].

In the present study, we searched PubMed only. Nevertheless, PubMed indexes the vast majority of high-quality studies published in biomedical journals [34]. In addition to that, we successfully tested our PubMed search strategy against the 34 studies included in the three selected reviews [9-11]. As a result, all 34 citations were retrieved.

5. Conclusion

High-quality cohort studies are needed. Direct exposure measures and objective diagnostic criteria are desirable to minimize potential biases. Furthermore, there is a need for a consensus on the minimal diagnostic criteria used in epidemiological studies on shoulder tendinopathies. Epidemiological studies on the possible occupational origin of shoulder tendinopathies should consider non-occupational risk factors (including sports) and comorbidities. So far, the occupational origin of shoulder tendinopathies is still an open question that needs to be properly answered.

Supplementary Materials: Supplementary Table 1, Supplementary Table 2, Supplementary Table 3.

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Supplementary Table 1. Level of evidence based on data quality for exposure assessment and diagnosis.

Diagnosis	Exposure assessment		
	Direct evaluation		Indirect evaluation
	Quantitative measures	Video analysis or video-based observations	Job title, self-reported assessment, job exposure matrix, experts' ratings
Imaging (plus physical examination)	++/++	++/+	++/-
Physical examination (symptoms plus clinical signs)	+/++	+/+	+/-
Self-reported symptoms	-/++	-/+	-/-

Modified from Curti S, Mattioli S, Bonfiglioli R, et al. Elbow tendinopathy and occupational biomechanical overload: A systematic review with best-evidence synthesis. J Occup Health. 2021 Jan;63(1):e12186.

Supplementary Table 2. Search strategy developed for PubMed.

Search strategy
#1
(shoulder pain[MH] OR shoulder impingement syndrome[MH] OR ((rotator cuff[MH] OR "rotator cuff" OR infraspinatus[TW] OR supraspinatus[TW] OR subscapularis[TW] OR biceps[TW] OR bicipital[TW] OR shoulder joint[MH] OR shoulder[MH] OR shoulder*[TW]) AND (cumulative trauma disorders[MH] OR pain[TW] OR complaint* OR disorder* OR discomfort* OR symptom* OR tendon* OR tendin*)) OR "rotator cuff tear*" OR "rotator cuff syndrome" OR "rotator cuff disease*" OR "subacromial impingement" OR "shoulder impingement*" OR "subacromial pain")
#2
(occupational diseases[MH] OR occupational exposure[MH] OR occupational medicine[MH] OR occupational risk[TW] OR occupational hazard[TW] OR (industry[MeSH Terms] mortality[SH]) OR occupational group*[TW] OR work-related OR occupational air pollutants[MH] OR working environment[TW] OR "at work"[TW] OR "repetitive work" OR "manual work" OR lifting[MH] OR workload[MH] OR physical exertion[MH] OR Moving and Lifting Patients[MH] OR "heavy lifting" OR "manual material handling" OR "manual lifting" OR "manual handling" OR "repetitive lifting" OR posture[MH] OR "awkward position*" OR "awkward postur*" OR "above shoulder" OR "upper arm elevation" OR "overhead work")
#3
#1 AND #2
#4
#3 NOT (animals[MH] NOT humans[MH])

Supplementary Table 3. References of excluded studies.

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Svendsen 2013	Svendsen SW, Dalbøge A, Andersen JH, et al. Risk of surgery for subacromial impingement syndrome in relation to neck-shoulder complaints and occupational biomechanical exposures: a longitudinal study. *Scand J Work Environ Health*. 2013 Nov;39(6):568-77.
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Dalbøge 2017	Dalbøge A, Frost P, Andersen JH, Svendsen SW. Surgery for subacromial impingement syndrome in relation to occupational exposures, lifestyle factors and diabetes mellitus: a nationwide nested case-control study. *Occup Environ Med*. 2017 Oct;74(10):728-736.
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Occupational Exposure to Solar Radiation and the Eye: A Call to Implement Health Surveillance of Outdoor Workers

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Summary

Globally, hundreds of millions of outdoor workers are exposed to solar radiation (SR) for most of their work. Such occupational exposure is known to induce various adverse health effects on the eyes, mainly related to its ultraviolet (UV) component. The present work is a call to action to raise awareness of the need for health surveillance to prevent chronic ocular diseases in outdoor workers. Photo-chemical chronic damage can induce pterygium at the eye's outer layer and cataracts in the lens. Considering carcinogenic effects, rare squamous-cell tumors of the cornea and/or the conjunctiva and ocular melanomas are associated with UV radiation exposure. Solar UV-related eye diseases should be considered "occupational diseases" when workers have sufficient exposure. Still, they are often not recognized and/or frequently not reported to the national compensation authorities. Therefore, to prevent the burden of these work-related eye pathologies, an adequate risk assessment with identification of appropriate preventive measures and a provision of periodic health surveillance to the exposed workers, particularly those at higher risk of exposure or with individual susceptibility, should be urgently implemented.

1. Introduction

Solar radiation (SR) is essential for human life and is related to various health benefits, such as reducing the risk of rickets, osteoporosis, and possibly other diseases due to its effect on vitamin D activation [1-3]. However, SR exposure is also a well-known health risk for outdoor workers (OW): the components of SR, i.e., ultraviolet (UVR), visible and infrared radiation (IR), defined as 'optical radiation' (OR), can have a significant health impact in particular on the eyes and the skin of the workers. Fortunately, the most hazardous UVR bands, i.e., all the UV-C and the majority (about 95%) of the

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Table 1. Optical radiation bands within solar radiation at the Sun vs. Earth's surface and ocular exposure [4-5].

Classification	Sub-class/ Wavelength (nanometers)	Emitted by the Sun	Reaches the Earth's surface	Reaches the outer layers of the eye	Reaches the lens	Reaches the retina
ULTRAVIOLET (UV)	UV-C/100–280	Yes	No	Yes[1]	No	No
	UV-B/280–315	Yes	Only 5%	Yes	Yes	No
	UV-A/315–400	Yes	Yes	Yes	Yes	Yes[2]
VISIBLE	from violet to red/400-780	Yes	Yes	Yes	Yes	Yes
INFRARED (IR)	IR-A 780–1400	Yes	Yes	Yes	Yes	Yes
	IR- B/1400–3000	Yes	Yes	Yes	Yes	No
	IR-C/3000-1000000	Yes	Yes	Yes	No	No

[1] *Only potentially, as there is no ocular exposure to solar UV-C at the Earth's surface.*
[2] *Only a small percentage, depending on age and on lens transparency, of UV-A with wavelengths around 390-400 nm able to reach the retina.*

UV-B, are absorbed within the stratospheric ozone layer before reaching the Earth's surface (Table 1) [4].

Occupational exposure to OR may derive from artificial (e.g., welding arcs) and natural sources. However, SR is probably the most widespread occupational exposure in terms of the number of workers exposed worldwide, i.e., all those performing outdoor activities or mixed indoor/outdoor jobs. Moreover, the sun is also the potentially most harmful occupational OR source due to the high exposure levels received by OW, resulting in a significant burden of several SR-related diseases [2, 4].

When SR reaches a human subject, its components can interact with the biological tissues, determining an effect based on the: (a) type of radiation (i.e., the specific classes and sub-classes of OR involved, related to the intrinsic characteristics of the radiation, including its energy), (b) intensity, duration and frequency of the exposure and (c) characteristics of the exposed biological tissue/body part concerning its specific interaction with the radiation [2, 4]. Due to the relatively low penetration ability of OR compared to other types of radiation, these effects mainly involve the skin and the eyes [2, 4].

The purpose of this review is to present a call to action in order to implement health surveillance for OW exposed to SR. We focus on the issue of the prevention of possible adverse ocular effects, considering that many efforts have been made in recent years to raise awareness on the problem of the prevention of skin cancers affecting OW, while SR-related eye diseases of the workers are still under-recognized. Only long-term effects are specifically addressed here, as short-term effects result from acute exposures to high levels of SR, usually representing accidental exposures. These effects cannot be prevented with health surveillance, which can only detect and monitor the phenomena, while for prevention purposes, other technical and organizational measures, as well as workers' information and training, can be implemented. According to the International Labour Organization (ILO) and the International Commission on Occupational Health (ICOH), health surveillance includes the "…procedures and investigations to assess workers' health in order to detect and identify any abnormality…" and its objectives must be clearly defined. These procedures have to be implemented and applied in all the working situations where a relevant occupational risk for the health of the exposed workers exists, and the health surveillance program must be tailored to the specific occupational risk considered and consistent with available scientific evidence and good practice [6-7]. According to these premises, the scientifically demonstrated biophysical mechanisms explaining the chronic SR exposure-related ocular damages will be presented in the following sections of this review. This will allow an evidence-based recognition of the long-term non-carcinogenic and carcinogenic effects, recently identified in various systematic reviews, that need to be investigated within a good health surveillance program. Finally, we will also discuss the specific contents of health surveillance for the prevention of long-term adverse eye effects occurring in OW exposed to SR, giving the currently available indications and inserting health surveillance in the context of the other applicable preventive measures to deal with the SR-exposure risk for the eyes at the workplace.

2. Solar Radiation Exposure of the Eyes and Adverse Effects: The Mechanisms Involved

The effects of SR exposure at the eye, similar to what happens to the skin, can be related to photochemical or thermal mechanisms. The former relates to the interactions of OR bands with specific molecules in the eye tissues, determining chemical reactions, possibly resulting in short-term and long-term ocular damage. On the other hand, thermal effects related to SR exposure are mainly acute effects, possibly occurring only after very intense and focused exposures, as a consequence of a significant increase in the temperature of the eye tissues [2, 4, 8-11]. In the case of UVR exposure, the effects are almost exclusively photochemical, while for IR exposure, the mechanisms involved are thermal, and in the case of exposure to visible light, both mechanisms can be crucial. In particular, photochemical effects can be more relevant for visible radiation with wavelengths between 400 and 550 nanometers, while thermal mechanisms are more typical of wavelengths between 600 and 700 nanometers [2, 4, 8-9].

The effects of OR exposure can appear in the eye's target regions where the specific OR band is absorbed (Table 1, Figure 1). For example, UV-C is absorbed mainly at the ocular surface (however, this UV band does not reach the Earth's surface within

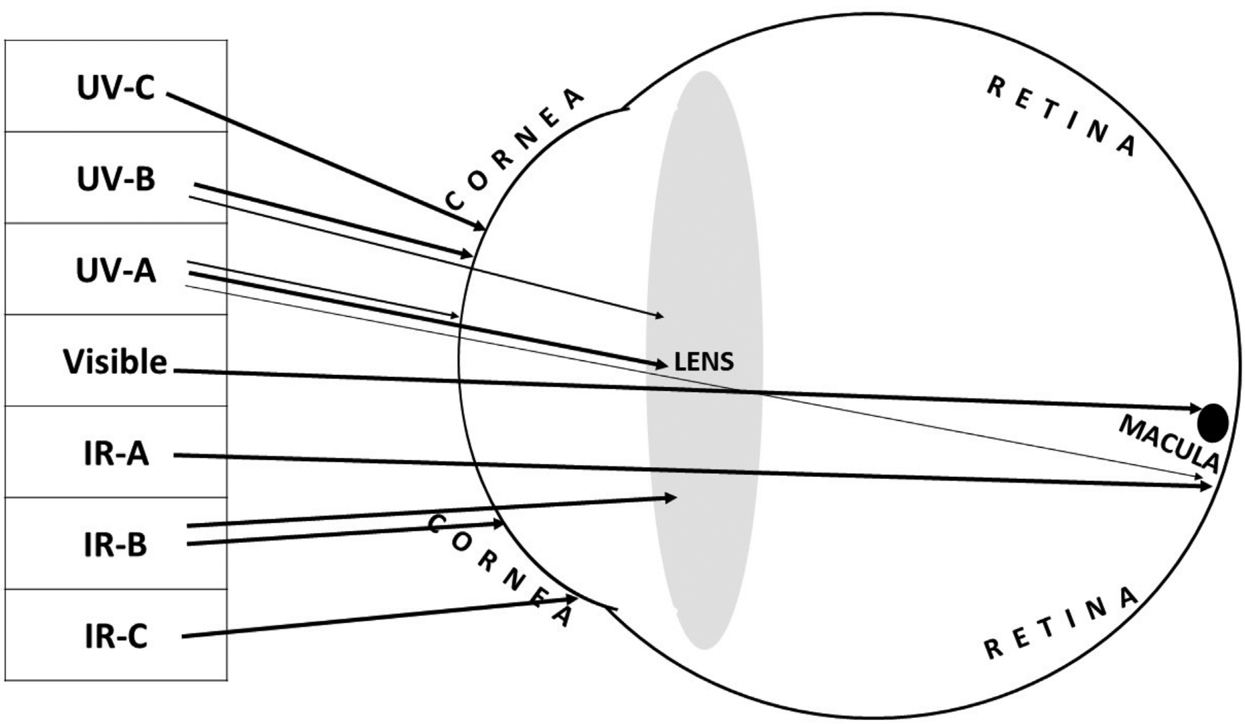

Figure 1. Penetration of the different components of optical radiation into the eye.

SR), while UV-B and UV-A are absorbed in the ocular surface and the crystalline lens. A small amount of UV-A (approximately 1-2% on average, depending on age, higher during childhood and lower at older ages) is also absorbed in the retina. The retina absorbs visible radiation and IR-A, while IR-B and IR-C mainly interact with the ocular surface, with the remaining IR-B absorbed by the lens (Figure 1) [2, 4, 8-9]. When considering how the different OR bands reach the eyes, it must be noted that various anatomical and physiological protections prevent excessive OR exposure, allowing good vision and decreasing the amount of harmful radiation absorbed by the eyes' structures. Firstly, the frontal and orbital bones of the skull provide anatomical protection, particularly against overhead OR exposures. Also, eyelashes, eyelids, and eyebrows have a significant protective function.

Moreover, various involuntary ocular reflexes defend the eyes from intense direct OR exposures, e.g., squinting and aversion responses, occur in a few fractions of a second [2, 4, 8-9]. The pupillary reflex is probably one of the most critical reflexes as, depending on the light intensity, there is the regulation of the pupil's diameter, increasing the amount of OR reaching the macula when light is scarce (mydriasis) and decreasing it when light is more intense (miosis). This reflex is specifically aimed at providing good vision under different illumination conditions, but it is also a suitable defense mechanism from excessive retina exposure to hazardous OR components [4, 9-10].

As introduced above, the effects of OR can be based on thermal or photochemical mechanisms. Thermal effects are due to an increase in the temperature of the eye, with adverse health effects only occurring if the energy has sufficient power. Otherwise, the tissue dissipates the heat with no health consequences [8]. For these reasons, the thermal effects of OR within the eye are mainly acute and more typical after exposure to artificial sources that can focus high energies on small regions of the eyes, e.g., in case of accidental exposure to LASERs [11]. These exposures can result in ocular thermal burns involving superficial and inner structures, such as the retina [8, 11]. It should be noted that, in the case of SR exposure, thermal retinal damage may occur when people directly look at the Sun for long periods without adequate protection, e.g., during partial solar eclipses [12].

On the other hand, photochemical effects are mainly related to the action of the photons, being absorbed by specific target chromophores in the different eye structures (Figure 1). Photochemical effects can result from intense short-term exposures and repeated exposures exerting chronic damage (i.e., inflammation, DNA mutations, formation of reactive oxygen species, protein denaturation, etc.) over many years [2, 4, 9, 13]. The acute effects of UV exposure mainly involve the ocular surface, particularly the cornea and the conjunctiva. Intense exposure to unprotected eyes can induce a photochemical lesion with acute and painful inflammation, redness, and photophobia, called photo keratitis and photo conjunctivitis, often presenting together [2, 4, 9, 13]. In contrast to thermal burns, UV-related injuries involve a latency period before appearance (usually about 30 minutes for the eyes). The reason is that UV rays need sufficient time to interact with the biological tissues and, in particular, with the chromophores inside the corneal and conjunctival cells, inducing the disruption of chemical bonds and the formation of new chemical bonds as a result of the energy released by the photons, therefore initializing the inflammation process [2, 4, 9, 13]. The massive penetration of UV rays in the eyes only happens when the visible component of the OR arising from the same exposure source is not sufficiently intense to cause glare and trigger consequent defense mechanisms of the eye. This can happen, for example, when UV rays are reflected by white or polished surfaces to penetrate the eyes, while direct exposures are shielded [2, 4, 9, 13]. Photo keratitis and photo conjunctivitis are possible on fresh snow surfaces [14] because of their high UV reflectance. Another possibility is using protective equipment such as eyeglasses or masks not explicitly designed for filtering the different UV components. In these cases, even if the equipment blocks a fraction of the OR, some bands of the UVR can reach the ocular surface, potentially causing acute damage.

Nevertheless, it should be noted that, in the case of SR exposure, these events are improbable, as all plastic lens materials block the most energetic

UV-B component and some UV-A, and many are treated to extend the blockage to near 400 nm. Meanwhile, glass lenses are less effective in blocking near UV if not adequately integrated with specific filters, and so are rarely used, especially in occupational settings, but even these materials can block most UV-B. Photoretinitis is another possible result of acute ocular exposure to SR. This is a photochemical lesion in the retina induced by UV-A and short-wavelength visible light ("blue light") [4, 8-9, 13-15]. It is unlikely to occur in OW since it requires affected individuals to stare directly at a very intense source like the Sun (e.g., eclipse retinopathy) for an extended period.

As noted earlier, photochemical effects are also possible due to long-term exposure: this is called the reciprocity rule of photobiology, known as the Bunsen-Roscoe law [16]. This is why OWs exposed to SR, mainly because of its UV component, are not only at risk for acute ocular effects that, according to a medico-legal definition, are occupational injuries but are also more likely to develop long-term adverse eye effects related to SR exposure.

3. Non-Carcinogenic Chronic Adverse Eye Effects Related to Long-Term Occupational Solar Radiation Exposure

The main non-carcinogenic long-term adverse eye effects induced by SR exposure that are preventable include pterygium for the ocular surface, cataracts for the lens, and, possibly, as the evidence level is still considered insufficient, macular degeneration for the retina [2].

The photochemical damage related to cumulative SR exposure, and in particular to its UV component absorbed at the ocular surface (i.e., cornea, conjunctiva), can determine a chronic inflammatory stimulus inducing pathological alterations with abnormal growth of the corneal and conjunctival cells [10, 17]. This may result in various diseases, some more likely to present as aesthetic alterations with no clinical relevancy, such as pinguecula [18]. However, others are more severe and potentially affect visual function if not treated, such as pterygium, abnormal growth of the conjunctiva from the nasal angle of the eye to the center, and finally, covering the cornea [19].

Pterygium prevalence is significantly higher among male subjects, who are more likely to perform outdoor work compared to females. In general, the reported prevalence estimates are highly variable, primarily depending on the latitude of the study's location. However, it is generally agreed that a higher disease prevalence correlates with lower latitudes, ranging, according to a recent systematic review, from 2.5% to 52% in the adult populations included [20]. Overall, outdoor work was strongly associated with the occurrence of pterygium, with research reporting significantly increased odds ratios in almost all the studies published on this topic [20], reaching values up to a 4-fold increased likelihood of OW developing the disease compared to indoor workers [20-21]. Another possible result of high-level chronic exposure to solar UV is decompensation of the cornea, in which loss of corneal endothelial cells breaks down the mechanism that maintains dehydration of the corneal stroma. These observations were reported for welders and some OW several years ago, while currently, the increased standards for eye protection seem to have significantly reduced the occurrence of these UV-related corneal disorders [22].

Penetrating through the ocular surface, the UV component of SR, mainly UV-A but also a fraction of UV-B [23], can induce long-term photochemical damage of the lens based on photo-oxidative mechanisms resulting in a UV-induced cataract [24]. There is solid mechanistic and experimental evidence suggesting that UVR induces cataracts through photo-oxidation and inflammatory response pathways, as well as through causing DNA damage. Animal studies also support a causal effect of UVR in the development of cataracts. In addition, epidemiological studies have shown strong support for an association between personal solar UVR exposure and the development of cortical cataracts and possibly other forms [23-24]. According to the World Health Organization (WHO), in 2006 the population-attributable fraction of cortical cataracts associated with SR was 25% [2].

Moreover, within its global health estimates of the total disease burden due to SR exposure, the WHO calculated a loss of 529.242 DALYs globally from cataracts attributable to solar UVR, with higher proportions of cortical cataracts at lower latitudes [2]. These estimates only covered cortical cataracts: more recently, new evidence also emerged showing a positive association between the performance of outdoor work with SR exposure and the development of nuclear cataracts [25], while other forms with posterior subcapsular opacities seem more related to lens damage induced by other types of radiation, particularly those which are ionizing in nature [26]. When it is considered that cataract is the leading cause of blindness worldwide, along with the significantly increased risk for OW of developing lens opacities [25], the WHO, together with the ILO, recently included solar UVR-induced cataract as one of the outcomes addressed in their joint project for estimating the work-related burden of various diseases [27].

Finally, another non-carcinogenic chronic eye disease should be mentioned here: age-related macular degeneration (AMD), currently the most important cause of vision loss in adults above 50 in high-income countries [28]. A hypothesis states that chronic photo-oxidative retinal damage is one of the main pathogenic pathways inducing degenerative disease [29]. In addition to UVR, as highly energetic blue light can induce photo retinitis, it may be supposed that chronic blue-light-related photochemical damage of the macula may play a role in the development of AMD [30]. Moreover, it should be noted that SR reaching the retina includes a small amount of UV-A in addition to blue light [15, 31]. Although the experimental evidence demonstrating AMD induction after long-term SR exposure is still considered inadequate, several epidemiological studies show AMD associations with outdoor work performance. A recent systematic review found ten studies with significantly increased odds ratios up to a 3-fold increased likelihood of developing AMD due to outdoor work [32].

4. Carcinogenic Eye Effects Related to Long-Term Occupational Solar Radiation Exposure

Eye tumors are rare, with two main groups related to SR exposure considered relevant for prevention purposes: epithelial tumors of the ocular surface and melanoma of the eye [33].

Regarding epithelial tumors, corneal and conjunctival squamous cells can develop carcinomas similar to the skin. Although extremely rare, research has demonstrated that epithelial tumors are associated with cumulative solar UVR exposure [33]. The incidence rates of these cancers (i.e., < 1 case per million people in Europe) are low for sufficient statistical power to perform epidemiologic studies in groups of OW, which are therefore lacking [33-34]. Nevertheless, various reports indicate that squamous cell carcinomas of the cornea and the conjunctiva show an increased incidence in countries at lower latitudes, such as African countries and Australia compared to Europe and the USA [34]. Among the few available epidemiological studies investigating possible risk factors for epithelial eye tumors, Lee et al. found an increased odds ratio of 7.5 (CI 95% 1.8-30.6) for chronic SR exposure, in particular at younger ages for those living 30° or less from the equator [35].

Although melanoma of the eye is rare (incidence <10 cases per million people), it is the most frequent intraocular malignancy among adults. This cancer is more frequent and aggressive than corneal and conjunctival carcinomas, with an increased risk of metastasis [33-34]. Intraocular malignant tumors have been reported as possibly associated with UV exposure, particularly in welders [33, 36]. Still, an increasing number of studies suggest a possible association with excessive SR exposure [33-34]. Nevertheless, as is the case with skin melanoma, which is believed not to be associated with cumulative UVR but only with repeated sunburns, there is still some scientific debate on the association of ocular melanoma with cumulative SR exposure, typical of OW [37].

5. Prevention of the Ocular Damage Related to Occupational Solar Radiation Exposure: A Focus on Health Surveillance

Considering the prevention of ocular damage related to occupational SR exposure, the usual approach includes a risk evaluation and, based on it, the implementation of adequate protective measures and health surveillance of exposed workers.

Risk evaluation of outdoor worker exposure to SR generally consists of estimating or measuring personal SR exposures of workers and comparing these to accepted occupational exposure standards. The standards produced by the ACGIH and ICNIRP provide 'acceptable' exposure limits for the prevention of acute and chronic eye conditions [13, 38]. Measurement of personal SR exposure of OW can be undertaken using a variety of techniques, including plastic film dosimeters [39], biological dosimeters [40], and electronic dosimeters [41]. However, these measurements primarily describe skin exposure, whereas there is a range of additional factors influencing ocular SR exposure. As such, ocular SR exposure has been assessed in a series of studies using dosimeters attached to manikins [42], sunglasses of OWs [42-43], and purpose-designed SR dosimeter contact lenses [44]. These studies have assessed SR exposure at the eye's surface and reported their results in terms of an 'Ocular Ambient Exposure Ratio' (OAER, i.e., the proportion of ambient SR which reaches the eye). The reported OAERs have varied dramatically from 4% to 46% [27], with an average annual OAER of 13% considered representative across job categories and seasons [45]. As such, to complete a risk evaluation for ocular SR exposure, the OAER is applied to personal SR exposure measurements, and these are then compared with the occupational exposure standards to determine whether there is an elevated risk of adverse eye conditions. Nevertheless, there is still a lack of data on ocular SR exposures in the occupational setting, and this may limit the possibilities of an adequate risk evaluation and detailed epidemiological research on the associations between work exposures to various OR components and eye damage.

Adequate preventive measures, including those aimed at the collective and the individual implementing these measures, should be coordinated through a Sun Safety Program, part of a workplace's Occupational Health and Safety Management System [46]. Considering SR exposure as an occupational risk factor, collective prevention can be provided with engineering and administrative controls. A fundamental collective measure for prevention is the adequate information and training of the workers on the risks and their reduction. Technical interventions include the coverage and shading of the outdoor workplaces to reduce the amount of harmful OR directly reaching the skin and the eyes of the workers. All the artificial and natural surfaces in the work environment must also be evaluated based on the albedo properties of the specific materials: as anticipated, the eyes are naturally protected from overhead exposure. At the same time, reflections are a relevant issue that must be prevented [46-48]. Considering organizational measures, these usually consist of the provision of (i) work breaks to be spent indoors or at least under well-shaded areas; (ii) modification of the working hours according to the season of the year (e.g., in summer, starting earlier in the morning and avoiding, or at least significantly reducing, the work activities during the central hours of the day when the UV index is ≥3); and (c) rotation of the exposed personnel. Individual protection mainly includes using personal protective equipment (PPE) [46-48]. Regarding ocular SR exposure, appropriate PPE includes eye protection and hats [49-50]. Sunglasses adequate for use at the workplace should comply with the requirements of standards for PPE [51-52], both in terms of the ability of the lens to properly filter all the harmful OR bands included in the SR spectrum, especially UVR (with appropriate labeling on the PPE), and of the shape of the sunglasses. Good sunglasses must have ample and properly shaped lenses that can be worn close to the eyes to enhance their protective function and prevent SR exposure from overhead or the side, and wide temples to protect the skin close to the eye. Moreover, the lenses must be appropriate for the specific type of activity performed: e.g., able to resist chemical or physical agents if needed, break and scratch resistant, anti-glare, etc. [46-48].

The choice of appropriate head covering depends on the type of occupational outdoor activity. In agriculture and fishing sectors, for example, broad-brimmed or legionnaire hats can shield the forehead and eyes appropriately. In the construction sector, workers must wear safety helmets that, for better protection against the risk of excessive SR exposure, can be larger on the front to shield the forehead and supplied with brim attachments to protect the ears and neck [46-48].

Moreover, as introduced above, to improve prevention, in case of residual risk after the assessment process and the implementation of other preventive measures, a specific health surveillance program should be set up for the exposed workers. It is uncommon to see health surveillance programs addressing OW to prevent SR-induced adverse eye effects [46]. In many countries, recent increased awareness of the need to protect OW from harmful SR exposure has been reported. However, the focus of these health surveillance activities is generally related to preventing possible adverse skin effects [48]. One of the main challenges in fully recognizing SR as an occupational risk factor is the unavailability, in the vast majority of the countries of the world, of regulations that identify an occupational exposure limit for SR, with this providing different considerations for ocular and skin exposures [27].

Another fundamental element for preventing SR-related adverse eye effects is the need to identify workers belonging to susceptible groups, which may be more susceptible to developing ocular and skin diseases, and therefore deserving of focused attention during preventive health surveillance activities [46-47]. Considering adverse ocular effects, a non-exhaustive list of possible conditions increasing susceptibility includes workers with alterations of the iris (e.g., coloboma or aniridia), with conditions determining chronic dilation of the pupil or with the absence of the lens (aphakia) or surgical removal of the lens (pseudophakia). In these cases, the alterations of the ocular structures result in possibly different levels of penetration of blue light and UV radiation into the eye. Other conditions to be potentially evaluated during health surveillance include those related to possible indications of early damage, e.g., the identification of drusen for macular degeneration or small opacities for cataracts. In such cases, the workers should be followed closely, as long-term exposure to SR may worsen the condition. Finally, other individuals who should be included among the group of susceptible workers are those with monocular vision, as in this case, the induction of disease in the healthy eye can lead to vision loss [46-47].

We argue, therefore, that a specific health surveillance program should be established for all workers exposed to potentially harmful solar UVR levels and, in particular, for those with a potentially increased susceptibility. Considering SR-associated adverse eye effects, the objective of this health surveillance would be the primary prevention, or at least (if the damage has already developed in its initial phase) early diagnosis of these diseases and their precursory ocular changes. Health surveillance programs usually include pre-employment and periodic medical examinations by trained occupational physicians, who may require, on an individual basis, supplementary assessments and management by ophthalmologists and optometrists for the specific problems detected [46-47]. As UVR is a carcinogenic agent, even if eye tumors are rare, the additional carcinogenic risk for the eyes of the exposed workers also has to be considered [33]. Finally, SR-related eye diseases occurring in OW should be reported to national compensation authorities so that they can be recognized as occupational diseases, thus raising awareness of the problem among the general public and exposed workers, as well as among employers, occupational health and safety professionals, and policymakers, who are often not fully aware of the problem [46-48]. Currently, these diseases are underreported, if not totally neglected, in countries that include such diseases in the available lists of occupational diseases and in countries that do not consider them. Accordingly, it is vitally essential that SR-related eye diseases be included in the official lists of occupational diseases in all countries. Such an approach is considered one of the first steps to fully recognize these pathologies as being related to outdoor work and therefore notified and compensated appropriately.

6. Conclusions

Epidemiological studies consistently report increased eye diseases among workers with long-term exposure to SR, including pterygium, cataracts, eye tumors, and, possibly, macular degeneration. These diseases should be recognized as "occupational diseases", but they are frequently not reported to the national compensation authorities. To prevent the burden of these work-related eye diseases, an adequate risk evaluation with the identification of appropriate preventive measures (e.g., eye protection) and the provision of health surveillance programs for exposed workers (and in particular for those with increased susceptibility) should be implemented as a matter of urgency.

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

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The Professional Future in Operated Carpal Tunnel Syndrome: A Cross-Sectional Study of Recognized Occupational Cases

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Abstract

Background: *Carpal tunnel syndrome (CTS) is frequently present among workers. This syndrome's professional and economic impact makes it a priority in occupational health. We aimed to describe the professional future of workers suffering from occupational CTS after surgery and the factors that could influence their retention at the job.* **Methods:** *A retrospective descriptive study of workers operated on occupational CTS was conducted from 2014 to 2019. The data was collected using pre-established and phone questionnaires to determine their professional future after surgery.* **Results:** *We included 99 workers with operated CTS. They had a mean age of 45±6.5 years, were predominantly female (97%), and had two dependent children in 72.7% of cases. They worked as a seamstress in 44.4% of patients with a mean professional seniority of 18±7.2 years. The professional future was a return to work with a job transfer at 44.4% and job maintenance with ergonomic adjustments at 39.4%. A job loss was noticed in 12.2% of cases. Early retirement was noticed in 8.2%, dismissal in 3%, and resignation in 1% of cases. The factors influencing the professional future were age 50 to 59 years (p=0.01) and dependent children (p=0.02).* **Conclusions:** *In our survey, most operated-CTS workers benefited from a job transfer and kept their job with ergonomic adjustments to their work conditions. Therefore, interventions aiming to improve the professional future of workers operated on CTS by ensuring sufficient staff and adjusting workplaces are needed.*

1. Introduction

Carpal tunnel syndrome (CTS) is the most common peripheral nerve entrapment syndrome frequently present among workers [1]. This syndrome is a major musculoskeletal disorder (MSD) of the upper limbs, leading to harmful adverse effects on workers' health and a high absenteeism rate. The impact of this disease, in terms of disruption of career and economic costs, makes it a priority of health at work [2]. However, there are few epidemiological studies of the prevalence of CTS in Tunisia, and there are mainly case series studies of work-related CTS [3-7]. The pathogenesis of this syndrome is the result of several factors, which are represented primarily by occupational constraints requiring to work in an «assembly line» or a «set pace,» which often makes the worker perform stereotyped and monotonous activities, repetitive movements, carrying heavy loads, and without sufficient rest breaks, linked with individual factors [8]. Therapeutic options are medical in moderate CTS forms and surgical in severe or drug-resistant forms. Moreover, even after suitable medical or surgical treatment,

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the patient may still have functional sequelae which limit his professional skills and cause a problem of professional integration and especially a problem of job retention.

We aimed to describe the professional future of workers suffering from occupational CTS after surgical treatment and the factors that could influence their retention at the job.

2. Methods

2.1. Study Design

It was a cross-sectional retrospective descriptive study that concerned patients with CTS treated surgically and recognized as an occupational disease for six years, from January 1st, 2014, to December 31st, 2019.

2.2. Settings

Data were collected at the National Health Insurance Fund (NHIF) head office in Tunis, where the northern committee for recognizing occupational diseases is. Data collection was based on a pre-established questionnaire. Patients operated on CTS have been identified from a database including all the recognized occupational cases of CTS (operated and non-operated ones) since 2014 and from medical records. An additional phone survey was needed to identify operated patients, specify the decision for medical fitness to work and complete the missing data.

2.3. Participants

During the study period, workers who were operated on CTS recognized as an occupational disease and accepted to answer the questionnaire were included. Workers not operated on or operated on after the study period were excluded. Workers not reached by phone and those who refused to answer the questionnaire were excluded.

2.4. Variables and Data Sources

The questionnaire included four sections on socio-demographic characteristics (age, gender, school level, marital status, dependent children), occupational characteristics (job category, workstation, occupational qualifications, professional seniority in the company, biomechanical occupational constraints, the time before resuming work after surgery) and medical characteristics (medical history, CTS characteristics especially the site, the onset and the evolution of symptoms before surgery, the severity of the disease, the association with other MSD, the postoperative course, and the practice of functional rehabilitation) as well as the assessment of professional outcomes. Participation in the phone survey was voluntary, and anonymity was respected. The administration of the questionnaire by phone could generate reporting bias. Coverage error in phone samples could explain the selection bias and underestimation of the target population.

2.5. Statistical Methods

Data were analyzed using the SPSS 19.0 software. Absolute frequencies and relative frequencies (percentages) were calculated for qualitative variables. Averages, medians, and standard deviations were measured, and extreme values were determined for quantitative variables. The Chi-square test was used to compare percentages of independent series. The two-interval Fischer exact test was used for nominal variables. In all statistical tests, the significance level was set at 0.05.

3. Results

3.1. Participants

During the study period, 99 workers operated on CTS recognized as an occupational disease and reachable by phone were included among 320 recognized cases (operated and non-operated on). Among the initial workforce, 125 patients were unreachable, 90 were not operated on CTS, four had surgery in 2020, and two refused to answer the questionnaire. The flow chart explaining the study population is shown in Figure 1.

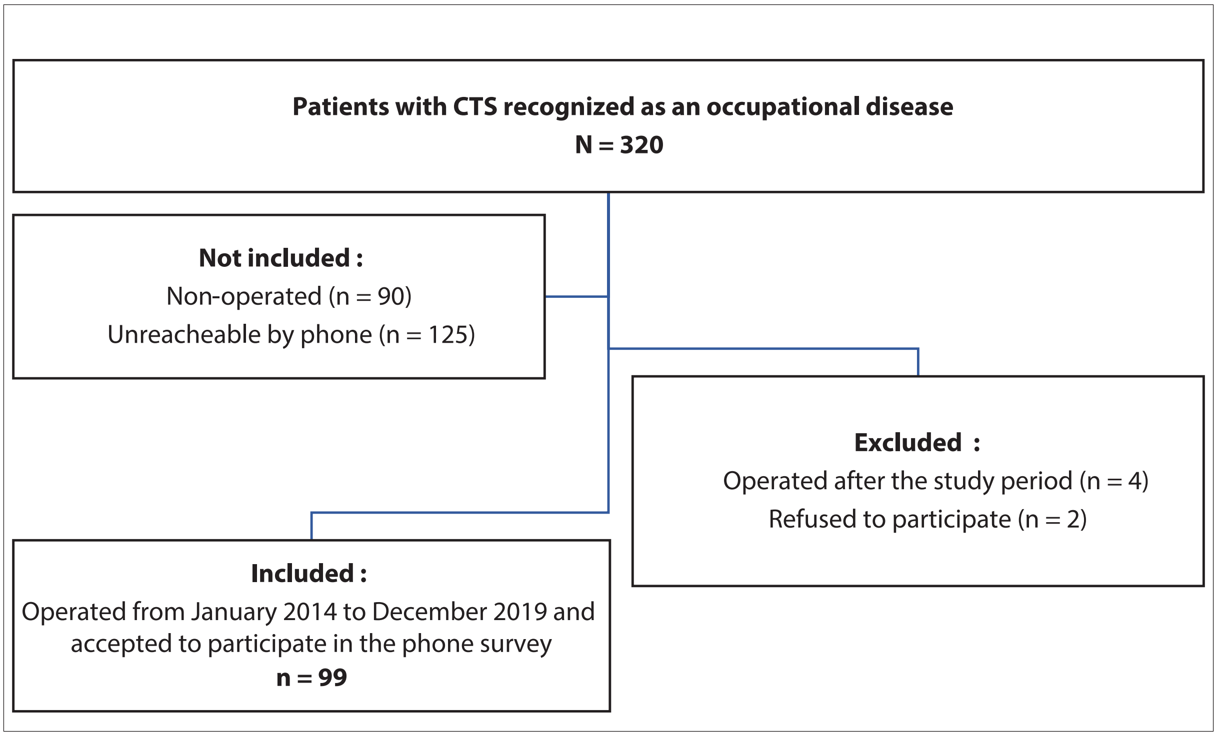

Figure 1. Flow chart of the study population.

3.2. Descriptive Data

3.2.1. Socio-demographic Characteristics

The mean age was 45±6.5 years old, ranging from 31 to 58 years. The 40-49 age range was the most represented (n=56; 56.6%). Our subjects were female (n=96; 97%), with a sex ratio M/F of 0.03. Eighty-six percent of our patients were married, and 72.7 % had at least two dependent children. The educational level was primary in 49.5% and secondary school in 47.5% of cases.

3.2.2. Occupational Characteristics

The socio-demographic and occupational characteristics of the population are shown in Table 1.

CTS was observed in the textile and clothing sector in 52.5% of the cases, followed by the electrical and leather industries in 25.3% and 13.3%, respectively.

The workstation was mainly of a seamstress (n=44; 44.4%), multi-skilled worker (n=24; 24.3%), and packing station (n=16; 16.2%). One dentist and 98 factory workers represented our population. They were qualified workers in 46.5% of cases. The mean job tenure was 20.1± 6.8 years, ranging from 6 to 38 years. The mean job tenure in the workstation, which caused CTS, was 18±7.2 years [5, 32]. Repetitive movements were noticed as the primary occupational constraint among all our included cases, followed by carrying heavy loads in 62.6% of the patients, as shown in Table 1.

3.2.3. Medical Characteristics

Personal medical history of obesity, hypothyroidism, hypertension, and diabetes has been found in 25.3%, 10.1%, 9.1%, and 6.1% of cases, respectively. Another MSD in the same upper limb combined with CTS was found in three workers. Two of them had shoulder tendinopathy, and one had epicondylitis.

Table 1. Socio-demographic and occupational characteristics of the population (n=99).

Variables	n. (%)
Age range, years	
30-39	22 (22.2)
40-49	56 (56.6)
50-59	21(21.2)
Gender	
Female	96 (97)
Male	3 (3)
Marital status	
Single	5 (5.1)
Married	86 (86.9)
Divorced	8 (8.1)
Dependents children	
0	20 (20.2)
1	7 (7.1)
>=2	72 (72.7)
Educational level	
Primary	49 (49.5)
Secondary	47 (47.5)
University	3 (3)
Sector of activity	
Textile and clothing	52 (52.5)
Electrical industry	25 (25.3)
Leather industry	13 (13.3)
Other	9 (8.9)
Job category	
Factory worker	98 (99)
Dentist	1 (1)
Workstation	
Seamstress	44 (44.4)
Multi-skills	24 (24.3)
Packing station	16 (16.2)
Quality control	7 (7.1)
Head of unit	4 (4)
Pressing	3 (3)
Dentist	1 (1)
Occupational qualification	
Qualified	46 (46.5)
Not qualified	53 (53.5)
Biomechanical occupational constraints	
Repetitive movements	99 (100)
Carrying heavy loads	62 (62.6)
Awkward postures	80 (80.8)
Prolonged pressure on the carpal tunnel	76 (76.8)

The CTS was bilateral in 70.7% of the cases, and 82.8% of the unilateral cases (24 out of the 29 patients) affected the dominant hand. The damage of CTS was severe in 19.2%, moderate in 13.1% of the cases, and not specified for the remaining cases. The identified symptoms were mainly paresthesia, pain, muscular weakness, and hypoesthesia in 89.9%, 68.7%, 58.6%, and 37.4% of the cases, as shown in Table 2. The average duration of symptoms progression before surgery was 3.3±3.03 years

Table 2. Medical characteristics of the population (n=99).

Variables	n. (%)
Medical history	
Diabetes	6 (6.1)
Hypertension	9 (9.1)
Obesity	25 (25.3)
Dysthyroidism	10 (10.1)
Others	17 (17.3)
CTS site	
Unilateral	29 (29.3)
Bilateral	70 (70.7)
In Dominant hand	94 (94.9)
CTS severity	
Moderate	13 (13.1)
Severe	19 (19.2)
Not mentioned	67 (67.7)
CTS symptoms	
Paresthesia	89 (89.9)
Pain	68 (68.7)
Muscular weakness	58 (58.6)
Hypoesthesia	37 (37.4)
Positive Tinel's and Phalen's tests	72 (72.7)
Associated MSD	
Shoulder tendinitis	2 (2)
Epicondylitis	1 (1)
Back and neck pain	6 (6.1)
Other	1 (1)
CTS hand surgery	
Unilateral	71 (71.7)
Simultaneous in both hands	27 (27.3)
Simultaneous with other MSD	2 (2)
Evolution of symptoms after surgery	
Complete resolution	35 (35.4)
Recurrence	26 (26.3)
Partial improvement	39 (39.4)
No improvement	25 (25.2)

with extremes from 3 months to 18 years. The hand surgery was unilateral in 71.7% of the cases. It was simultaneous in both hands in 27.3% and concurrent with another MSD in 2% of the cases.

Among participants, 7% reported postoperative wound infection. The evolution of the symptoms was favorable, with a complete resolution of symptoms in 35.4% of the cases within 8.4 months on average (a minimum of seven days and a maximum period of 36 months). A recurrence of symptoms was noticed in 26.3% of the cases within 10.6 months on average after surgery. Further surgery was indicated for one patient among the recurrent cases. A partial improvement of the symptoms was noticed in 39.4% and no improvement in 25.2% of the cases. Functional rehabilitation was done in 60.6% of the cases and immediately after surgery for 49.5%. The average time before returning to work after surgery was 3.36 months (from 1 to 24).

3.2.4. Professional Future

The professional future of the workers after returning to work following CTS surgery is given in Table 3. Our participants benefited from a job transfer in 44.4% of cases. Job maintenance at the same workplace with ergonomic adjustment has been implemented in 39.4% of patients, and 4% of the workers retained their job without workstation adjustment. A job loss was noticed in 12.2% of cases. Understaffing and the lack of suitable workstations were the main reasons for job maintenance at the same workplace without ergonomic interventions.

3.3. Other Analyses

When looking at the factors that can influence the professional future, we found that being 50 to 59 was significantly higher among workers who lost their jobs (58% of the job losses, p=0.01) than those who kept their jobs. The frequency of workers with at least two dependent children was significantly greater in the group retained at their jobs (p=0.02). Among the twelve workers who have lost their j12.2%), CTS was bilateral in eight patients who experienced symptom progression for over two years of evolution and was favorable in only three cases. In three cases, work was resumed within three months after surgery. However, no significant relationship was found between the professional future and patients' occupational or medical characteristics.

4. Discussion

4.1. Key Results

We identified in this study the recognized occupational cases of operated CTS, and we noticed an important rate of workers who kept their jobs after the surgery. The professional future was mainly a return to work with a job transfer at 44.4% and job maintenance with ergonomic adjustment at 39.4%. A job loss was noticed in 12.2% of cases. Early retirement was noticed in 8.2%, dismissal in 3%, and resignation from work in 1% of cases. The factors influencing the professional future were age 50 to 59 years (p=0.01) and dependent children (p=0.02).

Table 3. The professional future of the workers operated on occupational CTS (n=99).

Professional future	n. (%)
Return to work with a job transfer	44 (44.4)%
Job maintenance at the same workplace with ergonomic adjustment	39 (39.4)%
Job maintenance at the same workplace without ergonomic adjustment	4 (4)%
Resignation	1 (1)%
Early retirement	8 (8.2)%
Dismissal	3 (3)%

4.2. Interpretation

This study included a middle-aged population (45±6.5 years old), mainly in the 40-49 age range, and predominantly female, having at least two dependent children. As for the level of education, most of the participants had primary and secondary education. They mainly worked in the textile industry. A medical history of obesity, hypothyroidism, High blood pressure, and diabetes was found.

Our population's characteristics were similar to those found in previous studies among operated and non-operated CTS patients. Our results matched with those of a Tunisian study, including 106 patients suffering from CTS and treated by surgery [4]. Indeed, it has been reported in a case-control study on individual risk factors of carpal tunnel syndrome by Guan et al. that age is a risk factor for developing CTS [9]. Considering gender as a risk factor, female predominance has also been reported in previous studies [4, 10]. Women with CTS were likely to have moderate manual work, and men with CTS were likely to work in offices [10]. In this line, according to a national survey about occupational exposures in Tunisia between 2009 and 2013, the "gesture" constraints have been mostly found among women in 75.5% of cases [11]. Concerning the educational level, according to a case-control study led in India, it has been reported that the educational level was considered a CTS risk factor [12]. It is explained by the fact that low school-level workers are often regarded as unskilled workers and are more exposed at their workstations to postural constraints, resulting in MSD. According to previous studies, the textile and clothing sector is the largest source of occupational CTS [4, 9]. This sector, one of the foundations of the Tunisian economy and employability, exposes workers to many biomechanical risk factors of CTS. These factors are mainly working on assembly lines and having repetitive movements [8]. Concerning medical affections as risk factors for CTS, the results of a study by Guan W et al. [9] showed that wrist injury, diabetes mellitus, and hypothyroidism are all risk factors of CTS and that hypertension could be a protective factor in an early stage of CTS. In a study by Roquelaure et al. [13], diabetes mellitus and obesity were twice more frequent among CTS cases than in the general population. Unfortunately, in our study no, medical condition was found as a key factor in the professional future of workers with CTS.

As for the professional future, 44.4% of our participants benefited from a job transfer, and 39% kept their work position by adjusting their work conditions. A job loss was noticed in 12.2% of cases, and 4% of the workers retained their job without ergonomic adjustment. According to a study by Kho et al., 89% of patients returned to full-time work after surgery [14]. Parot et al. showed that 90 % of patients resumed their job after surgery when their study timeline [15]. According to Aloui et al., job loss has been observed in 9.6% of cases, whereas 26.5% of patients had kept the same positions [6]. Moreover, another Tunisian study found nearly the same job loss rates [7].

Furthermore, by studying the factors that could influence the professional future, we found that being 50 to 59 was significantly higher among workers who lost their jobs (58 % of the job losses, p=0.01) compared to those who kept their jobs. The same results have been found in a Tunisian study in which job loss was linked to age [11]. In another study, job loss has been significantly linked to age over 43 years (p=0.042) and marital status [6]. Also, according to Samson, the quality of recovery after a CTS surgery depends on the patient's age [16]. The health deterioration in old workers could explain these findings, the decline in functional abilities, and the physical weakening related to high physical demands at work. Another factor that may influence our study's professional future was having at least two dependent children, which was significantly greater in the group who have retained their jobs (p=0.02). The increase in job retention with the presence of dependent children could be explained by the fact that these workers would rather keep their jobs to support their children.

Except for these two socio-demographic factors, no occupational or medical characteristic was found as a key factor in the professional future. Other factors were found in the literature. In a study by Parot et al., the results have shown that the concomitant presence of multiple MSDs and at least a simultaneous surgical operation on another MSD of the upper limb relate to a poorer prognosis in terms of resuming work [15]. This issue has not been raised in our study, probably because of the limited number of patients with another MSD on the upper limb.

According to the same study, the executives had a better professional prognosis than the less qualified workers [15]. Another study has also identified the professional qualifications and the electromyogram data as factors influencing the professional future of workers who had a CTS operation [4]. The lack of a significant relationship between professional future and professional qualifications in our study could be explained by the fact that our participants were almost workers in the same occupational category. Among the reasons identified as a difficulty for workstation adjustments, the lack of suitable work positions, and the understaffing were found in our series. Difficulties of professional rehabilitation in the sectors where manual work is needed, such as the textile and clothing industry, could be the reason for job loss. Another reason that could explain these professional outcomes is the educational level of the workers; most of the workers had a low level of education and for whom job training would be difficult. Indeed, the reasons for delayed return to work after CTS surgery were inconsistent in the literature. In the study by Mahfoudh et al. [4], the occupational future of the operated workers was correlated with the professional qualification and the type of sensory and/or motor damage median nerve on electromyogram. Whilean in the study by Kho et al. [14], job type, motor nerve conduction velocity, and bilateral surgery were not predictive of delayed return to work interval after CTS surgery. Unfortunately, no occupational factor was associated in our results with the professional future after CTS surgery.

According to Samson, the quality of recovery after surgery depends on the age of the median nerve compression [16]. A delay in treatment could cause a negative post-operational evolution which could impact the professional future [17]. This evolution, characterized by an incomplete improvement of symptoms, was linked to delayed surgical treatment [18] and hard manual work [19] and was observed the most among patients with diabetes [20, 21].

According to our study, nce the professional future. Unfor influence the professional futuretunately, these are non-modifiable factors. However, it can be considered that the professional future of operated-CTS workers can be influenced by work conditions and the lack of ergonomic interventions at the workstation leading to job loss. Indeed, re-exposure to the same work constraints after returning to work could represent a factor of poor prognosis, both for the individual and for the company, in terms of impaired quality of life, lower productivity, and absenteeism. The collaboration between the actors in the prevention of health and safety at work for an adapted reintegration and retention at job of operated-CTS workers appears necessary.

4.3. Limitations

We must point out some limitations of our study, such as its retrospective design, the lack of completeness of information in the database, reporting bias during the phone surveys, and the high rate of unreachable patients by phone. Thus, a larger number of operated cases could have been included. The study's cross-sectional nature also prevented a long-term follow-up. Therefore, these limitations should be considered in the interpretation of our data. Longitudinal and analytical studies could help to assess the role of work-related risk factors on the professional future of workers with CTS and to limit inclusion bias due to the voluntary nature of the study.

4.4. Generalizability

In our study, we assessed the professional future of workers suffering from occupational CTS after surgical treatment and the factors that could influence their retention at the job. We can conclude that CTS has a significant professional impact, including job loss and retention at a job without ergonomic adjustments. The sampled population and selection criteria limit the generalizability of our results. Longitudinal studies would be needed to establish the causal relationship between professional risk factors and the professional future of the workers operating on CTS.

5. Conclusion

In our survey, most of the operated-CTS workers benefited from a job transfer and kept their work with the ergonomic adjustment of their work conditions. However, non-negligible rates of job loss and job retention without workstation arrangements were found. Given the lack of suitable workplaces for those who lost their jobs, interventions aiming to improve the professional future of workers operated on CTS by ensuring sufficient staff and adjusting workplaces are needed. Each company should elaborate its preventive measures based on analyzing work conditions to ensure a suitable rehabilitation program for workers suffering from CTS.

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To Work or Not to Work Remotely? Work-To-Family Interface Before and During the COVID-19 Pandemic

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Keywords: Remote Working; Technology Use; Work-family Conflict; Work-family Enrichment; Recovery

Abstract

Background: *This paper provides a brief, evidence-based reflection on two experiences with remote working, "old-normal" remote working and mandatory work-from-home during the COVID-19 pandemic. From the perspective of applied psychology in work and organizations, we used self-report instruments to assess variations in work-family conflict and enrichment, frequency of information and communication technologies (ICT) use, and recovery in two longitudinal studies.* **Methods:** *The first study involved 148 individuals from the technical-administrative staff of a large Italian University during an experimentation of remote working (one day per week) in 2019. The second study, conducted during the first lockdown in 2020, involved 144 individuals (convenience sample, heterogeneous by profession). All participants completed a self-report online questionnaire two times six months apart.* **Results:** *The two studies are not directly comparable, but they provide a dynamic idea of the effects of the two types of work arrangements. In Study 1, an experimental remote working condition (one day per week), participants reported decreased work-family conflict and improved recovery experiences. Study 2 noted a slight deterioration in work-family enrichment in the emergency remote working condition.* **Conclusions:** *These findings showed the usefulness of monitoring specific indicators related to the work-life interface using validated instruments and in a longitudinal perspective to assess each experience. We briefly discuss these aspects to inform future organizational decisions and actions for the "new normal".*

1. Introduction

During the COVID-19 pandemic, emergency remote working ensured continuity of work, reducing the risk of contagion, and was seen by some as a global experiment in remote working [1]. Indeed, the experience has been impressive, and many organizations, for example, in the public sector [2], which had previously resisted adopting remote working, have had to embrace it. In Italy, according to the Smart Working Observatory of the Polytechnic of Milan, 570,000 people (3.6% of the working population) worked remotely before the COVID-19 pandemic. On 09 March, the Italian government announced the first national partial lockdown. At the end of April, the Italian Ministry of Labor and Social Policy reported 1,827,792 remote workers, 8% of the workforce. The 68% of the public administration staff worked remotely during the first lockdown. Considering the large number of people involved in remote work during an emergency, many studies have been conducted on this

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form of work over the past three years. However, essential differences between emergency and standard remote work should be considered.

In this brief research report, we present key findings from two two-wave studies, one conducted before the pandemic (in a state condition where people could have chosen to work remotely) and the other one carried out during the first lockdown (in a mandatory work from home condition) [3]. Based on these findings, we emphasize the need to longitudinally observe specific indicators of the work-home interface to assess the effects of specific work arrangements in different contexts on a case-by-case basis.

Applying a psychological perspective, we focused on the work-to-family interface [4-6], referring to the Work-Home Resources Model (W-HR) [7], according to which the work-home interface can be described as a series of processes.

Each process proceeds from demands and resources in the work (or home) sphere, through changes in personal resources, to outcomes in the home (or work) sphere. Work-family conflict is a process in which demands in the work sphere deplete personal resources in the family sphere. Work-family enrichment is a process of resource accumulation: both domains can increase personal resources, improving home and family outcomes.

For both studies, data were collected through self-report instruments measuring work-family conflict and enrichment, recovery experiences, and frequency of information and communication technologies (ICT) used to observe differences in these dimensions between the two waves after remote working. The first study involved some technical-administrative employees of the University of Turin who participated in a "smart working experimentation" (maximum one day per week) in 2019. The second study included a heterogeneous and convenient sample of remote workers during the first lockdown (2020).

Although we know that the two studies are not directly comparable because they deal with different populations, we will discuss the variations of the variables over time and observe the differences between an experimental situation under non-emergency conditions and the first pandemic period. The discussion will allow us to outline some considerations for the future of organizations and remote working and, by describing the questionnaire used for monitoring, provide concrete guidance for future projects evaluating work arrangements.

1.1. Remote Working and the Work-Family Interface

Since the first introduction of remote working in the 1970s, the benefits have been and continue to be recognized [3, 8-10]. Reported benefits include: improving the quality of work by increasing concentration; promoting job satisfaction and well-being through better time management; promoting the experience of a balance between paid work and the rest of life; promoting inclusion and diversity management; offering work solutions that are also suitable for people with disabilities; protecting organizational continuity in a pandemic situation; reducing the commuting time between home and work; reducing costs; and reducing environmental impact [10, 11]. Some studies have confirmed that flexible work arrangements, such as remote work, can reduce stress levels by allowing greater control over one's time and work tasks [12]. A positive relationship has also been found between remote working and performance and job satisfaction [11, 13]. However, some risks of remote working have also been pointed out. For example, lower satisfaction due to social isolation [13] and negative consequences for pay, learning, and career development. In addition, the lack of physical boundaries has been shown to lead to a blurring of psychological and temporal boundaries between work and home, resulting in an excessive dedication to work [14]. These consequences may be related to national and organizational cultural factors associated with a strong appreciation of presence in the workplace [15]. Some systematic reviews of papers published in PubMed/Medline identified several problematic consequences of massive mandatory remote working, such as blurring of boundaries, anxiety, depression, stress, technostress, workaholism, fatigue, and lower satisfaction [9, 16, 17].

Since the onset of the COVID-19 pandemic, the scientific community of Work and Organizational

Psychology has worked to establish a research and intervention agenda [1]. Among the many areas of study highlighted in this agenda, the work-family interface and remote working are critical. The heavy use of ICT should also be considered, as well as problems related to a lack of recovery (with the impossibility of leaving the house and the closure of the main care facilities) [18].

The two two-wave studies presented in this paper were conducted using the same questionnaire but under two very different remote working conditions: (i) the first was voluntary, and the second (ii) was mandatory and in an emergency. In the questionnaire, we investigated specific dimensions related to the W-HR model [7]. In particular, we considered work-family conflict and enrichment, the use of ICT for work purposes [19], and the recovery process [20], as described below.

1.1.1. Work-Family Conflict and Enrichment

Based on role theories, according to which each role requires the person to invest energy and time, work-family conflict (WFC) is defined as a type of inter-role conflict in which the demands of work and family are mutually incompatible [21]. The study of conflict is fundamental to assessing work-related stress in Italy, as numerous adverse effects on emotional exhaustion and burnout [22], job satisfaction, and life satisfaction [23] have been identified.

A growing number of studies also looked at the positive side of the work-family interface, namely work-family enrichment (WFE) [5]. Enrichment is a process in which one role improves the quality of the other: "Work-to-family enrichment occurs when work experiences improve the quality of family life" [24] (p. 73). WFE is essential for employees and organizations and has been positively associated with work-, family-, and health-related outcomes (e.g. [25, 26]).

Although work-life balance is one of the goals of remote working, studies conducted before the health emergency have not confirmed the expected positive effects. Remote working often leads to increased interference between family and work, an issue that could cause a deterioration in concentration [10, 11, 27]. During the COVID-19 lockdown, people experienced the simultaneity of work and family roles, as it was impossible to separate the two domains physically. With schools and childcare facilities closed, parents had to work and perform care responsibilities simultaneously, including supporting homeschooling during the working day. This led to increased work and family demands and a deterioration of the work-family interface, as several works in Italy and abroad have shown (e.g. [28]). During the pandemic, using a person-centered approach, Huyghebaert-Zouaghi et al. [29] observed moderately stable levels of profiles related to the work-home interface [7] in a sample of workers from the United States and the United Kingdom, some of whom worked remotely. The longitudinal study, with two waves over three months between 2020 and 2021, also allowed them to observe that people faced more challenging and hindering demands when working remotely. Although there was no national lockdown in the two countries, the period over which the study was conducted does not allow for a distinction between emergency and non-emergency remote working.

Why does remote working not always improve the relationship between work and family? The main explanations relate to the loss of boundaries between the two spheres of life [30] and to the fact that working from home may lead to an indefinite extension of working hours on the one hand and increase family responsibilities assumed by the individual on the other [31]. These aspects have been exacerbated during the lockdown [28].

A systematic review by Vitória et al. [17] showed that the pandemic had a complex impact on WFC, exacerbated by some aspects (the "imposed" remote work) and attenuated by other variables (such as support both at work and at home); as for WFE, variations were rare, as also shown by the study of Chambel et al. [14], which, however, also did not find variations concerning WFC.

1.1.2 Frequency of Technology Use for Work Purposes

In the two studies presented in this paper, we observed how job demands related to technology use changed during remote working. Although ICT facilitated and accelerated various work processes and expanded the available information, it also exposed workers to specific work-related stress risks [8, 19]. This adverse process was also found among remote workers during the COVID-19 outbreak [32, 33]. In addition, the importance of creating conditions that allow people to disconnect from technology and recover has been widely emphasized, given that the request to complete additional work tasks using technology during rest time has been associated with WFC and a lack of recovery [8, 19].

1.1.3 Recovery Experiences

Recovery is the other element that the two studies conducted sought to investigate. Recovery is when the individual functional systems that have been stressed during a stressful experience, such as work, return to their pre-stress levels [34]. During recovery, personal resources are restored, or new ones are generated. The recovery process can be explained by the effort-recovery model [35] and the Conservation of Resource theory (COR) [36]. The former assumes that the functional systems activated during work should no longer be strained to return to restraint levels for the recovery process to be effective. The COR theory [36] states that individuals try to defend and maintain their resources to protect themselves from stress. Based on these premises, Sonnentag and Fritz [34] identified four recovery experiences: detachment from work, relaxation, mastery (including engaging in stimulating activities outside of work), and control over leisure. In addition to positive effects on well-being (e.g., [20]) and performance (e.g., [37]), recovery may moderate the relationship between WFC, psychological strain, and life satisfaction [38]. The lack of adequate recovery can lead to significant health problems in the medium and long term [20, 35]. Resources are central in the W-HR model [7], and recovery as a process of maintaining or creating new personal resources can be a compelling element in this positive dynamic.

2. Methods

2.1 Procedure

The first study was conducted in 2019 when the technical-administrative staff of the University of Turin participated in the experimentation of remote working for one day per week for six months. No more than 25% of the employees in each department participated. Participation was voluntary. In the case of excessive applications, a ranking was established based on some criteria (e.g., home-work distance). Participants completed a self-report questionnaire at the beginning of the experimentation in April 2019 for two weeks (Time 1 - T1) and after six months in October 2019 for two weeks (Time 2 - T2). The research project was conducted and supervised by a team of female researchers who created the questionnaire, collected the data through the LimeSurvey platform, and returned the results to participants after T2 through a summary of the findings. The second study was conducted at the beginning of the pandemic using a self-report questionnaire via the Google Forms platform in two separate waves: from 6 to 20 April 2020, during the first lockdown (Time 3 - T3), and after six months from 5 to 19 October (Time 4 - T4). Participation in the study was completely voluntary.

Both studies followed the Declaration of Helsinki: they did not involve any treatment or other procedures that might affect the psychological or social well-being of the participants. In both cases, participation in the study was voluntary in exchange for informed consent; anonymous data collection and data confidentiality were ensured according to Regulation GDPR 2016/679. An alphanumeric code allowed the assignment of participants to T1 and T2. As for the first study, the whole procedure was carried out with the support of the Uniform Guarantee Committee and approved by the union tables; study 2 obtained the approval of the Bioethics Committee of the University of Turin (Document No. 150561, 03 April, 2020).

2.2. Participants

In the first study, a total of 148 individuals (8.4% of the total technical-administrative staff of the University of Turin) completed the two questionnaires (response rate = 79%; respondents at T1 were 187), 62.8% of whom were women; the mean age was 45.46 years (SD=6.97). Of the respondents, 73% practiced care activities for children or parents.

In the second study, 144 individuals participated in the T3 and T4 surveys, working an average of 4 days per week. 68.1% of the sample was female, and the average age was 48.83 (SD=9.91). While in the first study, the participants were employed in the same organization and invited to participate in the survey, in the second study, the sample was a heterogeneous and convenience one, with participants from different sectors who were more difficult to reach remotely. This explains the lower response rate between T3 and T4, which is 21% (there were 670 participants in T3). While the number of dropouts is high, it is common in online surveys, especially when participants participate voluntarily and do not receive incentives [39]. In the sample, 41.7% worked in the private sector and 58.3% in the public sector. The occupational profiles were: white collar (56.3%), middle manager (25.7%), top manager (15.3%), and missing (2.8%). 71% of respondents reported caring for children or parents.

2.3. Measures

Work-family conflict (WFC) was assessed with the 5-item Italian version [4] of the measure developed by Netemeyer et al. [6] using a 5-point frequency scale from 1 "Never" to 5 "Always".

Work-family enrichment (WFE) was assessed with three items [5] using a 5-point agreement scale from 1 "Not at all agree" to 5 "Completely agree".

Frequency of technology use (FTU) was measured through 3 items [40] using a 5-point frequency scale from 1 "Never" to 5 "Always".

Recovery experiences were measured through 12 items (3 for each of the four recovery strategies, detachment, relaxation, mastery, and control; Likert scale from 1 "Not at all agree" to 5 "Completely agree") of Sonnentag and Fritz's [34] short scale (already used in Italian studies, e.g. [41]). An overall score of recovery experiences has been used in the two studies.

In addition, the questionnaire asked for information on gender, age, whether participants were involved in child or parental care activities, and, only in the second study, the number of remote working days per week, occupational sector, and profile.

For each construct, the average response score was calculated as indicated in the sources of the measures used and in previous work using the same scales. No cutoff values for these measures are reported in the international or national literature.

2.4. Data Analysis

The software IBM SPSS Statistics version 28 has been used to perform analysis. First, the normality of the scale items was checked using a z-score obtained by dividing the values for skew and kurtosis by their standard errors. Consistent with Kim's recommendations [42], the normality assumption is confirmed based on the sample size of the studies ($50 < n < 300$) when the z-score is less than $|3.29|$. The preliminary analysis confirmed the normality of the items except for three of the six items in the frequency of technology use scale, which was excluded.

Because of the high number of dropouts between the two survey waves, an independent-sample t-test was conducted to rule out significant differences between the final sample and the larger sample (which consisted only of participants in the first wave). Then, Cronbach's alpha coefficients were calculated. Finally, paired-sample t-tests were conducted to detect significant differences in the four observed variables (WFC, WFE, FTU, and recovery experiences) between each study's first and second waves.

3. Results

3.1 Preliminary Analysis

In both studies, to assess possible differences between the final sample and the larger sample that had participated only in the first wave, t-tests were conducted for all four variables. No statistically significant differences were found for any variables, as shown in Table 1. In addition, a χ^2 test showed that gender distribution did not vary between the two waves in either study (Study 1, χ^2=.44, p=.510; Study 2, χ^2=.92, p=.821).

3.2 Assessment of Significant Differences in the Four Variables Between the Two Waves

Table 2 summarizes the variables considered and the differences found, shown graphically in

Table 1. Means and standard deviations of all variables measured at the first wave and *t*-test results to compare sample at T1 with sample at T2 and sample at T3 with sample at T4.

Variable	M+SD Study 1-T1 Sample T1	M+SD Study 1-T1 Sample T2	*t-test*$_{(331\ df)}$	M+SD Study 2-T3 Sample T3	M+SD Study 2-T3 Sample T4	*t-test*$_{(812\ df)}$
WFC	2.73±0.88	2.71±0.87	0.12, *p*=.902	2.42±0.89	2.32±0.83	1.16, *p*=.245
WFE	2.77±1.03	2.80±1.03	-0.27, *p*=.790	3.33±0.98	3.27±1.04	0.69, *p*=.489
FTU	3.14±1.31	3.15±1.36	-0.58, *p*=.954	2.82±1.21	2.60±1.24	1.97, *p*=.054
Recovery	3.19±0.81	3.19±0.78	-0.09, *p*=.932	3.34±0.80	3.33±0.83	0.17, *p*=.867

All measures have a 5-point Likert scale. Study 1, T1 N=187, T2 N=148; Study 2, T3 N=670, T4 N=144.
WFC (work-family conflict); WFE (work-family enrichment); FTU (frequency of technology use).

Table 2. Means, standard deviations, Cronbach's alpha values of all variables, and *t*-test results.

Variable	M+/-SD & α Study 1-T1	M+/-SD & α Study 1-T2	*t*-test$_{(147\ df)}$	M+/-SD & α Study 2-T3	M+/-SD & α Study 2-T4	*t*-test$_{(143\ df)}$
WFC	2.71±0.87 α=.88	2.60±0.86 α=.90	2.13, *p*=.035	2.32±0.83 α=.89	2.33±0.92 α=.92	-0.17, *p*=.867
WFE	2.80±1.03 α=.87	2.86±1.07 α=.83	-1.01, *p*=.315	3.27±1.04 α=.87	3.01±1.00 α=.88	3.35, *p*=.001
FTU	3.15±1.36 α=.94	3.29±1.32 α=.95	-1.78, *p*=.077	2.60±1.24 α=.91	2.61±1.24 α=.91	-0.18, *p*=.859
Recovery	3.19±0.78 α=.90	3.34±0.76 α=.90	-3.27, *p*=.001	3.33±0.83 α=.91	3.23±0.86 α=.92	1.59, =.114

All measures have a 5-point Likert scale. Study 1 N=148; Study 2 N=144.
WFC (work-family conflict); WFE (work-family enrichment); FTU (frequency of technology use).

Figures 1 and 2. Study 1, conducted before the 2019 pandemic, showed significant differences between T1 and T2. In particular, the results showed that WFC decreased between T1 (*M*=2.71, *SD*=0.87) and T2 (*M*=2.60, *SD*=0.86) [*t* (147)=2.13, *p*=.035] and recovery experiences increased between T1 (*M*=3.19, *SD*=0.78) and T2 (*M*=3.34, *SD*=0.76) [*t* (147)=-3.27, *p*=.001]. In study 2, conducted at the beginning of the pandemic COVID-19, the only difference concerned WFE, which decreased significantly from T3 (*M*=3.27, *SD*=1.04) to T4 (*M*=3.01, SD=1.00) [*t* (147)=3.35, *p*=.001].

4. Discussion

Although these two studies are not directly comparable and considering the relative stability of dimensions related to the work-home interface during the pandemic [7, 29], some interesting results emerged. In particular, Study 1 showed that the introduction of a planned, agreed, and prepared remote working regime under normal conditions [43] enabled a reduction in WFC and an increase in recovery experiences: this is consistent with other studies describing the positive effects of a fully chosen work-from-home arrangement [9, 17].

In the first study, experimental remote working appeared to be associated with a reduction in WFC despite a perceived increase in the use of ICT for work purposes, likely offset by greater autonomy in managing work and personal time. On the other hand, WFE remained stable, in line with a general lower fluctuation of this variable [17]. When remote working was part-time (in this case, only one day per week), positive changes could be observed in some indicators considered, even in the face of an

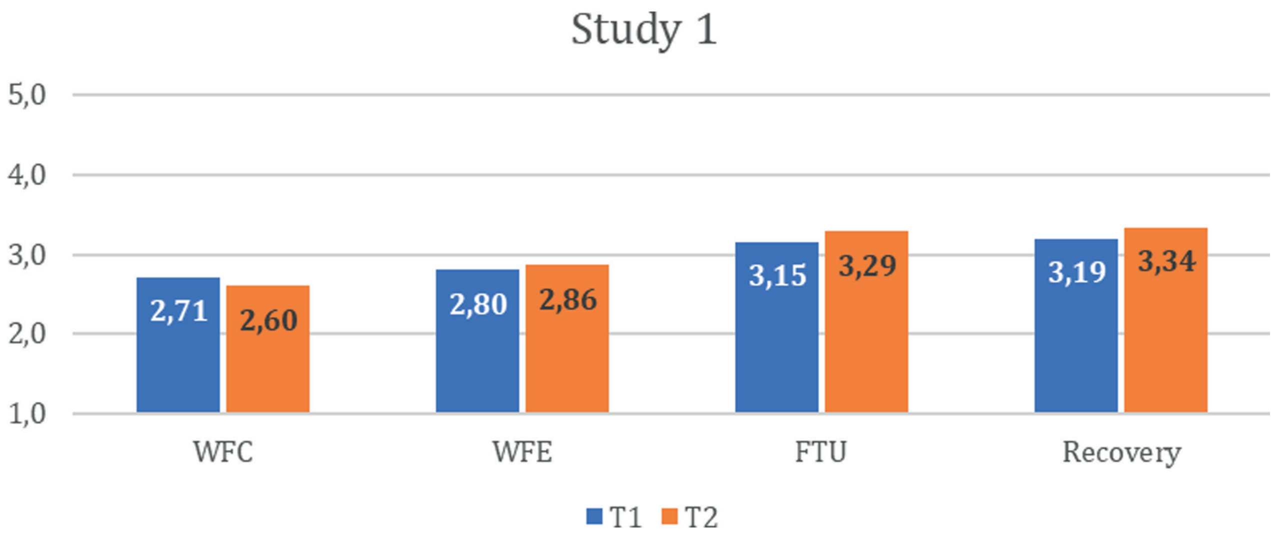

Figure 1. Variable Means of Study 1. WFC (work-family conflict); WFE (work-family enrichment); FTU (frequency of technology use).

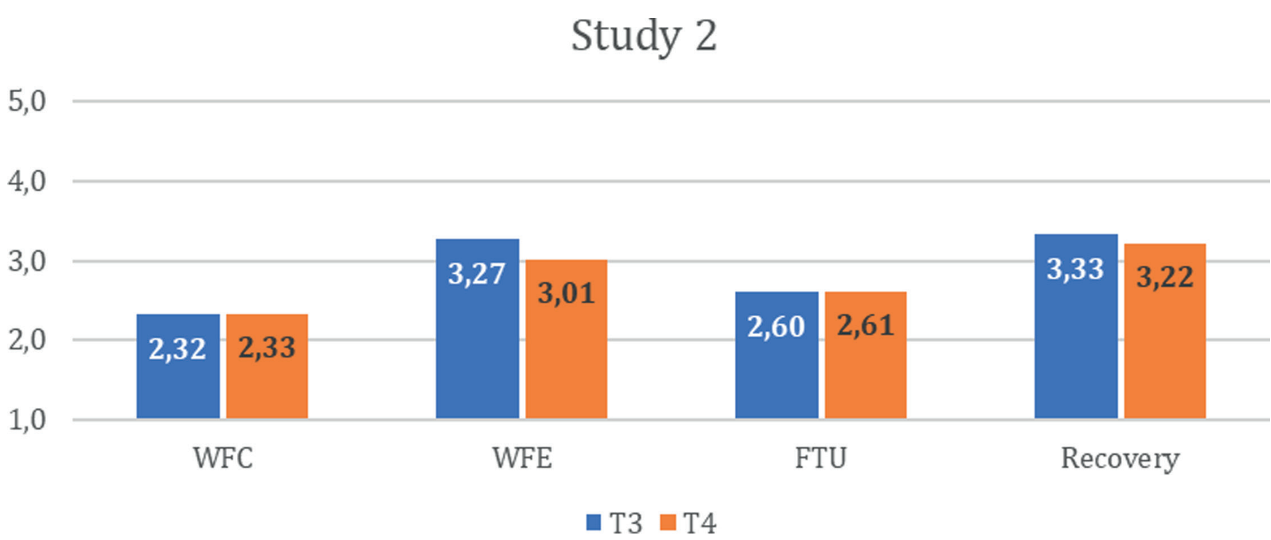

Figure 2. Means of all variables of Study 2. WFC (work-family conflict); WFE (work-family enrichment); FTU (frequency of technology use).

intensification of digital use. It is also important to emphasize that in the case of the experimentation, the workgroups in which the participants worked were prepared in advance for the new working mode, and the rest of life did not present any new critical aspects. Recovery experiences also improved, suggesting that workers involved had no problems disconnecting and finding ways to regain their personal resources. Overall, these results are consistent with the assumption that part-time remote working does not disturb the work-family interface [11].

In the second study, we observed a different trend in the variables: WFE decreased to a statistically significant extent, while WFC and the other variables remained stable. A stable level of WFC, but only in the work-to-family direction, was also found in the German study by Reimann et al. [44]. Other studies, such as the work mentioned above by Chambel et al. [14], have not found statistically significant changes for WFC or WFE in a sample of bank employees: This suggests the importance of conducting targeted monitoring to capture the specifics of different realities. Interestingly, the frequency of ICT use was not excessively high over the period considered. It had probably already reached the highest level in the first survey ("absorbing" the change in the way of working that occurred immediately, in the very first weeks) in a sample that was not so stressed in this respect.

4.1 Limitations

This contribution has many limitations, starting with the fact that the two studies presented refer to two different populations: therefore, the results are not systematically comparable. Furthermore, the mean values of the variables measured at the first wave show substantial differences between the two samples, which limits the possibilities for comparison. Indeed, Study 2 participants appeared to experience a more favorable working conditions regarding life balance (lower WFC, higher WFE, lower FTU). In addition, the sample in the first study represents almost the entire population involved in remote working before the pandemic, while the sample in the second study is one of convenience, which limits the generalizability of the results. Another important limitation of the study is that conflict and enrichment in the family-to-work direction were not measured. In addition, the size of the two samples does not allow us to capture differences concerning many variables that might be associated with the work-family interface, such as gender, age, living arrangements, caregiving responsibilities, presence, and the number of young children, family structure, socioeconomic level, presence of mental health problems, fear of the pandemic. Moreover, regarding the results of the second study, we did not consider the different employment sectors and types. Finally, there is no evidence in these two studies of perceptions of work quality or productivity, either in the form of self-report, supervisor assessment, or objective data. Moreover, an analytical reflection on the measures used could support future studies.

5. Conclusions and Implications

Although some research, including longitudinal studies, has addressed the work-home interface issue during the pandemic (e.g., [45]), to our knowledge, this is the only paper that presents two studies that used the same measures in remote work emergencies and remote work non-emergencies in a specific national context, providing an opportunity to monitor the different experiences of remote working experiences. While this brief research report has the limitations noted above, it is intended to stimulate thinking about monitoring and evaluating the impact of remote working on the work-to-family interface and to provide important insights to organizations engaged in evaluating and defining the next work arrangements.

According to the findings, it is essential that organizations carefully evaluate the choices to be made in the coming months by referring to previous experiences and monitoring the transition period. Moreover, the experience of the pandemic should be considered as a learning ground to assess training needs, critical issues encountered, and groups that need special attention due to less well-functioning relationships between leaders and followers, lack of autonomy, lack of clarity about goals, tasks, or roles [9, 17].

Referring to the few systematic data available during the pandemic, e.g., those of the technical-administrative staff of Italian universities [2], it appears that training was mainly brief and sometimes improvised, and in most cases related to the technologies and applications used for security and legal aspects, but less focused on the effective development of digital skills. An important training need is related to the support of work dynamics, organizational elements, and psychological dimensions that remote working requires.

This is a broad panorama for which it is important to make investments and find new ways of conceiving training to improve the quality of working life. These investments, consistent with the funding lines recently established by the government (Transition 4.0, Law 234/2021), among others, are necessary both for the "new normal" and for creating contingency plans. Promoting digitalization does not mean working only on technological infrastructure, developing ICT systems, and improving applications, nor working exclusively on developing knowledge and technical skills related to the digital world. From a transdisciplinary perspective, change must be understood as a whole that focuses on the relationship between people, organizational culture, work, and technologies, with particular attention to digital attitudes and competence at individual and organizational levels [9, 46]. The ultimate goal is always to promote both efficiency and quality of life.

Institutional Review Board Statement: The first and second studies were conducted according to the guidelines of the Declaration of Helsinki. As for the first study, the whole procedure was carried out with the support of the Uniform Guarantee Committee and approved by the union tables. Study 2 obtained the approval of the Bioethics Committee of the University of Turin (Document No. 150561, 03 April, 2020).

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

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

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Appendix

Supplemental Material A

Work-Family Conflict

Thinking about the balance between work and the rest of life, how often do you find yourself in the following situations on a scale of 1 - Never to 5 - Always?

- The demands of my work interfere with my home and family life.
- The amount of time my job takes up makes it difficult to fulfill family responsibilities.
- Things I want to do at home do not get done because of the demands my job puts on me.
- My job produces strain that makes it difficult to fulfill family duties.
- Due to work-related duties, I have to make changes to my plans for family activities.

Work-Family Enrichment

Thinking about the intertwining of your work and family life, we ask you to express your degree of agreement with the following statements using the scale from 1 - Not at all agree to 5 - Strongly agree.

- At work I develop new skills, and this helps me to be a better family member.
- At work I feel positive emotions, and this helps me to be a better family member.
- At work I feel a sense of accomplishment, and this helps me to be a better family member.

Recovery

Thinking about what usually happens when you finish work, please indicate how much you agree with the following statements using the scale from 1 - Not at all agree to 5 - Completely agree.
During time after work

- ... I forget about work.
- ... I don't think about work at all.
- ... I distance myself from my work.
- ... I do relax things.
- ... I use the time to relax.
- ... I take time for leisure.
- ... I seek out intellectual challenges.
- ... I do things that challenge me.
- ... I do something to broaden my horizons.
- ... I decide my own schedule.
- ... I determine for myself how I will spend my time.
- ... I take care of things the way that I want them done.

Frequency of Technology Use

Below are six questions regarding the frequency with which you are contacted outside your working hours. We ask you to answer using the scale from 1 - Never to 5 - Always.

How often do you...

- ...receive business emails after working hours?
- ...receive work emails on weekends and/or days off?
- ...receive work emails during holidays?

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Work-Family Boundaries in the Digital Age: A Study in France on Technological Intrusion, Work-Family Conflict, and Stress

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Keywords: Off-work Technology Assisted Supplemental Work (off-TASW); Work-family Conflict (WFC); Stress Perceptions

Abstract

Background: *Since previous studies have shown that the request of off-work technology-assisted supplemental work (off-TASW) can contribute to blurring the boundaries between the work and family domain by increasing work-family conflict (WFC), the purpose of this study is to go further, investigating how this relationship impacts stress perceptions.* **Method:** *A cross-sectional study that involved a sample of 221 French workers was carried out using a self-reported questionnaire. The data collected were analyzed by IBM SPSS 25.0 software, and a mediation model was tested.* **Results:** *The results showed that off-TASW was associated with higher levels of WFC (b=.32; p=.000), which was in turn associated with stress perceptions (b=.42; p=.000).* **Conclusions:** *This study contributes to understanding how the intrusion of technologies during off-work times impacts workers' perceptions of psychological wellbeing through work-family conflict. These findings should encourage the debate on the risks of staying connected to work through technologies during off-work and leisure time and stimulate the promotion of campaigns to make workers aware of their right to disconnection, to the benefits of detachment from work and recovery experiences.*

1. Introduction

From the '80s to now, we experienced a speedy evolution of Information and Communication Technologies (ICTs), which, combined with the advent of the Internet, have permeated the labor market, bringing new jobs, tasks, and ways of working. Technologies are useful for developing connections, information sharing, content creation, and storage [1]. Also, they facilitate work tasks [2] and participate in the achievement of organizational goals [3]. Furthermore, technologies permit shifting work from the official workplace to an offsite location [4], enabling people to work more smartly and flexibly [5], including working remotely from home, cafés, coworking spaces, transport, and also from far and isolated places, just having a functioning Internet connection. Correct use of technologies for work and a reasonable ICTs connection during off-work hours could be considered as resources in terms of job autonomy since they might help to defer workload and job demands [6] and they potentially enable people to differ work efforts and alternate moments of implication with a detachment to work [7]. However, the possibility of being constantly connected to work through technologies and as well to work anywhere at any time could at the same time lead to work intensification [8], interruptions and information

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overload [3], over-connectivity [9], workaholism [10], addiction to the Internet [11, 12] and to technologies in general [13]. Especially, the possibility of being solicited by job demands through technologies during off-work hours, weekends, and holidays could contribute to further blurring the boundaries between work and family domains [14], increasing the risk that professional imperatives may excessively nibble away the time normally devoted to rest, family, and leisure activities. By impacting the recovery and resources restoration process [15], work-related ICTs intrusion during off work could make people more vulnerable to job demands and stress [6].

Considering the pervasiveness of ICTs in our personal and working life, this study aims to investigate the role of the perceived request of technology-assisted supplemental work during off-work hours in wellbeing by analyzing its impact on stress perceptions through work-family conflict [14]. Several previous studies have investigated the relationship between technology-assisted supplemental work during off-work hours and work-related wellbeing outcomes, like job exhaustion [11], burnout [16], and workaholism [17]. However, the possibility of being solicited by professional demands through technologies during off-work hours, weekends, and holidays by increasing inter-role conflict due to the difficulty of simultaneously meeting job and personal needs may also impact general mental health, inducing stress perceptions. By studying the mechanism that links technology-assisted supplemental work during off-work hours to work-family conflict and stress perceptions, we intend to contribute to the debate on its role in the recovery and wellbeing process to make organizations, employers, health professionals, and employees aware of the health risks connected to the elevated off-work hours work-related technology intrusion in their life.

1.1. The Debate on the Risks of Work-Related Technology Intrusion in France and Italy

With the aid of technologies, employees can do teleworking, defined as the work shifted from the employer's premises to an offsite location thanks to using ICTs, such as desktop computers, laptops, smartphones, and tablets [4]. In addition, technologies help people to perform work more smartly and flexibly, as they enable a way of working, the so-called Italian legislation "*smart working*," where there are no time or space constraints. Employees can organize their activity by phases, cycles, and objectives to reconcile life and work times while favoring productivity growth [5]. Although the present study focuses on work-related technology solicitations during off-work hours, which may potentially impact work-family balance and induce stress perceptions, it is worth underlying that teleworking [18] and smart working [19] are in the focus of the debate regarding the impact of technologies' work-related use on people's wellbeing and of how technologies are changing the world of work and organizations.

If teleworking was implemented by organizations and regulations in 2004 and 2005 in Italy and France res, respectively [20], the debate about the risks of intrusion of technologies used for work-related reasons in our lives started later. In France, it was promoted by a study published in 2012 by the General Direction of Work and the Center of strategic analysis, which pointed out several risks associated: with work intensification, higher control of workers' activity, degradation of social relationships, information overload and porosity between life domains [21]. Facing all these issues, the social partners started to claim the right to disconnection [22] regulated by a law (the *Loi Travail* No. 2016-1088) that became effective in 2017. France was the first European country to adopt a general regulation to limit the risks of using technologies during off-work hours in the private sector. In Italy, the impulse to dialogue on the dangers connected to the use of technologies for work-related reasons was launched by the COVID-19 emergency [23]. Indeed, during the forced teleworking situations of the COVID-19 pandemic, people have had to adapt to working remotely.

Consequently, they have developed new skills and become more familiar with using technologies for work-related reasons. By having democratized and facilitated the adoption of teleworking and smart working, the global emergency has contributed to further blurring the boundaries between the work and the family domain, and it has spread a culture of the always-on [11, 24] where workers seem more subjected to feel the pressure to have to be constantly connected and available for work through technologies [3, 14, 15, 25] even when not explicitly requested. This has raised worldwide new concerns about the wellbeing of employees who adopt remote working methods, leading the Italian political and social parties to update the regulation on smart working with a National Protocol in 2021 [26]. This document acknowledges this practice's advantages and issues and provides guidelines for its correct implementation in the private sector.

Nowadays, in the post-COVID-19 era, the work-related over-connectivity through technologies has become common and transversal to many different job domains [27], and many organizations, private and public, as well as self-employed workers, have decided to adopt the new ways of working outside the office as widespread practices, in a hybrid or full mode. Therefore, it is important to continue the debate on the intrusion of technologies used for work since it may impact the process of employees' recovery and wellbeing [6]. Although the existing regulations, the risk of an over-connectivity to technologies is continuously increasing, and laws are helpful but don't are sufficient to prevent people's wellbeing from the negative consequences of the intrusion of technologies in our lives [28].

1.2. The Relationship Between Off-TASW, Work-Family Conflict, and Stress Perceptions

The concept of technology-assisted supplemental work (TASW) has been introduced by Fenner and Ren [29] to designate work-related tasks performed with the aid of new ICTs (such as laptops, smartphones, and tablets) at home or apart from home during holidays and free time in the absence of a formal agreement between the employee and the company. In this study, we use a conceptualization of TASW as the employees' perceived request, and not formally defined, to respond to work solicitations from their organization through technologies during off-work hours, weekends, and holidays [11, 14], to which we refer henceforth as off-TASW.

Previous studies have considered off-TASW as an additional job demand [11, 14, 15] in the Job Demands-Resources model [30] developed to explain the process leading to burnout and work engagement. According to this model, external factors lead to stress only under certain circumstances, for example, when they represent a threat and are perceived negatively because of a lack of resources or when combined with other demands; otherwise, they could be perceived as boosting for wellbeing. For this reason, to define negative external factors, the authors prefer to use the term "*job demands*" over the term "*stressors*" since a stressor, that is, an external factor that leads to stress, would exert only a negative potential, and not a positive one, on most people in most situations [31]. Differently, additional studies have identified off-TASW directly as a stressor [32], within the framework of the Transactional Stress Theory [33], or more specifically as a source of technostress, which is the stress induced by technology use [34], because of its negative effects, for instance, it hinders employees' work and non-work performance, it consumes resources and makes it difficult the process of recovery, and it blurs the boundaries between work and family [34]. All combined, the results from the studies that have considered off-TASW both as a job demand and as a stressor converge in showing its negative outcomes: off-TASW seems negatively related to work-family balance [35, 36], it leads to work-family conflict [37, 38], it reduces wellbeing [39], it causes strain and distress [40, 41], burnout [41], it increases workaholism [10], and it reduces recovery experiences [15].

Considering that our study investigates the relationship between off-TASW and two negative outcomes, namely work-family conflict and stress perceptions, the conceptualization of off-TASW as a stressor within the framework of the Transactional Stress Theory [33] seems more suitable. Following this theory, when people face a potential stressor, they undertake a primary appraisal to determine whether they feel threatened. Then they do a secondary evaluation to activate resources and coping strategies to counteract the stressor and to avoid or reduce its long-term negative consequences. A stressor induces stress, which is the immediate reaction to the stressor, which can lead to strain. It is the consequence of exhaustion due to constant exposure to stressors without resources or coping strategies to counteract them. Since technologies are omnipresent, techno-stressors are considered chronic stressors [34] experienced daily, resulting in depleting resources and making it harder to regain them through recovery. It follows a rise of vulnerability that can lead to inter-role conflicts, such as work-family and family-work conflict [35], which may increase the chance of feeling generally stressed. Since our study considers the relationship between a stressor, inter-role conflict, and stress without considering resources, coping strategies, or long-term reactions, we focus on the first part of the stress process, the primary appraisal.

To deepen the mechanism that links off-TASW to stress perception, we deemed it pertinent to include work-family conflict (WFC) as a possible mediator. In this study, we rely on Netemeyer and colleagues' conceptualization of WFC [35], who consider WFC along with family-work conflict (FWC) as two distinct but related forms of inter-role conflict where "demands of, time devoted to, and strain created by the job/family interfere with performing family/work-related responsibilities" [35, p. 401]. Inter-role conflict reduces commitment and job satisfaction, increases burnout, job tension, role conflict, role ambiguity, turnover intentions, and decreases life satisfaction [35]. Previous studies have stressed the importance of investigating demographic variables like sex, age, and having children when considering work-family conflict [14], as they are likely to influence its relationship with its antecedents and outcomes. Since our study focuses on the relationship between off-TASW and stress, we considered it relevant to investigate these dimensions with an explorative perspective by including them as control variables, although without defining specific hypotheses in their regard.

Therefore, based on the existing studies that have investigated the impact of off-TASW on work-family conflict and wellbeing outcomes, we suppose that:

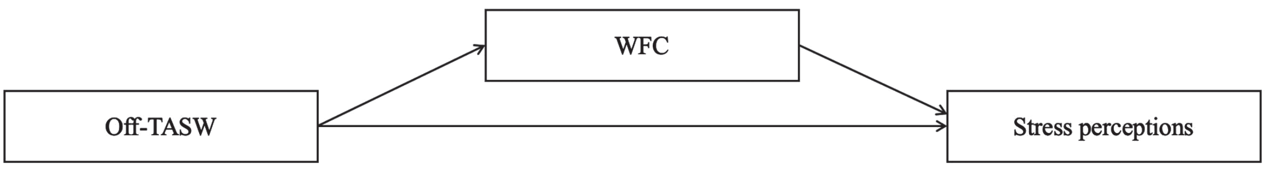
Hypothesis 1. The relationship between off-TASW and stress perception is mediated by WFC, controlling for sex, age, and having children. Figure 1 presents the hypothesized mediation model.

2. Methods

2.1. Participants and Procedure

A cross-sectional study was conducted with a convenience sample of workers contacted via the snowball exercise. Participants received a message by e-mail where they were invited to complete an online self-reported questionnaire. An introduction of the study was first presented, where the research objectives, a reminder of voluntary participation and answers' anonymity, and instructions for the filling were explained. The demographic and professional data collection and the part dedicated to the study variables followed.

The total sample of the study was composed of 221 French workers from various sectors (i.e., industry, commerce, teaching and research, health, tertiary, and administration). Among participants, 67 were men (30.3%), 154 were women (69.7%), and 45.2% had children. Their mean age was 36.73 (Standard Deviation, SD=13.53, min 20 years old—max 65 years old); 17.6% had a secondary school degree, 22.2% had a degree corresponding to two years in university, 27.1% a bachelor's degree and 30% a master's degree. 86.4% of the participants worked full time, 78.3% worked in the private sector, 78.3% had an open-ended contract, 17.3% had a contingent contract, 3.7% were self-employed, 43.9% were executives, 46.2% were employees, and 4.1% were managers. The 12.2% had a tenure of less than one year, 36.7% between 1 and 5 years, 18.6% between 5 and 10 years, and the rest more than ten years.



Note. Sex, age, and having children were considered in the model as control variables.

Figure 1. The hypothesized mediation model.

2.2. Measures

Off-work technology-assisted supplemental work (Off-TASW) was assessed with the French adaptation of a scale previously used by Ghislieri and colleagues [11, 14] composed of three items. People were asked how often their company demanded them to use technology to work during off-work hours, weekends, and holidays. Responses were on a five-point scale, ranging from 1 = never to 5=always. An example item was "How often does your organization require you to answer phone calls and e-mails during off-hours?" Cronbach's alpha was .88.

Work-family conflict was assessed by the French adaptation of the WFC scale developed by Netemeyer and colleagues [35], which consisted of five items representing the direction of conflict from work to family and one added item expressing the direction of conflict from family to work. Responses were measured on a 5-point scale, ranging from 1=strongly disagree and 5=strongly agree. An example item was, "It is difficult for me to fulfill my family obligations because of my work." Cronbach's alpha was .90.

Stress perceptions were assessed by the French version of the Perceived Stress Scale (PSS-10) developed by Cohen and colleagues [36], composed of ten items. People were asked how often during the past two months they have experienced the situations proposed. Responses were registered on a frequency scale of 5-point, ranging from 1=never and 5=always. An example item was, during the past two months, "I felt stressed and nervous." Cronbach's alpha was .87.

Control variables such as sex, age, and having children were considered in this study based on previous studies that have highlighted their importance when considering the interference between the work and family domains [14]. Sex and having children were coded as dummy variables (0=men, 1=women; 0=no children, 1=having children).

2.3. Statistical Analysis

Data analysis was performed using IBM SPSS Statistics 25.0 software. We calculated descriptive statistics (mean and standard deviation) for each scale, Cronbach's alpha to measure the internal consistency of the scales, and Pearson's correlations (*r*) to observe bidirectional relationships between variables. In addition, Mplus 8 software was used to assess the measurement model of the study variables of the hypothesized research model.

The mediation was tested by a regression analysis using Model 4 in the SPSS macro PROCESS, with a boot-strapping approach [37]. In the regression, stress perceptions were placed as dependent variables, off-TASW as the independent variable, WFC as the mediator, and sex, age, and having children as the covariates.

3. Results

3.1. Descriptive Statistics

Table 1 reports the study variables' means, standard deviations, correlations, and internal consistencies. As expected, off-TASW was related to WFC

Table 1. Means, Standard Deviation, and Correlations Among the Study Variables in the total sample.

	Range	M	SD	1	2	3	4	5	6
1. Sex	0-1	-	-	-					
2. Age	-	36.73	13.53	.07	-				
3. Having children	0-1	-	-	.11	.69**	-			
4. Off-TASW	1-5	1.95	1.03	-.04	.06	-.05	(.88)		
5. WFC	1-5	2.16	.87	.01	.06	.01	.32***	(.90)	
6. Stress perceptions	1-5	2.52	.66	.15*	-.16*	-.12	.14*	.41***	(.87)

*N= 221; *p < .05; **p < .01; ***p < .001. Cronbach's alpha in brackets along the diagonal.*

(r=.32) and stress perceptions (r=.14). Furthermore, WFC was related to stress perceptions (r=.41).

3.2. Model Testing

The measurement model was first assessed as part of the data analysis strategy. By using Mplus 8, a Confirmatory Factor Analysis (CFA) revealed that the 3-factor solution yielded an adequate fit to the data ($\chi^2_{(149)}$=294.84, p<0.05; CFI=0.92; TLI=0.91; RMSEA=0.06, SRMR=0.06), thus verifying that all the items loaded onto their corresponding three underlying latent variables of our research model. Moreover, considering the research model was evaluated using self-reported data, we tested for potential Common Method Bias issues [38]. The common artifactual variance was assessed through Harman's [39] one-factor test, thus showing that the first factor accounts for 34.09% (as recommended, less than 50%). Findings support, therefore, the non-presence of CMB in the measures used in the present study.

Regression analysis investigated the hypothesis that WFC mediates the relationship between off-TASW and stress perceptions controlling for sex, age, and having children. The results of the hypothesized model are reported in Table 2. Concerning the direct effects, off-TASW was positively related to WFC, b=.32 (p=.000), 95%CI=[.16; .38] and stress perceptions, b=.15 (p=.023), 95%CI=[.01; .18]. Furthermore, WFC was a significant predictor of stress perceptions, b = .42 (p = .000), 95%CI=(.22; .41).

Our final model explained approximately 10% of the variance in WFC (R^2=.10) and 23% of the variance in stress perceptions (R^2=.23). After controlling for the mediator, WFC, off-TASW was no longer a significant predictor of stress perceptions (b=.02, p=.796), 95%CI=[-.07; .09]. Therefore, results are consistent with full mediation.

The estimated indirect effects are shown in Table 3. More specifically, the indirect coefficient was significant within a 95%CI that did not comprise zero, b=.14, SE=.03, 95%CI=[.08; .20], meaning that off-TASW was associated with stress perceptions scores that were approximately .14 points higher as mediated by WFC. Concerning control variables, sex was positively related to stress perceptions. Thus, women reported higher levels of stress in response to off-TASW and WFC; the relationship between age and stress perceptions resulted also significant, however with a small beta standard coefficient (b=-.18, p =.035), this still seems to indicate that younger workers reported slightly higher scores of stress perceptions.

4. Discussion

The use of technology, especially among young people, is increasing increasingly, thus invading every area of people's lives. It seems almost impossible to implement that distancing from technology called "*IT distancing*" or "*digital detox*" [40]. The risk, therefore, is to be always connected, and this does not only happen at work. Even outside work tasks

Table 2. Path coefficients for WFC and stress perceptions.

N=221 Path coefficients						
	To WFC		To Stress		To Stress	
	b	SE	*b*	SE	*b*	SE
Sex	.01	.12	.17**	.09	.16**	.08
Age	.02	.01	-.17	.00	-.18*	.00
Having children	.02	.16	-.02	.12	-.03	.11
Off-TASW	.32***	.05	.15*	.04	.02	.04
WFC					.42***	.04
	R^2=.10***		R^2=.07**		R^2=.23***	

*Note: * p<.05; ** p<.01; *** p<.001; standardized coefficients are reported.*

Table 3. Mediation analysis summary.

Effect	β	SE	95% CI		*p*
			LL	UL	
Total Effect					
Off-TASW → Stress	.15	.04	.01	.18	.023
Direct Effect					
Off-TASW → Stress	.01	.04	–.07	.09	.796
Indirect Effect					
Off-TASW → WFC → Stress	.14	.03	.08	.20	

*Note: N= 221; * p .05; ** p< .01; *** p<.001; 95% CI= 95% confidence interval using the boot-strap bias-corrected method using 5000 samples. L =lower limit; UL=upper limit. Standardized coefficients are reported.*

and office hours, people use technology for personal purposes, creating a vicious circle where technology is omnipresent [41]. It is likely to interfere with people's capability to accomplish their several life roles leading to negative consequences on their wellbeing. Conceptualizing stress as a process within the framework of the Transactional Stress Theory [33], we intended to understand better the mechanism through which off-TASW is linked to stress perceptions. Our hypothesis posited that off-TASW might be perceived as a work techno-stressor likely to induce stress perceptions through WFC, a form of inter-role conflict conceptualized in our model as a first consequence of off-TASW. The results confirmed our hypothesis: in our sample, off-TASW is related to higher WFC, which is, in turn, related to stress perceptions.

Furthermore, WFC was revealed to mediate the relationship between off-TASW and stress perceptions. More specifically, among our 221 participants, we found that when they feel the intrusion of technologies during off-work hours, leisure time, weekends, and holidays, job demands spill over to the family, and consequently, stress perceptions increase. This is in line with previous studies that have found positive relationships between the intrusion of technologies during off-work hours and WFC [14, 42, 43, 44] and the literature that identified WFC as an antecedent of mental health [45]. In our study, the direct relationship between off-TASW and stress perceptions disappears when considering WFC. Therefore, as an inter-role conflict, WFC is a source of stress deeply implicated in explaining the relationship between off-TASW and stress perceptions. This finding is consistent with previous studies that found WFC to mediate between job stressors and impaired psychological health [46]. Furthermore, the results of this study add to the previous literature that identified an indirect relationship between off-TASW and negative work-related wellbeing outcomes, for example, the intrusion of technologies during off-work times and job exhaustion explained by internet addiction [11], reduced recovery [15] and workaholism [17]. Being connected to work through technologies during off-work hours seems to represent for the participants of our study a demanding condition that implies resource consumption which makes it difficult for them to meet at the same time their work and family needs leading these two roles into conflict with raising in their stress perceptions as a result. When testing our model, we decided to control for some demographic characteristics considered important in the literature on work-family balance [14], namely sex, age, and having children. Our results showed that sex is related to WFC and stress perceptions: women reported more work-family conflict and stress perceptions in response to off-TASW than men. Therefore, in our sample, off-TASW seems to make it more difficult for women to meet their family demands and raise their perception of WFC, which is related to higher stress perceptions. This result may be explained by an asymmetry between men and women in their work and family roles [47], where women's roles are stereotypically home maintenance and family care.

In contrast, men feel less concerned with family and caring tasks [48], and social expectations prefigure them more present in the work field than in the family [49]. Furthermore, among our participants, a really small significant relationship was also found between age and stress perceptions, suggesting that younger workers in our sample may feel more stressed in response to WFC and technological solicitations. This is in line with previous studies showing that younger people are more at ease in using technologies [50], and they tend to develop more addiction to technologies [51] that may represent a risk to their mental health.

4.1. Practical Implications

This study has practical implications for occupational physicians, organizations, employers, and workers. The last report of the European Survey of Enterprises on New and Emerging Risks, ESENER 2019 [23], has associated digitalization with psychosocial risks and investigated how establishments manage digitalization risks in the workplace. Workers were asked whether establishments have discussed the possible OSH (Occupational Safety and Health) impact of technologies. Although in 2019, just a small percentage of respondents, 18% and 16% in France and Italy, respectively, responded affirmatively, we can consider that after the COVID-19 pandemic that has brought working from home as a new normal, this topic has become more urgent. In line with the previous literature, our study showed that off-TASW was a techno-stressor that induces stress perceptions by increasing WFC. Research evidence converges that it may be considered a new psychosocial risk factor in the workplace. Since psychosocial risks are one of the main concerns for organizations and employers, occupational physicians should include this topic in their interventions and aim to awaken people to these issues.

In France, primary prevention campaigns about psychosocial risks and the chances of using technologies for work-related reasons are more common among the community of occupational physicians that intervene in organizations than in Italy. Particular attention is given to raising awareness among workers about their right to disconnection and to suggesting them strategies to disconnect from technologies, during and outside working hours, for example, taking breaks, segmenting work into different tasks, alternating sitting positions to stand up, by doing physical activities during free time, by reducing exposure to screen and devices before sleeping and by making healthy lifestyles choices. This outreach practice is essential and should continue by relying on research studies that constantly update the knowledge on the risks of digitalization. In Italy, the law on prevention and safety in the workplace (D.Lgs.81/2008) specifies the obligation for employers to assess risks to the safety and health of workers, including those connected to work-related stress. Employers are responsible for editing the Risks Evaluation Document (Documento di valutazione dei rischi, DVR), which identifies the possible risks present in a workplace and is used to analyze, evaluate and try to prevent dangerous situations for workers. The employer may appoint a competent doctor to collaborate in risk assessment and health surveillance [52]. Considering the actualization of the regulation on smart working in Italy, employers and occupational physicians should include in the DVR the risks connected to this new way of working and the professional use of technologies. Campaigns of primary prevention that have suggestions on good practices, such as those cited previously, should be encouraged in organizations. It can be argued that organizations could promote specific training for their employees to make them aware of the moderate use of technology, the psychological and physical problems that prolonged use entails, and the right to disconnect outside working hours [53]. Appropriate human resources policies could also be adopted within the company to decrease or even discourage the use of e-mail and other forms of communication outside working hours [27] or by creating a server shutdown for each worker outside their working hours [54]. An important role is that of managers who should show flexibility towards their employees and not contact them outside working hours because it would make them feel obliged to respond to their boss' requests or expect employees always to be on call, ready, and able to respond promptly to any request for information [55].

4.2. Limitations

This study has important limitations. Firstly, it is cross-sectional, and a causal relationship between the study variables cannot be established. It is, therefore, possible to imagine alternative patterns that may explain the link between the variables considered in this study; for example, people who report high levels of stress might find it difficult to be efficient both in the professional and the family domain, and they could tend to stay connected to work through technologies during off-work hours to compensate [3]. Future studies with longitudinal and cross-sectional designs should deepen the relationship between off-TASW, WFC, and stress perceptions to verify further the relationships investigated in our study. Secondly, since we used a convenience sampling method, our results are not generalizable because our sample does not represent a particular population.

Further studies should test the relationships of our analysis using a representative sample or selecting a population that shares the same socio-demographic and professional characteristics, for example, employees from a specific firm or working in the same department. Concerning measurements, we used a conceptualization of TASW that did not consider the effective use of technologies during off-work times in response to the solicitations by workers' organizations. Further studies should adopt other conceptualizations of off-TASW to measure to what extent technologies are used during off-work and how this use impacts WFC and stress. Moreover, following previous studies, to measure WFC, we used an adaptation of the Netemeyer and colleagues' WFC and FWC scales [35], combining four items of WFC with one single item of FWC [24]. It would be interesting to investigate the impact of off-TASW on inter-role conflict and stress, taking WFC and FWC separately. Furthermore, we considered exclusively the primary appraisal of the stress process. Further research should extend the secondary appraisal analysis by considering resources and coping strategies that people may activate to counteract techno-stressors inducing WFC and stress.

Moreover, we considered stress perceptions, a psychological dimension, as an outcome. Further studies should also evaluate the impact of off-TAWS on physical health results, namely muscle-skeleton disorders. Finally, our results showed gender differences, future studies should investigate further the role of gender in the studied relationships, and it might be interesting to consider also other situational aspects that may be important confounders associated with work-family conflict, for example, characteristics of a person's situation, such as the condition of living (alone, with a partner or with people to care of), the number and age of children and also professional characteristics, namely number of off-work working hours.

5. Conclusions

In conclusion, the spread of an over-connected culture in the work context brings some risks. It contributes to blurring the boundaries between the work and family domain, increasing work-family conflict and the stress level of working people. Even if some regulations already exist concerning smart working and the right to disconnection, our results encourage continuing the debate on the health risks associated with the intrusion of technologies during off-work times to make urgent the actualizations of occupational physicians' practices in terms of promotion of primary prevention addressed to organizations, employers, and workers.

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

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

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Chromosomal Aberrations, Micronuclei, Blood Parameters and Received Doses in Workers Exposed to Ionizing Radiation

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Keywords: Cytogenetic Testing; Healthcare Workers; Occupational Disease

Abstract

Background: *This study aimed to analyze the impact of low doses of ionizing radiation on healthcare workers using dosimeter data and several biomarkers of effects and to assess the suitability of those tests.* **Methods:** *Data from the last medical examinations, obtained from the medical records of 148 healthcare workers, were analyzed. They were divided into three groups of workers: nuclear medicine (NM), interventional radiology (IR), and general radiology (GR). The examination included hematological parameters and cytogenetic tests: unstable chromosomal aberrations (UCAs) and micronucleus test (MNT). The received cumulative 5-year dose was calibrated into personal dose equivalents Hp (10)(PDE).* **Results:** *There were older employees and more women in NM than in the other two groups. NM workers had more years of exposition than employees in IR and GR. PDE and years of exposition were significantly higher in NM. In the multivariate logistic regression model NM group was positively related to UCAs after adjusting for age, sex, and smoking. According to the results of the multivariate analysis, female healthcare workers and those employed at IR had higher values of erythrocytes than males and those employed in NM or GR departments.* **Conclusions:** *Nuclear medicine workers are at a higher risk of developing neoplastic due to consistent exposure to low doses of ionizing radiation. The results indicate that the UCAs test might be more suitable for detecting radiation-induced damage at low doses than MNT. Compulsory monitoring of the health status at periodic examinations is required to prevent occupational diseases of nuclear medicine workers.*

1. Introduction

Ionizing radiation, often used in medicine, can cause adverse medical conditions when safety procedures are not followed [1, 2]. Radiation toxicity depends on the type of radiation emissions and characteristics of the tissue itself [2, 3-5]. Occupational diseases, including occupational carcinoma, are higher in more sensitive organs. Levels of radiation emissions are regulated in the Rulebook on determining occupational diseases [6].

Mature lymphocytes, taken from peripheral blood, had been used for bio-dosimetry testing, essential in radiological protection and occupational medicine. These assays include unstable chromosomal aberrations (UCAs) and the micronucleus

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test (MNT). UCAs in peripheral blood lymphocytes have been recognized as biomarkers of the effect of ionizing radiation. MNT has been used as a screening method to demonstrate the cytoplasm's aberrant chromosomal material (micronuclei) [7]. Both tests are significant indicators for identifying an occupational disease, such as cancer, caused by small doses of ionizing radiation in the workplace over a few years [1, 2, 8-13].

Unstable chromosomal aberrations include different types, such as acentric, dicentric, and ring chromosomes, as well as unspecific damages [8, 13]. The frequency of the UCAs and the number of micronuclei (MN) is higher in people exposed to acute irradiation, and a significant correlation has been identified with the dose received. Also, frequencies depend on the radionuclide metabolism and the patient's health condition [9, 14, 15].

It has been proven that nuclear workers have an increased risk of cancer, recognized as an occupational disease, due to the increased frequency of unstable chromosomal aberrations and the number of micronuclei [15]. The hematopoietic system is the most sensitive, reticulocytes (as descendants of erythroblast) and leukocytes [1, 16]. In Serbia, the effects of occupational exposure to ionizing radiation have to be assessed with regular preventive-periodical medical examinations.

Certain areas of medicine, such as nuclear medicine, interventional radiology, and general radiology, use ionizing radiation for diagnostic and therapeutic purposes, and the employees are occupationally exposed to relatively low doses. According to the Rulebook on Limits of Exposure to Ionizing Radiation and Measurements for Assessment of the Exposure Levels [17] for occupationally exposed persons, permissible yearly effective doses range from 6 mSv to 20 mSv [1]. Previous or initial examination and periodical check-ups are compulsory in Serbia, and this is regulated in the Rulebook on the Preliminary and Periodical Medical Examinations of Workers with Elevated Health Risk at their workplaces [18]. The check-ups include the hematological parameters and specific cytogenetic tests (UCAs and MNT) following the law [19].

The purpose of this study was to compare the influence of low doses of ionizing radiation on exposed medical workers in nuclear medicine, interventional radiology, and general radiology. Also, different settings were applied through analysis of UCAs, MNT, hematological parameters, and the cumulative 5-year dose. These groups were chosen according to the source and type of ionizing radiation: nuclear medicine employees have been exposed to alpha, beta, and gamma radiation from open sources, while interventional and general radiologists have been exposed to X-rays only (closed sources, only emitting while the devices were energized).

2. Methods

The data for this study had been collected during the last preventive periodical medical examinations in the Serbian Institute of Occupational Health following the Law on Radiation Protection and Nuclear Safety and Security [19]. Analyzes have been done following the ethical principles of the Declaration of Helsinki and the principles of the Ethics Committee of the Faculty of Medicine, University of Belgrade. Information was obtained from the medical records of 148 healthcare workers exposed to ionizing radiation at the University Clinical Centre of Serbia.

The UCAs were obtained by the modified Moorhead's micro method [20]. For this analysis, 0.1 ml of heparinized peripheral vein blood lymphocytes were treated with 0.1 % phytohemagglutinin (PHA) and left aside at 37 °C for mitosis stimulation. After 45 hours, this culture was treated with colchicine to stop mitosis when the chromosomes were most visible in the metaphase. Then, after 2 hours of sample preparation, UCAs were measured. The positive results for workability are if more than one dicentric per 200 metaphases lymphocytes, one or more ring chromosomes per 200 metaphases lymphocytes, and more than two entries per 200 metaphases lymphocytes [21, 22].

The micronucleus test was performed using the Fenech and Morley method [23, 24]. Peripheral blood lymphocytes were used to observe the micronuclei. After 45 hours of cell cultivation, cytochalasin-B, an actin inhibitor, was added to block the cytokinesis and facilitate the karyokinesis (a division of the nucleus only). After 72 hours from the beginning of the test, a binuclear lymphocyte with a certain number of micronuclei in the cytoplasm was obtained. The test result was positive if it included 25 or more micronuclei, according to the reference values adopted by the Laboratory for Cytogenetics at the Serbian Institute of Occupational Health.

The hematological samples (erythrocytes, reticulocytes, total leukocytes, lymphocytes, monocytes, neutrophils, eosinophils, and platelets) were collected by processing the peripheral vein blood using a Beckman Coulter HMX system. The absolute values of cell counts (reticulocytes, monocytes, neutrophils, and eosinophils) were considered. To reduce the confounding effects, the subjects also had to fill out a compulsory questionnaire containing information on smoking habits, anti-neoplastic drugs, recent viral diseases, and possible exposure to chemical solvents, pesticides, and ionizing radiation for diagnostic purposes in the last six months. All these factors were used as the exclusion criteria in this study, except for the smoking habits, especially having difficulties collecting adequate information in mind.

Data on the received cumulative 5-year doses have been obtained using personal dosimeters (TLDs), calibrated in terms of the personal dose equivalent Hp(10) using the Harshaw TLD 6600 Reader. The comparisons were made between healthcare workers in three work areas (nuclear medicine, interventional radiology, and general radiology) in the frequency of UCAs, MNT results, hematological parameters, and cumulative 5-year received dose (5-year PDE) measured during the work shift.

Data were processed using the IBM SPSS 20 package for Windows. The analyses included the Chi-square test, Fisher test, One-Factor Analyses of Variance (ANOVA), Sidak Multiple Comparisons test, Kruskal–Wallis test, and Mann-Whitney test.

The univariate and multivariate linear regression analysis was used to determine factors related to hematological parameters adjusted on age, sex, and smoking status. The univariate and multivariate logistic regressions were used to determine the independent predictors for UCA and MNT adjusted on age, sex, and smoking status. Results are expressed as linear regression coefficients (B) or the odd ratios (OR) where appropriate and their 95% confidence intervals (CI). All tests were two-tailed. Statistically significant was considered as of $p < 0.05$.

3. Results

The study comprised 148 subjects, including 104 females (55 in nuclear medicine, 25 in interventional radiology, 26 in general radiology) and 44 males (8 in nuclear medicine, 22 in interventional radiology, 11 in general radiology) of average age 45.73±11.59 yrs, with the average total work experience 19.43±10.9 yrs (39 at most) and average 15.37±9.36 yrs (35 at most) of exposure.

The subjects were divided into three groups based on their area of work. There were 65 (43.9 %) workers in nuclear medicine, 47 (31.8 %) in interventional radiology, and 36 (24.3 %) in general medicine. The

Table 1. Different predictors and work area.

Variables	Interventional radiology	Nuclear medicine	General radiology	P
Age	38.7+9.8	51.9+11.2	43.6±8.4	***p*<0,001**
Sex	22/47 male	8/64 male	11/37 male	***p*<0,001**
	25/47 female	56/64 female	26/37 female	
Smoking	20/47 no	27/64 no	18/37 no	*p*>0,05
	27/47 yes	37/64 yes	19/37 yes	
EWP (yrs)	9 (0-32)	18.5 (0-35)	15 (3-31)	***p*=0.002**
5-year PDE (mSv)*	5.6 (3.1-25.11)	8.9 (2.33-44.35)	4.3 (3.62-41.26)	***p*<0.001**

**The effective dose of occupationally exposed persons is: very high if it is greater than 50 mSv in a year; high if it is greater than 20 mSv in a year; increased if it is more significant than six mSv in a year; low if it is less than or equal to 6 mSv for a year; very low if it is less than or equal to 2 mSv in a year; negligible if it is less than or equal to 1 mSv for a year.*

difference between these three groups according to the different predictors is presented in Table 1.

According to the predictors such as age, sex, smoking, exposure work period (EWP), and received cumulative dose for 5 years (personal dose equivalent/PDE), examined predictors differed significantly between groups. A statistical significance was found in the age, sex, exposure work period, and the received 5 years dose.

One-Factor Analysis of Variance (ANOVA) was conducted to analyze the effect of the group according to age. The significance was detected ($F_{(2,143)}$=9.220, p<0.001, Partial Eta Squared=0.050). There were much older employees in nuclear medicine than in other two groups. More women were employed in nuclear medicine (Chi-squared test, χ^2= 16,027; p<0.001).

Nuclear medicine workers had more years of exposition than employees in interventional and general radiology (Kruskal-Wallis test (χ^2=12,276; p=0.002).).

The five-year cumulative doses, calibrated in personal dose equivalents Hp (10) (5-year PDE), presented in the Table 1, exhibited a statistically significant difference among the three groups using the Kruskal-Wallis test (χ^2=22,191; p< 0.001). A statistically significant difference was found between the nuclear medicine group and the interventional radiology group (Mann-Whitney U=458, p<0.001). The difference between the nuclear medicine and general radiology was also highly statistically significant (Mann-Whitney U=510.5, p<0.001), while there was no statistically significant difference between interventional radiology and general radiology (Mann-Whitney U=604, p=0.294). The results of the UCAs test, from the last periodic examination, are presented in the Table 2.

The MNT results, from the same examination are presented in the Table 3.

One-Factor Analysis of Variance (ANOVA) was conducted to analyze the effect of group and gender on the erythrocyte count. The results showed a statistically significant difference in the values of erythrocytes between employees in the three groups ($F_{(2,140)}$=3.715, p=0.027, Partial Eta Squared=0.050).

Multiple comparisons were performed using the Sidak test. A significantly higher erythrocyte count was detected in the interventional radiology group compared to general radiology (p=0.009) and compared to nuclear medicine (p<0.001). Other hematological parameters (reticulocytes, leukocytes, neutrophils, monocytes, eosinophils, lymphocytes,

Table 2. Frequency of the unstable chromosomal aberrations (UCAs) in the occupationally exposed employees in different areas of work.

Work area	Normal frequency N [%]	Higher frequency N [%]	Total N [%]
Nuclear medicine	49 (84.5)	9 (15.5)	58 (100.0)
Interventional radiology	27 (96.4)	1 (3.6)	28 (100.0)
General radiology	26 (100.0)	0 (0.0)	26 (100.0)
Total	**102 (91.1)**	**10 (8.9)**	**112 (100.0)**

Table 3. The outcome of the micronucleus test at the last periodical examination in occupationally exposed employees in different areas of work.

Work area	Normal number of micronuclei N [%]	Elevated number of micronuclei N [%]	Total N [%]
Nuclear medicine	46 (83.6)	9 (16.4)	55 (100.0)
Interventional radiology	19 (76.0)	6 (24.0)	25 (100.0)
General radiology	27 (87.1)	4 (12.9)	31 (100.0)
Total	**92 (82.9)**	**19 (17.1)**	**111 (100.0)**

Table 4. Multivariate regression model of variables associated with UCAs.

Variables	OR (95 % CI)	*p* value
Age	0.97 (0.88-1.06)	0.459
Sex	0.28 (0.04-1.74)	0.897
Smoking	0.29 (0.06-1.48)	0.295
Cumulative doses	1.03 (0.93-1.15)	0.545
Nuclear Medicine	21.02 (1.65-268.07)	**0.019**

Table 5. Multivariate regression model of variables associated with RBC.

Variables	B (95% CI)	*p* value
Age	0.002 (-0.005-0.009)	0.533
Sex	-0.53 (-0.69 to -0.38)	**<0.001**
Smoking	0.08 (0.64-1.08)	0.232
Cumulative doses	0.59 (-0.05-0.21)	0.793
Interventional radiology	0.19 (0.02-0.35)	**0.024**

platelets) did not show significant differences between the groups (p>0.1).

In the multivariate logistic regression model nuclear medicine group (p=0.019) was positively related to UCAs after adjusting for age, sex and smoking (Table 4).

Workers employed at nuclear medicine department had higher risk for elevated UCAs compared to workers employed at interventional radiology or general radiology. According to the results of the multivariate analysis, factors associated with values of erythrocytes were sex and interventional radiology group after adjusting for age and smoking (Table 5).

Female healthcare workers and those employed at interventional radiology had higher values of erythrocytes than males and those employed at nuclear medicine or general radiology departments.

4. Discussion

Based on the available literature, it is generally agreed that ionizing radiation can affect various health parameters and cause carcinogenesis. The biological effects of small doses on human health have been debated for many years. Still, the literature on their impacts on workers' health in different work settings, especially in healthcare, is scarce [11, 12, 14, 25, 26]. It was noted that prolonged exposure to radiation in the workplace increases the risk of developing cancer in cardiac catheterization laboratory staff with the highest exposure levels [27].

Differences in response to radiation (chromosome aberrations) between radiation-sensitive and radiation-resistant individuals should be considered in the risk assessment from radiation exposure [28]. A study on nuclear power plant workers in South Korea demonstrated that chromosomal damage could be induced in individuals exposed to doses below the occupationally permissible limits [29].

To observe the effects of low doses of ionizing radiation, UCAs and MN as biomarkers of the effect are important not only for the assessment of work ability but also for the assessment of radiation risks due to stochastic-cumulative effects that do not directly depend on the dose [3, 14, 25]. A review of the effects on healthcare workers exposed to low doses of ionizing radiation confirms the relevance of UCAs and MN, which are consistently increased in radiation-exposed workers compared to unexposed [30]. In one study, nuclear medicine workers were associated with higher received doses and an increased frequency of UCAs [14]. The frequency of UCAs cumulates with the received dose (X-ray and Gamma radiation) [3, 14], and in one study, a six-year cumulative effect of the received dose was observed [31].

Our study found a significant difference between the UCAs among the three groups, where the nuclear medicine group had a much larger proportion of positive UCA tests after adjusting for age, sex, and smoking. This implies a higher risk of cancer among nuclear medicine workers, requiring strict exposure, health monitoring, and adherence to all the safety protocols.

The MNT is considered important in the bio-dosimetry of employees in nuclear medicine because of an elevated risk of internal radiation contamination [7]. It represents chromosomal instability and can also indicate chromosomal damage induced by radiation [32]. This test is also suitable for rapid automated detection of chromosomal damage [33].

One study found that the MNT is generally comparable in sensitivity to the chromosomal aberrations test [34]. Another study suggests the usefulness of the MN test for detecting the effects of low cumulative ionizing radiation doses in medical screening programs [35]. A recent study concluded that chromosomal aberrations (dicentrics) are more typical for exposure to radiation than micronuclei [36].

In our study, no statistically significant difference was found in the outcome of the MNT between the three groups. Since we found a significantly higher received dose Hp (10) in the nuclear medicine group, compared to the other two groups, the MNT may not be suitable as the UCA test for detecting genetic damage due to small received doses of ionizing radiation. In assessing this damage, it would be advisable to perform both tests wherever possible.

The specific positive findings, such as UCAs, can be explained by the specific risk of workplace exposure to radio-nuclides with higher radiobiological effects (a, b and γ emitters).

Hematological parameters react to the received dose, especially the number of leukocytes and lymphocytes. Studies on experimental animals and the exposed human population show that the hematopoietic system responds to acute high-dose irradiation and to repeated lower irradiation doses of the whole body [37]. However, monitoring the effect of exposure to small doses is very difficult.

In a study of hematological parameters in the hospital staff chronically exposed to low doses of ionizing radiation, a decrease in the value of most hematological parameters was observed, with a statistically significant difference in comparison to unexposed workers found in the mean corpuscular hemoglobin and lymphocyte count [37]. The authors conclude that exposure to doses lower than 20 mSv could affect the immune system's quality and contribute to anemia.

In our study, female healthcare workers and those employed in interventional radiology had higher values of erythrocytes than males and those employed in nuclear medicine or general radiology departments. This finding is unspecific and cannot be explained by the influence of ionizing radiation. In interpreting hematological findings, attention had been required because of many non-radiation-related factors that can impact the results. An exact dose-response relationship in the hematological parameters at low exposed radiation doses on analyzed subjects had not been detected. In contrast, the cytogenetic tests did follow an increasing dose-response trend, which barely reached statistical significance in the UCA test. The cytogenetic tests are more specific for radiation-induced damage than hematological parameters and therefore offer a more reliable insight in cases of exposure to low radiation doses.

5. Conclusions

The most radiation-exposed group consisted of employees in the area of nuclear medicine. In the presented study, this exposure was associated with slightly higher UCA frequency which is still good for assessment of work ability. This, in turn, causes a higher risk of cancer occurrence in the future. Results of this study suggest that the UCA test might be more suitable than MNT for detecting low ionizing radiation impacts on employees' health.

Employees exposed to low doses of ionizing radiation are at a higher risk of developing neoplastic and blood-related diseases. Out of all three groups of subjects (nuclear medicine, interventional radiology, and general radiology), employees in nuclear medicine are at special risk due to different types of exposure (work with radio-nuclides).

Mandatory health status monitoring at periodic examinations and adequate safety at work is required to prevent occupational diseases.

Institutional Review Board Statement: This study involves human participants and was approved by the Ethics Committee of the Faculty of Medicine, University of Belgrade (No 440/X-10).

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

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

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Trends in Occupational Diseases in Italian Industry and Services From 2006 To 2019

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Keywords: Occupational Diseases; Incidence Rate Ratios; Italy; Time Trend

Abstract

Background: *There is a paucity of data on occupational disease incidence in Italy, and we analyzed the trend on time as an incidence rate ratio (IRR).* **Methods:** *Occupational diseases reported to the Italian National Insurance for Occupational Diseases (INAIL) in industrial and services sectors from 2006 to 2019 were considered and analyzed. Annual case counts were analyzed using a Poisson regression model to estimate incidence trends.* **Results:** *The incidence of occupational diseases in the industrial and services sectors in 2019 was 261 cases for 100,000 workers, with musculoskeletal disorders (MSDs) representing 65% of the total cases, their incidence being 169.5 cases per 100,000 workers. The incidence of ear diseases (ED) decreased to 20.8 cases for 100,000 workers. The annual change in incidence (IRR) was 1.08 (CI 95% 1.07-1.11) for MSDs, 1.08 (CI 95% 1.06-1.10) for cancers, and 1.04 (CI 95% 1.03-1.06) for respiratory diseases. The trend was significantly negative for ear diseases, 0.96 (CI 95% 0.96-0.97), and skin diseases 0.93 (CI 95% 0.92-0.93). No changes were found for asbestos and mental disorders.* **Conclusions:** *During the study period, occupational diseases increased in Italy, mainly for MSDs, due to a changeover in eligibility criteria from 2008. However, the overall incidence was lower than in other EU Countries. More efforts are needed to harmonize the legislation for joint action in preventing and recognizing occupational diseases.*

1. Introduction

Studying incidence trends in occupational diseases (ODs) is important to prioritize and evaluate preventive measures to reduce their occurrence. Despite the importance of such an analysis, only some data are available in the literature. [1] Stocks et al. [1] reported trend analyses in contact dermatitis, occupational asthma, noise-induced hearing loss, carpal tunnel syndrome (CTS), and upper limb musculoskeletal disorders in ten EU countries from 2000 to 2012. They demonstrated a general decrease in ODs with few exceptions. Noise-induced hearing loss was reported to increase only in some EU Countries (Belgium, Spain, Switzerland, and the Netherlands). CTS and upper limb musculoskeletal disorder trends are completely different in different EU Countries, mainly due to different reporting systems [1]. EUROSTAT [2] collects data from EU Countries on ODs. Still, differences are wide due to different reporting classification systems' aims, namely compensation or prevention, and

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comprehensive data on ODs is available for a limited list of ODs in Europe.

More recently, van der Molen et al. [3] reported the trend in the incidence of ODs in Italian agricultural sectors, finding a significant increase in musculoskeletal disorders (MSDs) from 2008 due to a changeover of recognizing system applied by the Italian Insurance against occupational diseases (INAIL – Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro). [4] To enhance this study, we now report the incidence of ODs in another major economic sector, i.e., the industrial sector, in Italy from 2004 to 2019.

The present study aimed to determine the incidence and trend of reported ODs incidence rate (IRR) in Italy's industrial and services sectors from 2006 to 2019.

2. Methods

2.1. Study Design and Procedures

ODs notified to INAIL in the national industrial and services sectors from 2006 to 2019 were considered. ODs in Italy are compulsorily reported by a physician in case of "suspected occupational origin". The disease has to be acknowledged, i.e., a cause-effect link has to be ascertained, for the worker to be compensated. OD is defined when a disease is caused by work-related factors and is listed in the Italian List of Occupational Diseases, updated in 2008. [4] Incidence of ODs was determined for six groups of diseases present in the Italian list: Cancers: C00-D48; ear diseases: H60-H95, mainly noise-induced hearing loss: H83.3; musculoskeletal and connective tissue diseases: M00-M99 (mostly added in 2008); respiratory diseases: J00-J99; skin diseases: L00-L99; psychiatric disorders F00-F99 (not included in the official list of occupational diseases in Italy).

The data for this study were taken from two databases: i) the number of reported ODs for industrial and services sectors was taken from the INAIL website [5] for the last five years and from INAIL reports available online for the previous years; ii) the number of total workers in the Industrial and services sectors was taken from a database provided by the Italian National Institute of Statistics (ISTAT) [6].

2.2. Statistics

The annual incidence of occupational diseases was calculated by dividing the number of reported ODs per year (provided by INAIL) [5] by the total number of workers occupied in industrial and services sectors that year (supplied by ISTAT). [6] To estimate incidence trends, the annual case numbers were analyzed using a Poisson regression model using the time (year) as a continuous variable and the estimate of the yearly population of occupied workers in industry and services sectors. Statistical analyses were performed with StataCorp V.15. Texas, USA.

3. Results

In total, 544,924 ODs among Italian industrial workers over 14 years were notified (Figure 1), and occupied workers in industry and services sectors varied from 18,073,000 in 2006 and 18,863,438 in 2019.

Figure 1 shows the incidence trend for total and musculoskeletal occupational diseases in the period considered. In 2006, the number of all the diseases considered was 24,984, and the incidence was 138.2 cases per 100,000 workers. Musculoskeletal disorders were the most frequent ODs, with 51.0 cases per 100,000 workers, followed by ear diseases, with 34 cases per 100,000 workers. In 2008-2009, the rise of ODs started, mainly corresponding with the increase in musculoskeletal diseases, with an incidence of 64.0 and 85.4 cases per 100,000 workers in 2008 and 2009, respectively.

In 2010, the total number of diseases considered raised to 35,587, with an incidence of 198.2 cases per 100,000 workers mainly due to musculoskeletal disorders (n= 20,766 cases representing 58.3% of all ODs).

In 2019, 49,271 cases of ODs were reported, with an incidence of 261.2 cases for 100,000 workers; musculoskeletal disorders represented 65% of the total cases (n=31,973) with 169.5 cases per 100,000 workers. The incidence of ear diseases decreased to 20.8 cases for 100,000 workers. Similarly, a decrease in incidence during the timeframe considered was observed for skin diseases (from 5.14 to 1.82 cases per 100,000 in 2006 and 2019, respectively), while cancers increased from 5.8 to 13.1 cases per 100,000 workers and respiratory diseases increased

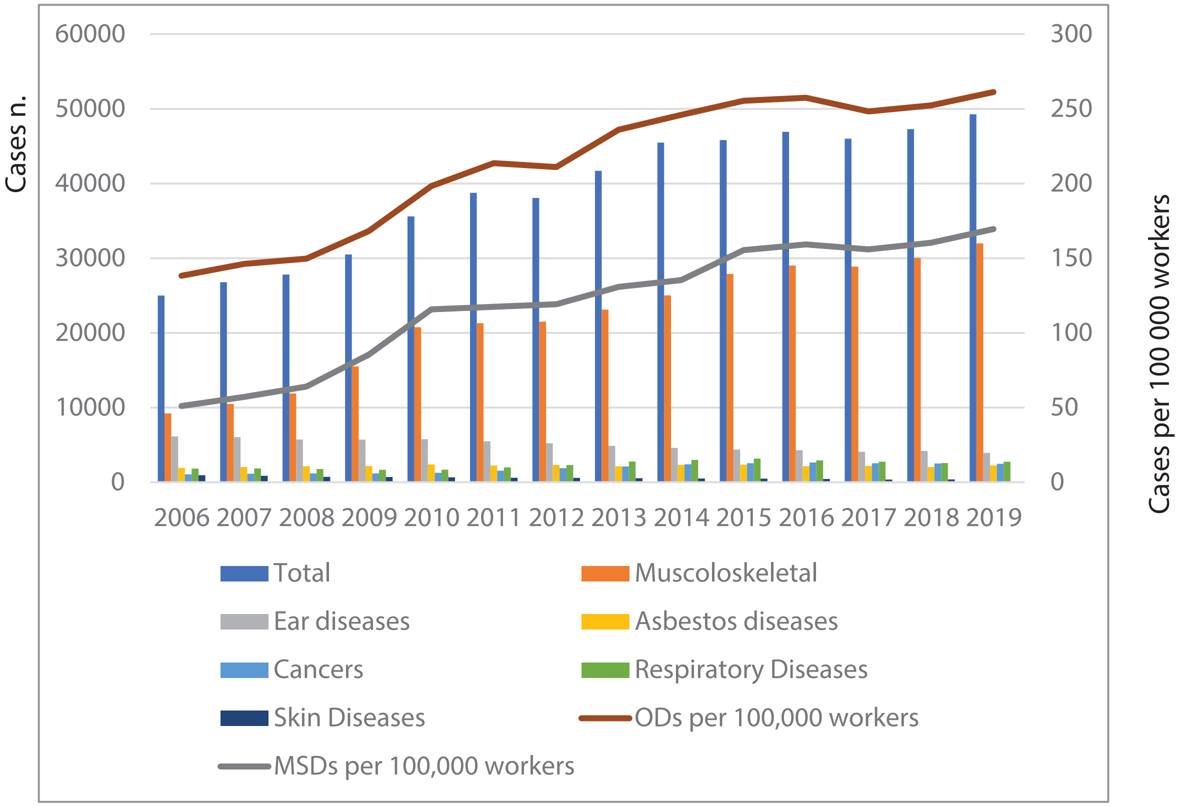

Figure 1. Absolute number (N) and Incidence cases per 100,000 workers of total and specific OD in the industrial and services sectors from 2004 to 2019. Ear diseases (mainly noise-induced hearing loss).

from 10.1 to 14.5 cases per 100,000 workers in 2006 and 2019, respectively. To better visualize the trend in ODs over time figure 2 reported occupational diseases (ODs) in the Italian industrial and services sectors from 2004 to 2019, considering 2004 as the reference year. Ear diseases (mainly noise-induced hearing loss) also include other ears' diseases. Decreasing in ear and skin diseases are clearly shown as well as the increasing in MSDs, cancers and respiratory diseases

Table 1 shows the absolute number of ODs in 2019 and the trend over the 14 years evaluated using the Poisson regression. Over this period, the annual change in incidence (IRR) was 1.08 (CI 95% 1.07-1.11) for MSDs, 1.08 (CI 95% 1.06-1.10) for cancers, and 1.04 (CI 95% 1.03-1.06) for respiratory diseases. The trend was significantly negative for ear diseases [0.96 (CI 95% 0.96-0.97)] and skin diseases [0.93 (CI 95% 0.92-0.93)]. No changes were found for asbestos and mental diseases.

4. Discussion

Our study investigated the trends in the incidence of ODs in the large Italian industrial sectors and services from 2006 to 2019 and found a significant increase in MSDs, cancers, and respiratory diseases and a decrease in ear and skin diseases (Figure 2).

The large increase in MSDs is due to the change in Italian legislation in 2008 and the reduction of underreporting for diseases that were not considered work-related in the past. This effect was already shown in the investigation done by van Der Molen et al. in 2020 [3], analyzing ODs in the Italian agriculture sector. However, we did not observe a sharp increase in MSDs after 2008 shown in agriculture. In agriculture and industry/services, MSDs were the most common ODs (74% and 53% of overall diagnoses, respectively). While the industrial and services sectors have seen a significant decrease in noise-induced hearing loss throughout the years, the

Table 1. Incidence of occupational diseases in the Italian industrial and services sectors. IRR is the annual change in incidence from 2006 to 2019, assuming a linear trend. ICD-10, International Classification of Diseases; OD, Occupational Disease; IRR, incidence rate ratio. In bold are reported significant values.

		Trends over time, 2006–2019		
Diagnosis (ICD-10)	**Absolute N in 2019**	**ODs**	**IRR**	**95% CI**
Total	49 271	544 924	**1.05**	**1.04 to 1.06**
MSDs	31 973	306 547	**1.08**	**1.07 to 1.11**
Ear diseases	3 930	70 404	**0.96**	**0.96 to 0.97**
Respiratory diseases	2743	32 995	**1.04**	**1.05 to 1.06**
Cancers	2466	26 471	**1.08**	**1.06 to 1.10**
Asbestos diseases	2234	30 558	1.00	0.99 to 1.01
Mental diseases	477	6 474	1.00	0.99 to 1.02
Skin diseases	345	8 089	**0.93**	**0.92 to 0.93**

incidence in agriculture has risen after 2008. This is probably due to the increased awareness of the possibility of receiving compensation for noise-induced hearing loss in agriculture.

In contrast, noise-induced hearing loss in the industrial sector was the principal OD, and the decrease could be explained by better prevention linked to Italian Laws 626/99 and 81/2008. The differences between the agriculture, industry, and services sectors are linked to the workforce characteristics in the two sectors. The former comprises familiar small enterprises, while bigger enterprises with higher union presence characterize the second. The overall incidence of occupational diseases was higher in agriculture [3], with 1,285 *vs* 248.3 cases per 100,000 workers in 2017 in agriculture and industry, respectively. Similar differences were found for musculoskeletal disorders (961 vs. 155.9 cases per 100,000 workers), while cancer incidence was higher in the industry and services sectors (11 *vs* 13.8 cases per 100,000 workers, respectively).

During the analyzed period, we found a significant increase in cancers and respiratory diseases reported, possibly due to the increased knowledge of their potential occupational causation and the improvement of medical surveillance for workers linked to the Italian Low 81/2008.

The incidence of skin diseases decreased in the considered period with lower incidences than international data [7, 8]. Indeed, skin diseases in Italy are less reported, and incidence data are probably underestimated. [9] Moreover, Mediterranean skin, frequently exposed to the sun, presented a lower prevalence of atopic eczema, one of the most important risk factors for contact dermatitis. [9] The decreasing trend for occupational skin diseases aligns with a European registry study [1] and EUROSTAT data. [2] No differences were found for asbestos-related illnesses, for which Italian law makes the relationship with exposure clear and stable over time.

In the Netherlands [10] and Scotland [11], the most reported ODs were mental diseases followed by MSDs, while in Italy in 2009, mental diseases accounted only for 1.9% of all ODs. Mental disorders are not included in the list of occupational diseases for which the Italian insurance system recognizes the relationship with some exposures. This example further demonstrates how the incidence of occupational diseases is biased by criteria used in compensation, largely affected by the context, i.e., by the societal acceptability of detrimental effects of work on workers' health.

The creation of the EU COST ACTION MODERNET (Monitoring trends in Occupational Diseases and tracing new and Emerging Risks in a NETwork) tried to analyze data to compare them between countries [12]. However, the comparisons of incidence are problematic, considering the differences between OD surveillance systems in each EU country. [1, 13-15] Our study demonstrated increased occupational diseases reported in Italy due to the changeover in legislation. To better act

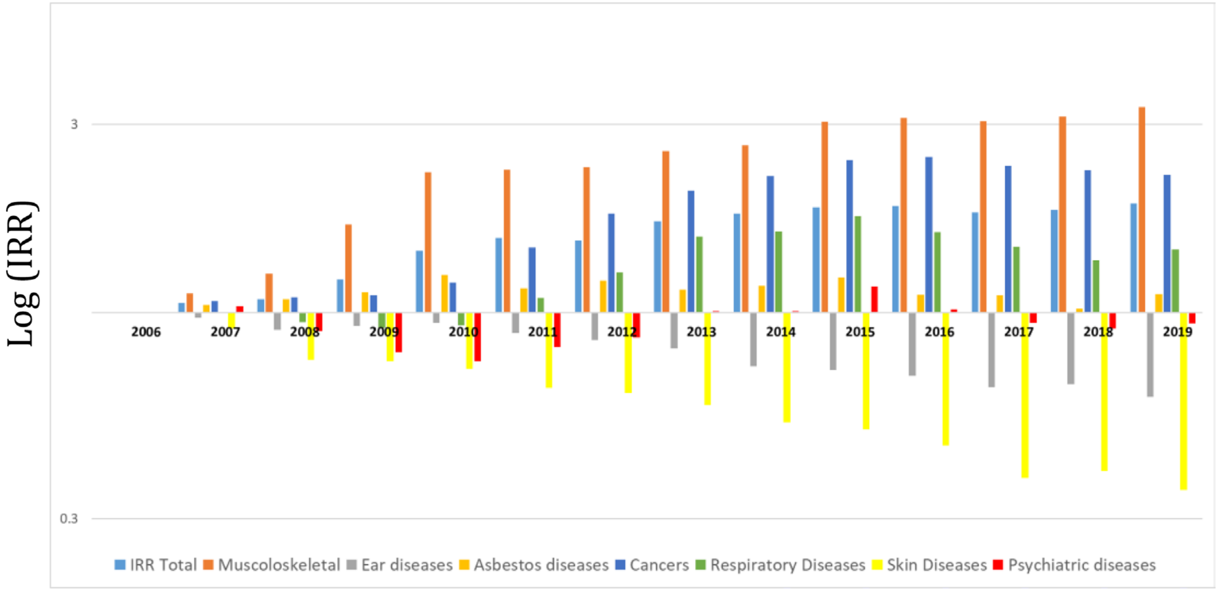

Figure 2. Incidence rate ratio of reported occupational diseases (ODs) in the Italian industrial and services sectors from 2004 to 2019, considering 2004 as the reference year. Ear diseases (mainly noise-induced hearing loss) also include other ears' diseases.

in the prevention of occupational diseases EU needs common legislation: differences in the incidence of occupational diseases trend in Italy seems to be mainly due to legislation and criteria applied by the insurance institution than to an actual increase in disease incidence. More efforts are needed for common legislation in the EU to recognize occupational diseases and for a common frame to promote prevention and fair compensation if justified.

5. Conclusion

Our study reported the incidence of ODs in Italian industrial and services sectors from 2004 to 2019, showing an increasing trend due mainly to MSDs and, to less extent, to cancers and respiratory diseases. Incidence data on occupational skin diseases and ear diseases showed declining trends. No differences were found for asbestos and mental-related illnesses. More efforts are needed to harmonize ODs legislation in the EU for better prevention and fair compensation.

Declaration of Interests: The Authors declare no conflict of interests.

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La Medicina del Lavoro

Letter to the Editor
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Shift Office Work

The article by Güngördü et al. [1] notes that in employees of a Turkish hospital, there is an association between occupational stress and sleep problems. The result is not new since longitudinal occupational studies have shown that stress and sleep are in a reciprocal relationship: excessive stress causes sleep problems, and workers with poor-quality sleep suffer more from stress [2]. The originality of the article lies in the occupational category studied because studies on office hospital workers are lacking. Therefore, it would have been essential to explain what risk the sample under investigation is exposed to and whether it includes night work.

The authors deal extensively in the Introduction with night work and the disruption of circadian rhythms caused by night work that interferes with the quality and quantity of sleep. Also, in the Discussion, they refer to the problems of night shift workers and the disruption of the sleep-wake cycle induced by night work. This would suggest that the offices of Turkish hospitals are open at night.

We do not know Turkish hospitals, but we know that offices do not work night hours in Europe. European hospital clerks perform two types of activities: desk clerks, who operate a single day shift, and counter clerks, who start early in the morning and work two shifts. The latter is more stressful due to a more significant workload and user pressure, which can not infrequently result in uncivil behavior and verbal violence. Work-related violence in healthcare workers may be associated with sleep disturbances [3, 4]. If we were to interpret the causes of stress in counter workers, we would think primarily of the customers, not the double shift.

The association between stress and sleep that the authors observed in Turkey should have been interpreted considering the working conditions of employees.

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Authors' Reply

In Turkey, medical secretaries and data entry personnel participate in procedures such as data entry and experience little exposure to patients and their relatives. Shift work is mandatory for 24-hour health care service in the health sector. When we say shift work in the health sector, the first groups that come to mind are healthcare workers, such as nurses and physicians, and office workers in our country also work in shifts. The hospital office workers in our study are the medical secretary, data entry personnel, and administrative personnel. While the medical secretary and data entry personnel among the hospital office workers can work in shifts, the administrative personnel work during the daytime.

Employees are exposed to stress due to many factors in the workplace environment. Organizational factors such as working hours and shift systems are among the causes of stress in the workplace. Job stress can cause sleep problems. At the same time, sleep disturbance is a common problem faced by night shift workers. As a result of the disruption of the circadian rhythm due to shift work, a decrease in sleep quality and quantity occurs.

Considering the risks that hospital office workers are exposed to, we planned our study considering that shift work and job stress may cause more sleep disorders. In our study, sleep quality, work-related stress, and related factors were evaluated in hospital office workers. We found that shift work and increased job stress scores in hospital office workers increased the risk of poor sleep quality.

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