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La Medicina del Lavoro

Editorial

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Zero excess risk from exposure to genotoxic carcinogens: how long does it take after exposure cessation

We received a letter from Professor Benedetto Terracini commenting on the paper "Mortality from bladder cancer in dyestuff workers exposed to aromatic amines: a 73-year follow-up" by Ciocan and co-workers [1]. The letter and the Authors' reply have been accepted for publication in the following pages.

Our journal is neither in favor nor against mentioning the workplaces where a particular study has been conducted. Omitting the location would be an absence of information for a newspaper: a correct chronicle requires that five "W", including "where", be specified. A scientific journal is however interested in the core message and its external validity, rather than its historical contextualization. The scientific literature, including *La Medicina del Lavoro*, would not consider the omission of the name of the industry a cause of concern requiring a correction. But it wouldn't even delete it, if mentioned: the names are specified when the authors wish to do so.

We accepted for publication the paper by Ciocan et al. [1], because of the interest of its message, since it quantified the very long persistence of the increased risk of bladder cancer related to aromatic amine exposure – a well-known risk factor for bladder cancer. Like other cancers sharing similar underlying genotoxic mechanisms, the excess risk was still elevated after more than 40 years after the last occupational exposure. Likewise, the risk of lung cancer among smokers tends to level off towards that of nonsmokers several decades after cessation [2]. After the publication of the paper "Linear Non-Threshold (LNT) historical discovery milestones" by E. Calabrese [3], the article by Ciocan et al. seems to be "food for thought" on critical mechanistic aspects of occupational cancer.

Also, mainly thanks to the workers' fight for their health and a new legal framework in Europe, the working settings and conditions are today much different from those experienced at the IPCA many decades ago. Is it realistic to believe that today's owners and managers would deliberately violate norms and good practices (*a sine qua non* to consider them guilty in a trial for crimes), knowing that workers' health could be endangered up to the extreme consequences? Failure to implement prevention measures should be regarded as a failure of our discipline and requires continuous action and monitoring by governments and social parties.

References

1. Ciocan C, Godono A, Franco N, et al. Mortality from bladder cancer in dyestuff workers exposed to aromatic amines: A 73-year follow-up. *Med Lav*. 2022 Apr 26;113(2):e2022017. Doi: 10.23749/mdl.v113i2.12893. PMID: 35481579; PMCID: PMC9073764
2. Peto R, Darby S, Deo H, Silcocks P, Whitley E, Doll R. Smoking, smoking cessation, and lung cancer in the UK since 1950: combination of national statistics with two case-control studies. *BMJ* Vol. 321.
3. Calabrese E. Linear Non-Threshold (LNT) historical discovery milestones. *Med Lav*. 2022; 113(4): e2022033.

La Medicina del Lavoro

Original article

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Incidence of malignant mesothelioma and asbestos exposure in the Emilia-Romagna region, Italy

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Keywords: Mesothelioma; incidence; exposure; asbestos; sector of working

Abstract

Background: *The aim of this study is to describe the incidence of malignant mesothelioma (MM) and asbestos exposure in an Italian region in the period 1996-June 2021.* **Methods:** *The study included cases with microscopic confirmation and those with instrumental confirmation. For each case, information on sex, age, tumour site, morphology and date of diagnosis was collected, along with details of exposure to asbestos.* **Results:** *3,097 cases of MM (2,233 males and 864 females) were registered: 90.8% with microscopic confirmation. A total of 2,840 cases involved the pleura (92%), 230 cases the peritoneum (7%), and a small number of cases the pericardium and testis (9 and 18, respectively). Most cases (78.0%) occurred after 65 years of age, while only 1.5% concerned individuals with age<45 years. The standardized incidence rate for the entire period (adjusted to the 2000 Italian standard population and calculated per 100,000 person-years) was equal to 3.9 in males and 1.4 in females, and the trend showed an increase with age in both sexes. Concerning asbestos exposure, 79.7% of cases were exposed (86.7% males and 60.1% females). In 70.3%, exposure was occupational (83.4% males and 33.2% females), while 20.7% of females and 0.8% of males had familial exposure. Building construction, rolling stock manufacture/repair and metalworking were the most prevalent economic activities associated with occupational exposure.* **Conclusions:** *This study offers an overview of MM in an Italian region characterized by high incidence and high exposure due to its particular production activities.*

1. Introduction

Malignant mesothelioma (MM) is a rare tumour of great scientific interest owing to its well-documented correlation with occupational and/or environmental exposure to asbestos and to its increased incidence in Italy and in many other industrialized countries [1-7].

Although asbestos was definitively banned in Italy in April 1994 (pursuant to Italian Law No 257/92), the lengthy latency period between exposure and the onset of disease, the increase in life expectancy, and improvements in diagnostic techniques have led to an increase in the incidence of MM in recent years [8-10]. MM remains a deadly cancer with a very poor prognosis, with a median survival period of ten months [5,9].

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Several countries have established specialized registries to monitor the incidence of MM over time, identify sources of exposure to asbestos, provide medical and legal assistance to patients and their families, evaluate survival, and forecast future trends in the incidence of MM [4, 11-13].

Italy had been using large quantities of chrysotile and amphiboles from 1945 until the 1992 ban and is currently among the countries with the highest frequency of MM worldwide [14]. In Italy, a National Mesothelioma Registry (ReNaM) has been implemented and organized as a network of regional registries [4].

The aim of this study is to describe the results of the Mesothelioma Registry (ReM) in the Emilia-Romagna region in the period 1996-2021 and the associated data on exposure to asbestos.

2. Methods

The ReM for Emilia-Romagna (Italy) covers a region of northern Italy characterized by a large population (currently about five million inhabitants) and a high rate of industrialization. A Cancer Registry specifically dedicated to the study of the incidence and etiology of MM has been active since 1 January 1996. Its task, along with performing the functions of the COR (Regional Operational Centre) for the Emilia-Romagna region, is to register all cases of MM and to acquire information to formulate the correct diagnostic definition and standardized attribution of occupational and non-occupational asbestos exposure according to the standardized rules of the ReNaM [12]. The Emilia-Romagna ReM actively and systematically collects data on all new diagnoses of MM in the region. The collection, coding and registration of cases follow standardized rules at national and international level [15-16].

All cases of MM, with morphology 90503, 90513, 90523 and 90533 [16], occurring between 1 January 1996 and 30 June 2021 in patients with the disease identified in the pleura, pericardium, peritoneum or tunica vaginalis of the testis residing in the Emilia-Romagna region at the time of diagnosis have been registered. The data on incidence are complete until 2019, but a few more months will be required to gather the data for the years 2020-2021 before a complete picture of incidence can be established. For each case, in addition to pathology reports, the medical records on significant hospitalizations in any healthcare institution have been routinely collected, whether public or private, within the region or further afield. Information on both occupational and non-occupational exposure is collected through the ReNaM's ad hoc questionnaire.

Data are collected in all public and private healthcare institutions and anatomical pathology units in the region, the hospital departments where patients with MM are cared for, and all regional public health departments. The ReNaM staff usually acquires reports of newly diagnosed cases in real time, which makes it possible to collect information on exposure to asbestos directly from the patient, when possible, or from a next-of-kin using an ad hoc questionnaire, often administered in hospital or at home and generally returned within two months of diagnosis. To verify the completeness and accuracy of incident cases, the data periodically acquired from the regional computerized archives (mortality and hospital discharge records) are linked with information from the regional population cancer registries and other COR network members.

Cases are reported by sex, age, tumour site and year of diagnosis. The distribution of exposure is reported by sex and by specific economic activity: the staff of the Mesothelioma Registry administers the questionnaires and collects information relating to the various work activities. Subsequently, the multidisciplinary team discusses and evaluates the main activity to which the exposure can be attributed. The other activities are nonetheless reported in the questionnaire.

The standardized incidence rate for the period 1996-2019 was calculated separately for males and females. Incidence rates were adjusted to the 2000 Italian standard population and calculated per 100,000 person-years. Cases were collected until mid-2021, when the region was heavily impacted by the COVID-19 pandemic.

3. Results

In Emilia-Romagna, 3,097 MM cases were registered between 1996 and 2021. The distribution by age, diagnostic definition, sex and site is shown in Table 1. Most of the cases were diagnosed in the age groups 75+ (1,401 cases, 45.2%) and 65-74 (1,014 cases, 32.8%), and mainly affected the pleura. Few cases (47 cases, 1.5%) were recorded at a younger age (<45 years) and in this subgroup the pleura/peritoneum ratio is 2:1. Concerning diagnostic definition, 2,645 cases (85.4%) were classified as *certain*, 166 cases (5.4%) as *probable* and 286 cases (9.2%) as *possible*.

The distribution by year of diagnosis and site is shown in Table 2. A total of 2,840 cases involved the pleura (92%), 230 cases the peritoneum (7%), 9 the pericardium and 18 the testis. Over the years the number of cases has almost doubled, rising from 75 cases in the 1990s to 150 in more recent years, and

Table 1. Case Distribution by age, diagnostic definition, sex and site. Cases from 1996 to 2021 (updated to 30 June 2021).

	Males					Females				Total (%)
	Pleura	Peritoneum	Pericardium	Testis	Total	Pleura	Peritoneum	Pericardium	Total	
Age (years)										
<45	18	9	-	4	31	11	5	-	16	47 (1.5)
45-54	90	10	-	3	103	36	10	1	47	150 (4.8)
55-64	337	24	-	3	364	97	22	2	121	485 (15.7)
65-74	701	44	4	3	752	232	29	1	262	1,014 (32.8)
75+	933	44	1	5	983	385	33	-	418	1,401 (45.2)
Total	*2,079*	*131*	*5*	*18*	*2,233*	*761*	*99*	*4*	*864*	*3,097 (100)*
MM diagnostic definition										
certain*	1,793	119	3	17	1,932	619	91	3	713	2,645 (85.4)
probable**	110	9	2	1	122	37	6	1	44	166 (5.4)
possible***	176	3	-	-	179	105	2	-	107	286 (9.2)
Total	*2,079*	*131*	*5*	*18*	*2,233*	*761*	*99*	*4*	*864*	*3,097 (100)*

**Histology with well-defined and suggestive morphology of malignant mesothelioma + immunohistochemistry.*
***Histology with dubious morphology + well-defined cytology suggestive of malignant mesothelioma.*
****Absent histology + well-defined radiological and instrumental reports suggestive of malignant mesothelioma.*

Table 2. Case distribution by year of diagnosis and site.

	Site				
Year	Pleura	Peritoneum	Pericardium	Testis	Total
1996	63	8	-	2	73
1997	70	7	3	-	80
1998	77	4	1	1	83
1999	67	6	-	-	73
2000	76	9	-	1	86
2001	88	6	-	2	96
2002	98	15	-	1	114
2003	97	6	1	1	105

Table 2 (*Continued*)

	Site				
Year	**Pleura**	**Peritoneum**	**Pericardium**	**Testis**	**Total**
2004	110	8	2	-	120
2005	107	10	-	2	119
2006	100	7	-	-	107
2007	101	14	-	-	115
2008	122	9	-	1	132
2009	111	11	-	-	122
2010	117	12	1	-	130
2011	144	10	-	1	155
2012	142	10	1	2	155
2013	147	5	-	1	153
2014	122	11	-	1	134
2015	141	10	-	-	151
2016	150	10	-	-	160
2017	146	11	-	1	158
2018	142	14	-	-	156
2019	135	8	-	-	143
2020	119	5	-	1	125
2021*	48	4	-	-	52
Total	*2,840*	*230*	*9*	*18*	*3,097*

**At 30 June 2021.*

the increase has involved almost exclusively cases affecting the pleura. The standardized incidence rate (adjusted to the 2000 Italian standard population and calculated per 100,000 person-years) confirms this trend: this increased in males from 2.4 in 1996 to 4.4 in 2016, and in females from 0.8 in 1996 to 1.4 in 2018 (Figure 1).

As regard asbestos exposure, for 166 cases the type of exposure was not defined (patients died or it was not possible to make a classification) and for further 248 cases the information was not available since patients or family members could not be contacted or refused to provide information. The distribution by type of exposure for the 2,683 remaining cases (87% of the total) is reported in Table 3.

Occupational exposure was more frequent in males (83.4% in males vs 33.2% in females), whereas familial exposure was more frequent in females (20.7% in females vs 0.8% in males). Women also showed a higher proportion of cases exposed to environmental asbestos and of subjects for whom the type of exposure was improbable (the available data suggest that exposure to asbestos is unlikely) or unknown (the available data are insufficient to reconstruct the exposure history). By professional exposure, we mean all those sectors of economic activity in which workers have come into contact with material containing asbestos, which was used for thermo-acoustic insulation or as a protective device against fire and heat. In terms of the economic activities involved (Table 4), in Emilia-Romagna most of the males were employed in the construction sector ('construction' means building constructions and therefore bricklayers, while 'construction work completion' means sheet metal work and painting) and in the repair of railway rolling stock (the so-called "Officina Grandi Riparazioni" in Bologna).

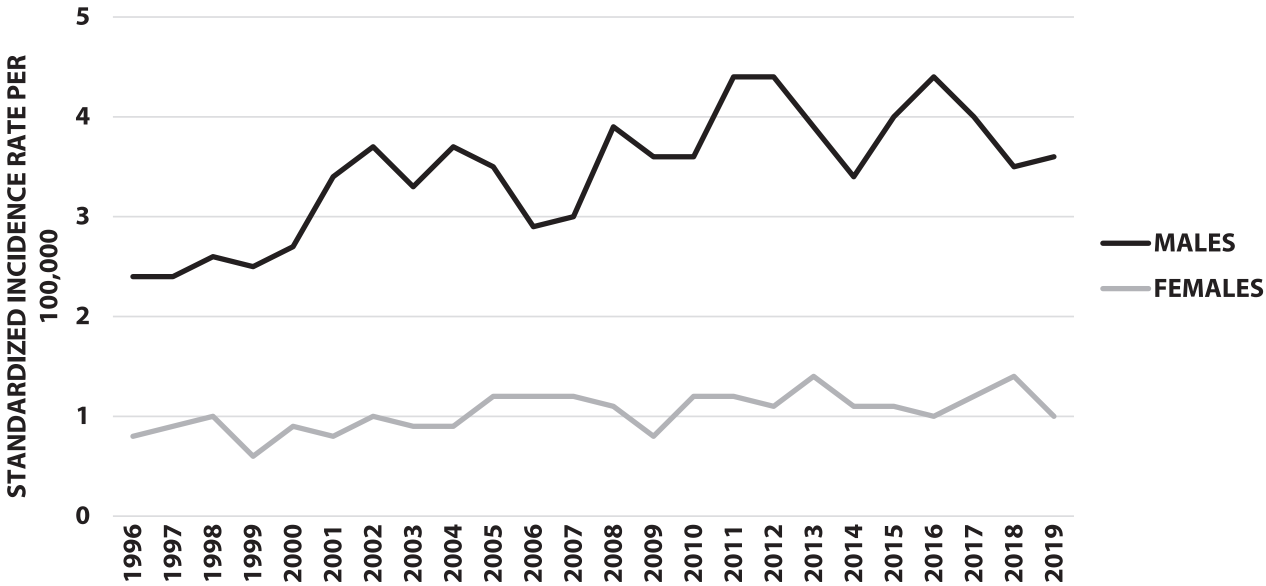

Figure 1. Standardized incidence rates (Italian population per 100,000), by sex. Years 1996-2019.

Table 3. Distribution of malignant mesothelioma by type of asbestos exposure and sex.

Type of exposure	**Males**		**Females**		**Total**	
	N.	**%**	**N.**	**%**	**N.**	**%**
Occupational	1,652	83.4	234	33.2	1,886	70.3
Familial	15	0.8	146	20.7	161	6.0
Environmental	29	1.5	28	4.0	57	2.1
Non-occupational	20	1.0	15	2.1	35	1.3
Improbable	63	3.2	87	12.4	150	5.6
Unknown	200	10.1	194	27.6	394	14.7
Total defined cases	*1,979*	*100.0*	*704*	*100.0*	*2,683*	*100.0*

Table 4. Distribution of occupational exposure to asbestos by economic activity and sex.

Economic activity	**Male**		**Female**		**Total**	
	N.	**%**	**N.**	**%**	**N.**	**%**
Construction	271	16.4	1	0.4	272	14.4
Manufacture/repair of rolling stock	190	11.5	3	1.3	193	10.2
Engineering industry	155	9.4	12	5.1	167	8.9
Sugar refineries/other food industries	113	6.8	41	17.5	154	8.2
Production of cement/asbestos products	93	5.6	32	13.7	125	6.6
Production of chemical/plastic material	100	6.1	6	2.6	106	5.6
Construction work completion	84	5.1	1	0.4	85	4.5

Table 4 (*Continued*)

Economic activity	Male		Female		Total	
	N.	%	N.	%	N.	%
Glass/ceramic/rubber manufacturing	58	3.5	20	8.6	78	4.2
Transportation	75	4.6	3	1.3	78	4.2
Production/repair of vehicles (not trains or ships)	68	4.1	4	1.7	72	3.8
Manufacturing/processing of metallic products	61	3.7	3	1.3	64	3.4
Textile industry	37	2.2	15	6.4	52	2.8
Trade	42	2.6	9	3.8	51	2.7
Production of electricity, gas and water	40	2.4	-	-	40	2.1
Social services/recreational activities/healthcare	20	1.2	18	7.7	38	2.0
National defence	37	2.2	1	0.4	38	2.0
Agriculture/animal breeding	24	1.5	12	5.1	36	1.9
Metallurgical industry	31	1.9	4	1.7	35	1.9
Other manufacturing industries	27	1.6	3	1.3	30	1.6
Other	126	7.6	46	19.7	172	9.1
Total	*1,652*	*100.0*	*234*	*100.0*	*1,886*	*100.0*

As regard women, most of the workforce was employed in sugar refineries (17.5%), followed by the production of asbestos-cement products (13.7%), which was an activity that required a great deal of patience and precision. Later, women were employed in the manufacture of glass and ceramics and to a more limited degree in the textile industry, which was not highly developed in this region.

4. Discussion

This study provides an overview across 25 years of the incidence of mesothelioma cases recorded in the Emilia-Romagna region and provides detailed information on asbestos exposure.

The study includes over 3,000 MM cases (10% of the entire national case series) recorded in a region that has implemented a widespread network for reporting new cases and a team dedicated to the correct assessment of occupational exposure, which is also valuable for compensation purposes.The incidence rate (adjusted to the 2000 Italian standard population and calculated per 100,000 person-years) for the last completed year (2019) was 3.6 in males and 1.0 in females, a figure slightly higher than the value registered in Italy in 2017 (pleura: 3.4 in males and 0.9 in females; peritoneum: 0.1 in males and 0.09 in females) [8, 15]. Given the small numbers of cases, we are not able to report the rates separately by sex and by site. The slightly higher incidence in females in our region may be due to the fact that in some provinces females were typically hired to manufacture of small products made of cement/asbestos. Since the disease can be associated with even modest exposure to asbestos, each new case must be considered a 'sentinel event' of previous exposures and should be carefully evaluated [7, 17-28].

It should be noted that the 125 cases diagnosed in 2020 could reflect a reduction in diagnoses during the COVID-19 pandemic, as has been widely demonstrated for other cancers [20]. This trend also seems to be confirmed by the 52 cases recorded in the first six months of 2021.

In our region, the average age of diagnosis is 70 years, the Male/Female ratio is 2.5, value that overlap exactly with national data [15]. The average age at diagnosis for Italy, as a whole in the period examined, was 72.0±10.7 years. A total of 78.0% of the patients in Emilia-Romagna were at least 65 years of age at the time of diagnosis, compared to the 72.0% recorded nationally [8, 15].

The primary goal of the ReNaM is to ensure that the data and information collected are complete and accurate. In a previous study, we showed that the completeness and accuracy of the information have improved [29] and that underreporting has probably been very low in recent years. Diagnostic quality can be considered good: 90.8% of cases are accompanied by cyto-histological confirmation thanks to the widespread practice in the regional health services of performing minimally invasive biopsies, which also make it possible to examine elderly patients and/or patients with reduced performance status.

A total of 93.2% of cases in Italy are diagnosed in the pleura, while 6.3% are identified in the peritoneum. In our series, the number of peritoneal cases is slightly higher (7.4%) compared to Italian [8, 19] and international data [20,22], a situation perhaps linked to a greater involvement of gynaecologists, andrologists and abdominal surgeons in recruiting cases of peritoneal relevance.

Information on exposure has been collected in 87% of cases (the Italian average is 79%). Great efforts have been made in recent years to find healthcare personnel who can be assigned to interview patients at their hospital beds or in their homes in order to have direct information from the patient on any exposure related to his/her previous work activity. A multidisciplinary team comprising an occupational physician, an industrial hygienist and an environmental expert has been tasked with assessing exposure and then reporting any occupational disease where applicable. Occupational exposure (70.3%) is similar to that reported for Italy (69%). The familial exposure data (6%) found in our study are a little higher than the national average (5%).

It is also interesting to note that 14.4% of occupational exposures in our region are related to construction, while the second position is held by 'construction and repair of railway rolling stock', which caused a large number of MM cases in the entire period examined. For women, on the other hand, the production of asbestos cement products and food industries that employed a lot of female personnel after II World War caused a large number of cases among workers in these companies, resulting in an exposure level of almost 30%.

In addition to occupational (higher in males) and familial exposure (higher in females), it is worth mentioning the occurrence of MM without known exposure. Both improbable and unknown exposure are more frequent in women, suggesting an actual environmental exposure, in line with what is described in the literature [30].

The strengths of this work include the *completeness* of the data (the recorded cases are compared each year with the data from population cancer registries for the Emilia-Romagna region) and the *accuracy* of the diagnoses (over 90% of cases have cyto-histological confirmation, 9% have instrumental confirmation, and cases with DCO-Death Certificate Only-represent only 0.2% of the cases recorded).

Another strength is the timeliness of diagnosis and the rapid reporting of each case to the registry and direct patient interviews, when possible (1,123 patients in our series), with a specific questionnaire returned within two months from diagnosis. The availability of recent data, updated to the first half of 2021, is also an advantage for our study.

Among the limitations of this study are the lack of information on disease stage and the absence of information on treatment.

5. Conclusions

This study offers an overview of MM in an Italian region characterized by high incidence and significant exposure due to its particular production activities. The health emergency caused by the spread of the SARS-CoV-2 virus has had a considerable impact on the operational capacity of the CORs. The regional health systems have necessarily been called on to address the pandemic crisis using every available resource, and in some cases this has also led to operational difficulties for the CORs, both in the detection of incident cases and in their ability to analyze anamnestic methods of exposure to asbestos.

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

References

1. Novello S, Pinto C, Torri V, et al. The Third Italian Consensus Conference for Malignant Pleural Mesothelioma: State of the art and recommendations. *Crit Rev Oncol Hematol*. 2016;104:9-20.
2. Ministero della Salute. Piano Nazionale Amianto: Linee di intervento per un'azione coordinata delle amministrazioni statali e territoriali; Roma, marzo 2013.
3. Hughes S. Relazione sulle minacce per la salute sul luogo di lavoro legate all'amianto e le prospettive di eliminazione di tutto l'amianto esistente; Parlamento Europeo, Doc di seduta A7- 0025/2013.
4. Marinaccio A, Binazzi A, Marzio DD, et al. ReNaM Working Group. Pleural malignant mesothelioma epidemic: incidence, modalities of asbestos exposure and occupations involved from the Italian National Register. *Int J Cancer*. 2012 May 1;130(9):2146-54.
5. Alessi M, Amadori D, Amunni G, et al. Stato dell'arte e prospettive in materia di contrasto alle patologie asbesto-correlate; Quaderni del Ministero della Salute, n° 15, maggio-giugno 2012.
6. Delgermaa V, Takahashi K, Park EK, Vinh Le G, Hara T, Sorahan T. Global mesothelioma deaths reported to the World Health Organization between 1994 and 2008. *Bull World Health Organ*. 2011; 89:716-24.
7. Bertazzi PA. Descriptive epidemiology of malignant mesothelioma. *Med Lav*. 2005;7(4):287-303.
8. Marinaccio A, Binazzi A, Branchi C, et al. Sesto Rapporto - Il Registro Nazionale dei Mesoteliomi. INAIL, Milan 2018.
9. Magnani C, Bianchi C, Chellini E, et al. III Consensus Conference on Malignant Mesothelioma of the Pleura. Epidemiology, Public Health and Occupational Medicine related issues. *Med Lav*. 2015;106(5):325-32.
10. Alpert N, van Gerwen M, Taioli E. Epidemiology of mesothelioma in the 21st century in Europe and the United States, 40 years after restricted/banned asbestos use. *Transl Lung Cancer Res*. 2020;9(Suppl 1): S28-S38.
11. Goldberg M, Imbernon E, Rolland P, et al. The French National Mesothelioma Surveillance Program. *Occup Environ Med*. 2006 Jun;63(6):390-5.
12. Neumann V, Günthe S, Mülle KM, Fischer M. Malignant mesothelioma - German mesothelioma register 1987-1999. *Int Arch Occup Environ Health*. 2001 Aug;74(6):383-95.
13. Yeung P, Rogers A, Johnson A. Distribution of mesothelioma cases in different occupational groups and industries in Australia, 1979-1995. *Appl Occup Environ Hyg*. 1999;14:759-67. Doi:10.1080/104732299302189.
14. Park EK, Takahashi K, Hoshuyama T, et al. Global magnitude of reported and unreported mesothelioma. *Environ Health Perspect*. 2011 Apr;119(4):514-8.
15. Il registro nazionale dei mesoteliomi, VII rapporto, 2021. Tipolitografia Inail - Milano, dicembre 2021. ISBN-978-88-7484-716-7.
16. ICD O third edition Fritz AG: International Classification of Diseases for Oncology: ICD-O (ed 3). Geneva. Switzerland. World Health Organization. 2000).
17. Nesti M, Adamoli S, Ammirabile F, et al. Linee Guida per la rilevazione e la definizione dei casi di mesotelioma maligno e la trasmissione delle informazioni all'ISPESL da parte dei Centri Operativi Regionali. II Edizione. Roma, maggio 2004.
18. Mangone L, Storchi C, Bisceglia I, Romanelli A. Malignant Mesothelioma in the Italian region Emilia-Romagna: incidence and asbestos exposure update to 2020, *Annals of Research in Oncology*, Vol. 1(3), 199-208, 2021.
19. Romanelli A, Marinaccio A, Mirabelli D, et al. Progetto di ricerca ISPESL B/45/DML/03, I mesoteliomi maligni a localizzazione extrapleurica, 2005.
20. Robinson BW, Musk AW, Lake RA. Malignant mesothelioma. *Lancet*. 2005;366:397-408.
21. Chiappino G, Mensi C, Riboldi L, Rivolta G. Il rischio amianto nel settore tessile: indicazioni dal Registro Mesoteliomi Lombardia e definitiva conferma. *Med Lav*. 2003;94(6):521-30.
22. Sugarbaker PH, Welch LS, Mohamed F, Glehen O. A review of peritoneal mesothelioma at the Washington Cancer Institute. *Surg Oncol Clin N Am*. 2003;12(3):605-21.
23. Britton M. The epidemiology of mesothelioma. *Semin Oncol*. 2002;29(1):51-61.
24. Huncharek M. Non-asbestos related diffuse malignant mesothelioma. *Tumori*. 2002;88:1-9.
25. Mangone L, Romanelli A, Campari C, Candela S. Il mesotelioma maligno in Emilia-Romagna: incidenza ed esposizione ad amianto. *Epid Prev*. 2002;26(3):124-9.
26. Peto J, Decarli A, La Vecchia C, Levi F, Negri E. The European mesothelioma epidemic. *Br J Cancer*. 1999;79(¾):666-72.
27. Boffetta P. Health effects of asbestos exposure in humans: a quantitative assessment. *Med Lav*. 1998;89(6):471-80.
28. Spirtas R, Heineman EF, Bernstein L, et al. Malignant mesothelioma: attributable risk of asbestos exposure. *Occup Environ Med*. 1994;51:804-11.
29. Mangone L, Di Felice E, Storchi C, et al. The effects of improving the mesothelioma surveillance network on sensitivity, timeliness in reporting and asbestos exposure assessment. *Med Lav*. 2017 Oct 27;108(5):367-76.
30. Baumann F, Carbone M. Environmental risk of mesothelioma in the United States: An emerging concern-epidemiological issues. *J Toxicol Environ Health B Crit Rev*. 2016;19(5-6):231-249.

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Long-term COVID symptoms, work ability and fitness to work in healthcare workers hospitalized for sars-CoV-2 infection

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KEYWORDS: Long-term, COVID-19, work ability; healthcare workforce; occupational medicine

Abstract

Background: *COVID-19 can affect the persistence of symptoms and work ability (WA), hence the fitness to work of healthcare workers (HCW). We describe the effects of COVID-19 in hospitalized HCWs of a large Hospital in Lombardy and their implications on WA and fitness to work.* **Methods:** *Fifty-six HCWs of Fatebenefratelli-Sacco Hospital have been hospitalized for COVID-19 since March 2020. Clinical and fitness-to-work data were acquired from Occupational Health Surveillance Program. A structured questionnaire was administered to 53/56 HCWs 18 months after infection to investigate Long-COVID symptoms and WA.* **Results:** *Symptoms most reported at recovery (rhino-pharyngeal swab-NPS-negative) were exertional dyspnea (86.8%), asthenia (86.8%), arthro-myalgia (71.7%), sleep disorders (64.2%), resting dyspnea (62.3%), cough (56.6%). 69.6% underwent evaluation at outpatient clinics experienced in long-COVID. Ten months after recovery, symptoms related to physical well-being decreased while memory and anxiety/depression were more persistent. At recovery, the WA score decreased from 10 to 8, and then an improvement from 8 to 9 was noted during the survey. At the return-to-work examination, fit-to-work judgements with restrictions increased from 31.4% to 58.7%; then, a slight decrease in the rate of judgements with restrictions was observed at the survey's time.* **Conclusion:** *Post-COVID-19 symptoms can persist for a long time and could impact WA and fitness-to-work of HCW. Adequate health surveillance protocols should guarantee the health protection of HCW with persistent disorders after COVID-19.*

1. Introduction

Coronaviruses are a family of viruses associated with a wide range of symptoms, such as common cold, pneumonia, and severe acute respiratory syndrome (SARS) and can also affect the gut [1]. A new strain of coronavirus – SARS-CoV-2 – was first reported in Wuhan, China, in December 2019. It has since spread to every country around the world [2]. The clinical syndrome associated with

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Sars-CoV-2 infection has been called COVID-19 (CoronaVirus Disease-19) [3].

Although many people remain asymptomatic, the most common symptoms appear approximately 4-10 days after exposure. The main symptoms of COVID-19 can be very mild to severe and include fever, cough, and shortness of breath. While most patients seem to have mild disease, about 15% progress to a more severe illness requiring hospitalization. Approximately 5% become critically ill, including pneumonia, respiratory failure and, in some cases, death [4]. Many people continue to describe ongoing symptoms long after the acute phase of COVID-19, often referred to as long-COVID. The World Health Organization (WHO) defines long-COVID syndrome as the persistence of signs and symptoms related to COVID-19 infection for more than twelve weeks and not explained by an alternative diagnosis. Weakness (41%, 95%CI 25.43 to 59.01), general malaise (33%, 95%CI 14.91 to 57.36), fatigue (31%, 95%CI 23.91 to 39.03), concentration impairment (26%, 95%CI 20.96 to 31.73) and dyspnea (25%, 95%CI 17.86 to 33.97) were the most described symptoms of the long-COVID syndrome. Patients also reported a large spectrum of less prevalent symptoms and signs, such as sweating, chest pain, sore throat, anxiety and headaches: the prevalence of these symptoms was usually less than 20% [5].

Some hereditary and acquired factors can affect both host sensitivity and disease severity. Older age, male gender, diabetes, cardiovascular diseases, malignancy and immunodeficiency conditions are the most critical hosting factors for COVID-19. Other pathologies recognized as risk factors for COVID-19 infection and morbidity are pulmonary disease (such as COPD and asthma), cerebrovascular diseases, chronic renal disease, chronic liver disease, severe autoimmune diseases and malnutrition [6]. Italian Ministry of Health [7] provided specific instructions on the management of workers who qualify at a high risk of COVID-19 and related adverse events (called "fragile") due to health conditions: in particular, these conditions included immunodeficiency, cancer, severe disability or serious chronic diseases in poor clinical control. In these cases, workers were asked to stay at home carrying out their job remote (so-called "smart working" or "work from home"), also via assignment to different tasks belonging to the same employment level. If it was impossible to activate "work from home", the period of absence from work was treated as hospitalization from an insurance point of view. Workers with chronic diseases in poor control are not included in the list provided by the Ministry of Health. However, they could require appropriate evaluation by the Occupational Physician (as part of the so-called "exceptional" health surveillance program) because of their job [7]. Indeed, some environmental and occupational factors can play a role in Sars-CoV-2 transmission and COVID-19 development, and HCW can be considered at high risk of infection [8]. COVID-19 can have significant repercussions in terms of both persistence of clinical symptoms for a long time and work ability (WA) [9], which could affect the HCW's fitness at return-to-work time.

This study aimed to describe the main long-term effects of COVID-19 infection among HCWs of a large University Hospital in Lombardy requiring hospitalization and the subsequent implications regarding perceived WA and fitness to work.

2. Methods

Fatebenefratelli-Sacco University Hospital is part of the Italian public healthcare system. It comprises four Hospital Centers (Sacco, Fatebenefratelli, Macedonio Melloni, Buzzi) and several Territorial Outpatient Units in Milan and employs 5,605 workers.

Our study included all workers of Fatebenefratelli-Sacco University Hospital who required hospitalization for COVID-19 disease. As required by the regulations issued by the Italian Ministry of Health [9], all hospitalized workers affected by COVID-19 underwent a clinical evaluation at the Occupational Health Unit at the time of return to work with the expression of a fitness to work judgment. Four Occupational Physicians were involved in the medical surveillance of hospitalized HCWs. Periodic meetings to discuss the most complex cases and the presence of an Occupational Medical Coordinator allowed a homogeneity in the criteria used for cases' managing and issuing the fitness to work judgements. Each HCW was visited at the time of return to work and underwent further medical examinations by the same Occupational Physician from his return to work until today. Data were collected from the beginning of the pandemic until 15th March 2022. Data related to demographic characteristics, remote pathological diagnosis and fitness to work were acquired from the occupational health unit's caring for the health surveillance program. A structured questionnaire was developed and administered to all participants to investigate the presence of symptoms related to long-COVID syndrome and their impact on perceived WA. The questionnaire was divided into three main sections (as shown in the Supplementary file): (i) The first one was composed of 30 items related to the presence of symptoms at the time of the recovery from the infection and their duration if eventually resolved. (ii) In the second section, 30 questions investigated the persistence of symptoms at the time of the questionnaire administration and their clinical course. (iii) The third section included three items related to perceived WA. All participants were asked to score their WA from 0 to 10, considering that before infection as 10, both at the time of recovery and at the time of questionnaire administration; the third item investigated (c) the time required to reach the current level of perceived WA. A trained physician administered the questionnaire in February and March 2022, about 18 months (95%CI 17.3-19.3) after the diagnosis of infection. All participants were informed about the purpose of the questionnaire and declared their consent to participate in the study. All data have been collected and analyzed anonymously in compliance with current privacy regulations.

Descriptive analysis was performed in terms of age, sex, type of job, fitness to work and clinical history of the subjects. Frequencies and percentages are provided for nominal data. Due to the small sample size and the normality check, the median (25th-75th percentiles) for continuous data and non-parametric tests were preferred. Due to the different temporal lag between the infection and the time of administration of the questionnaire among cases, we scheduled a follow-up cut-off at ten months from the infection onset to study the persistence of symptoms related to the long-COVID syndrome by using a mid-p McNemar test. The threshold of a significant p-value was set to 0.003 after Bonferroni's correction for multiple comparisons. The Kaplan-Meier method was then used for survival analyses of patients still having specific mild symptoms during recovery. The log-rank test was used to detect significant differences between age groups, sexes, presence of chronic diseases, and hospitalization days.

Statistical analysis was performed with R-Studio (R Core Team-2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/).

3. Results

3.1 Characteristics of study's population and prevalence of post-COVID symptoms

Since the beginning of the COVID-19 pandemic, among the Fatebenefratelli-Sacco University Hospital workers, 56 HCWs affected by COVID-19 required hospitalization care. As shown in Table 1, hospitalized cases were equally divided into males and females with a median age of 55. 33.9% were physicians, 41.1% were nurses, 17.9% were nursing assistants, and 3.6% were other HCWs (radiology technicians, laboratory technicians, biologists, and other health professionals not included in the main groups reported).

At the time of the positive rhino-pharyngeal swab (NPS), 40% of the hospitalized HCWs worked in a COVID-19 area. Clinical history of hospitalized HCWs most showed overweight/obesity (57.1% of cases), hypertension (25% of cases) and respiratory disorders (particularly asthma, 16.1% of cases). 7.5% of hospitalized HCWs were active smokers. All hospitalized HCWs involved in our study were not yet vaccinated against Sars-CoV-2 at the time of infection, and 23.5% of conditions that required hospital care occurred in unvaccinated HCWs between December 2020 and April 2021, after the beginning of the vaccination campaign. Hospitalization lasted more than 21 days in 32.1% of cases, between 10 and

Table 1. Socio-demographic and clinical characteristics of the studied population.

	n.	%
Total hospitalized HCWs	56	100
Age, median (25th-75th Percentiles)	55 (50-61.2)	-
Females	28	50
Job category		
Physicians	19	33.9
Nurses	23	41.1
Nursing assistant	10	17.9
Other sanitary workers	2	3.6
Non-sanitary workers	2	3.6
Working area		
COVID-19 hospital area	23	41.1
Non-COVID-19 hospital area	31	55.4
Non-sanitary area	2	3.6
Duration of hospitalization (days)		
4-9	16	28.6
10-21	22	39.3
22-118	18	32.1
Clinical history		
Overweight/obesity	32	57.1
Hypertension	14	25
Respiratory disorders	9	16.1
Neurological disorders	3	5.4
Endocrinological disorders	4	7.1
Hematological disorders	4	7.1
Psychiatric disorders	2	3.8
Cardiovascular disorders	2	3.8
Diabetes	1	1.8
Sars-CoV-2 vaccination status at the time of infection		
Not vaccinated	56	100
Fully vaccinated	0	0.0
Partially vaccinated	0	0.0

21 days in 39.3% and less than ten days in 28.6% of hospitalized HCWs.

Fifty-three HCWs (94.6%) agreed to participate in the survey by answering the questionnaire administered at a mean time of 18 months after the diagnosis of infection. As shown in Table 2, the most reported symptoms after COVID-19 recovery (negative NPS) were resting and exertional dyspnea. Generalized asthenia (86.8% of hospitalized HCWs) followed, in order, by arthromyalgia (71.7%), sleep disorders (64.2%), resting dyspnea (62.3%) and cough (56.6%). Anosmia and ageusia were reported respectively from 47.2% and 43.4% of interviewed HCWs.

No differences were found in symptoms prevalence at the time of COVID-19 recovery comparing HCWs subgroups sorted by age (under 55 y.o vs over 55 y.o.), gender (male/female) and clinical history (cases with no chronic illness vs those with known chronic diseases). Due to these symptoms, 69.6% of hospitalized HCWs underwent examination and clinical management at outpatient clinics with expertise in long-COVID syndrome. Ten months after COVID-19, a sharp decrease in many long-COVID symptoms' prevalence was found. A significant reduction in physical symptoms was found as compared to the time of recovery: in particular, cough, resting dyspnea, asthenia, ageusia, exertional dyspnea, anosmia, chest pain and arthromyalgia. Conversely, symptoms related to mental and psychological well-being, such as loss of memory, anxiety and depression, resulted in prolonged persistence at the time of the questionnaire administration with a non-significant decrease compared with data at the time of negative NPS. Anosmia, cough and cephalgia, when resolved at the questionnaire administration, were the symptoms with the referred most rapid resolution time (approximately 15 days). At the same time, loss of memory, sleep disorders, anxiety/depression and asthenia required a longer resolution time (about 135 days, 120 days, 75 days, and 90 days). We compared HCWs subgroups sorted by age (under 55 y.o vs over 55 y.o.), gender (male/female) and clinical history (cases with no chronic illness vs those with known chronic diseases) at the time of ten months after COVID-19 resolution. A higher prevalence of anosmia was found in cases without chronic illness versus those with one or more chronic diseases (p=0.02) (Figure 1A), and a higher prevalence of arthro-myalgia was found in subjects over 55 as compared to younger people (p=0.03).

Table 2. Post-COVID-19 symptoms among Hospitalized HCWs (n=53).

Symptom	N. of patients with symptoms at negative NPS test n. (%)	N. of patients recovering from symptoms ten months after infection n. (%)	Duration of symptoms (d) Median (25th-75th percentiles)
Cough	30 (57)	23 (77)*	15 (15-30)
Resting dyspnea	33 (62)	28 (84)*	15 (15-38)
Exertional dyspnea	46 (87)	19 (41)*	30 (15-90)
Arthromyalgia	38 (72)	16 (42)*	30 (15-68)
Chest pain	17 (32)	14 (82)*	38 (15-90)
Tachycardia or palpitations	19 (36)	8 (42)	15 (15-45)
Ageusia	23 (43)	20 (87)*	15 (15-38)
Anosmia	25 (47)	18 (72)*	15 (15-30)
Asthenia	46 (87)	25 (54)*	90 (15-180)
Cephalgia	25 (47)	14 (56)	15 (15-15)
Loss of memory	25 (47)	6 (24)	135 (98-172)
Hair loss	22 (41)	9 (41)*	60 (60-150)
Sleep disorders	34 (64)	9 (27)*	120 (60-150)
Anxiety/depression	25 (47)	8 (32)	75 (26-158)

**Mid-p McNemar test p<0.003.*

3.2 Perceived work ability after COVID-19 infection and at the survey's time

Fifty hospitalized HCWs were asked to give a score from 0 to 10 to their perceived WA at the time of COVID-19 recovery (negative NPS) and at the time of questionnaire administration, considering 10 of their WA before COVID-19 infection. Out of the remaining part of interviewed hospitalized HCWs, two cases quit their job at Fatebenefratelli-Sacco University Hospital due to retirement, and one patient has not yet returned to work due to complications of the COVID-19 infection.

As shown in Table 3, at the time of negative NPS, interviewed HCWs referred to a median WA score of 8, with no differences between males and females and between under and over 55, respectively. Although nursing assistants had the worst score, there were no significant differences compared to other job categories.

At the time of questionnaire administration, referred WA score improved in all hospitalized HCWs – from a median (25th-75th percentiles) of 8 (5.25-10) to 9 (8-10), $p<0.05$. The stratification by age, gender, chronic disease and job category shows that over 55 y.o., females and subjects with the known chronic disease showed the most WA improvement. On the other hand, in under 55 cases and HCWs without chronic illness, the WA increase was lower but still significant. Overall, all HCWs reach high scores at the time of the questionnaire except for nursing assistants resulting in a median (25th-75th percentiles) of 8 (6.25-9.75). Interviewed HCWs referred to a mean time to reach the current level of perceived WA of about 223 days. No significant differences were found in WA scores comparing groups divided according to the average distance between COVID-19 infection and the time of questionnaire administration.

3.3 Comparison of fitness to work before and after COVID-19 infection and at the survey's time

As shown in Table 4, out of all hospitalized HCWs (n. 56), before COVID-19 infection, the

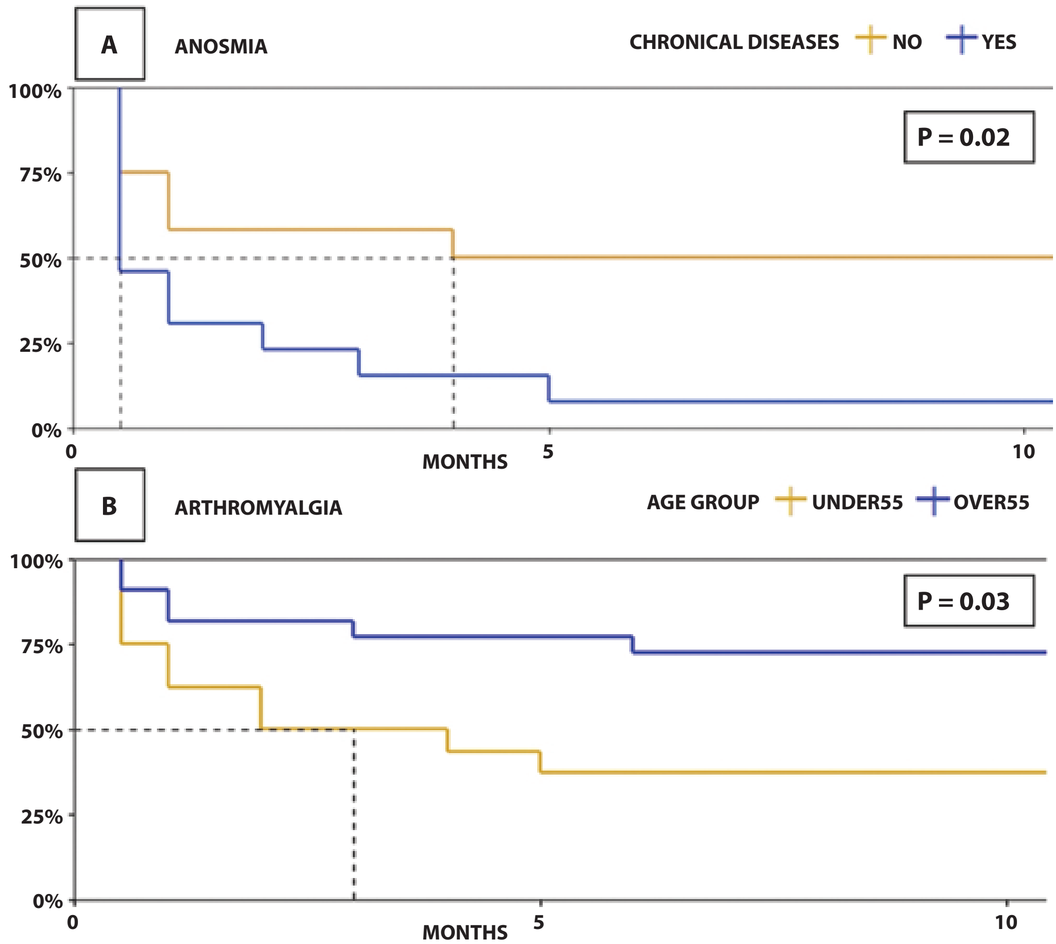

Figure 1: Significant results related to long-COVID symptoms prevalence among subgroups of the studied population at ten months after COVID-19 recovery. A: different prevalence of anosmia between "healthy" cases and cases with one or more chronical disease (p=0.02); B: different prevalence of arthromyalgia between cases under and over 55 years old (p=0.03).

occupational physicians issued a fitness-to-work judgement without restrictions for 69.6% of them. Of the HCWs with a fit-to-work judgement with restriction (n. 17), 39.1% were nurses, 30% were nursing assistants, and 21.1% were physicians. A fit-to-work judgement with restriction was more common among female vs male HCWs (39.3% vs 21.4%) and HCWs with a chronic disease vs those without a chronic illness (38.1% vs 7.1%). Before COVID-19 infection, among our study's population, the occupational physician's most common types of restrictions were jobs leading to physical exertion (19.6%) and night shift work (10.7%).

The occupational physician examined forty-six hospitalized HCWs at the return to work after hospitalization for COVID-19; of the remaining HCWs, nine quit their job at Fatebenefratelli-Sacco University Hospital before the "return to work" medical examination due to retirement or change of workplace. In contrast, one case has not yet returned to work due to complications of the COVID-19 infection. Clinical assessment at the return to work was carried out at 172.3±149.3 (mean±sd) days from the diagnosis: 63% of HCWs returned to work within six months since the infection, while four HCWs continued their

Table 3. Perceived work ability after COVID-19 infection and at the time of the survey stratified by age, gender, chronic disease and job category.

Perceived work ability (min 0 - max 10) *	n.	WA at COVID-19 recovery Median (25th-75th percentiles)	WA at the time of the survey Median (25th-75th percentiles)
All interviewed HCWs[§]	50	8 (5.25-10)	9 (8-10)
Gender			
Male	25	8 (6-10)	9 (8-10)
Female	25	7 (5-9)	9 (8-10)
Age group			
<55 y.o.	24	8 (6-10)	9.5 (8-10)
>55 y.o.	26	6 (5-8.75)	9 (8-10)
Chronic diseases			
No	13	8 (6-9)	10 (9-10)
Yes	37	7 (5-10)	9 (8-10)
Job category			
Physicians	17	8 (5-10)	9 (8-10)
Nurses	21	8 (6-10)	9 (8-10)
Nursing assistants	10	6 (3.5-7.5)	8 (6.25-9.75)
Other sanitary workers	1	10	10
Non-sanitary workers	1	9	9

**Scores expressed considering the WA as 10 before COVID-19 infection.*
[§]Exact Wilcoxon-Pratt Signed-Rank Test, p<0.05 (performed only for all interviewed HCWs).

absence for more than a year after the illness. At the time of return to work after COVID-19 infection, a reduction of full fit-to-work judgements (from 69.6% to 39.1%) was observed, resulting in increased fit-to-work judgement with restrictions (from 31.4% to 58.7%). One HCW was temporarily unfit to work during the first occupational health examination due to persisting neurological and muscular impairment developed after COVID-19. Such clinical complications required prolonged absence from work, justified by the need for cognitive and motor rehabilitation to achieve acceptable conditions.

In Table 4, we highlighted an increase in all kinds of restrictions at the "return to work" compared with baseline with a rise of the limitations related to night shift work (from 10.7% to 39.1%). No significant differences were found in the rate of judgments with restrictions among HCWs subgroups stratified by age (under 55 vs over 55), gender (male vs female), clinical history (HCWs with no chronic diseases vs cases with known chronic diseases) and job category.

Occupational physicians furtherly examined all cases under examination at the time of return to work. Comparing the fit to work judgement at the time to return to work and the last formulated fit to work judgment (expressed at an average time of nine months from the first one), we observed a decrease in the restrictions' rate (from 58.7% to 45.7%) with a consequent increase of the rate of fully fit to work judgement (from 39.1% to 54.3%). No significant differences were found in the rate of judgment with restrictions among HCWs subgroups sorted by age (under 55 vs over 55), gender (male vs female), clinical history (HCWs with no chronic diseases vs cases with known chronic diseases) and job category.

Table 4. Fitness to work among the study's population before COVID-19 infection, at the time of return to work and at the time of the survey.

	Before COVID-19 infection (n. 56)		At the time of return to work (n. 46)		Last fitness to work judgement (n. 46)	
	n.	%	n.	%	n.	%
Type of judgement						
Full fit to work	39	69.6	18	39.1	25	54.3
Temporary not fit	0	0.0	1	2.2	0	0.0
Fit with restrictions	17	31.4	27	58.7	21	45.7
Type of restriction						
Physical exertion	11	19.6	16	34.8	11	23.9
Night shift work	6	10.7	18	39.1	14	30.4
Stress/Mental load	0	0.0	2	4.3	2	4.3
Upper limbs overload	1	1.8	1	2.2	1	2.2
Lower limbs overload	2	3.6	3	6.5	1	2.2
Biological risk exposure	2	3.6	4	8.7	2	4.3
Work rhythms	0	0.0	5	10.9	1	2.2
Other	1	1.8	1	2.2	1	2.2
Gender						
Male	6/28	21.4	13/23	56.5	13/23	56.5
Female	11/28	39.3	14/23	60.9	8/23	34.8
Age group						
<55 y.o.	8/25	32	12/20	60	10/20	50
≥55 y.o.	9/31	29	15/26	57.7	11/26	42.3
Chronic diseases						
No	1/14	7.1	4/10	40	3/10	30
Yes	16/42	38.1	23/36	63.9	18/36	50
Job category						
Physicians	4/19	21.1	8/17	47.1	5/17	29.4
Nurses	9/23	39.1	11/17	64.7	9/17	52.9
Nursing assistants	3/10	30	7/9	77.8	6/9	66.7
Other sanitary workers	0/2	0.0	0/1	0.0	0/1	0.0
Non-sanitary workers	1/2	50.0	1/2	50.0	1/2	50.0

4. Discussion

Our study among HCWs hospitalized due to acute COVID-19 provided relevant data to describe the evolution of symptoms, the perceived work ability and their impact on fitness to work up a mean time of eighteen months after COVID-19. All hospitalized HCWs involved in our study were not yet vaccinated against Sars-CoV-2 at the time of infection. While the vaccination campaign against Sars-CoV-2 started on 27th December 2020, in our study population, hospitalizations due to COVID-19 occurred between March 2020 and April 2021. Among 86.5% of these cases, the infection occurred before the start of the Sars-Cov-2 vaccination campaign. In 23.5% of the cases, the infection occurred during the vaccination campaign, but it was always among unvaccinated HCWs. These data confirm the effectiveness of the vaccination campaign against Sars-CoV-2 in preventing severe forms of infection, as demonstrated by our previous study [8].

Concerning the persistence of symptoms at the time of COVID-19 recovery (NPS negative), we found a high prevalence of exertional dyspnea and generalized asthenia, followed, in order, by arthro-myalgia, sleep disorders, resting dyspnea and cough. A recent study [11] evaluated the persistence of physical and psychological symptoms after COVID-19 in patients examined at an outpatient clinic specialized in long-COVID syndrome to assess their duration and the predictive factors associated with their resolution. Our results showed a high prevalence of dyspnea, fatigue and myalgia/arthralgia among the HCWs evaluated after hospitalization due to a severe form of COVID-19. In a recent study, Huang L et al. [12] characterized the evolution of health outcomes in hospital survivors after acute COVID-19. Two years after COVID-19 infection, they found a significant decrease in the proportion of COVID-19 survivors with at least one sequelae symptom, with fatigue, muscle weakness and sleep difficulties always being the most frequent. In their population, anxiety and depression symptoms significantly decreased two years after infection. At the time of the last follow-up, 8% had anxiety symptoms, while 6% had depression symptoms. In our study, we also found a substantial decrease in many long-COVID symptoms' prevalence at the time ten months after COVID-19 recovery: in particular, a significant reduction of symptoms related to physical well-being (such as cough, resting and exertional dyspnea, asthenia and arthromyalgia) was shown in our population.

Conversely, symptoms related to mental and psychological well-being, such as loss of memory, anxiety and depression, resulted in more persistence in our population at the time of the questionnaire administration with a non-significant decrease compared with data at the time of negative NPS. The prevalence of mental health disorders after acute COVID-19 varies widely among studies [13, 14], and they might be attributed to many causes, such as the direct effects of SARS-CoV-2 infection, isolation, physical distancing, or incomplete recovery of physical health [15]. In our population, the incomplete recovery of physical health after COVID-19 and the noted psychological impact of the Sars-CoV-2 pandemic on HCWs [16] can explain the persistence of these symptoms. However, the potential role of worsening known chronic diseases in reducing psychological well-being cannot be excluded in some cases.

Concerning the other persistent symptoms of long-COVID syndrome, we found a higher prevalence of anosmia in "healthy" HCWs versus subjects with known chronic diseases. A possible explanation for these findings is that HCWs with no chronic diseases have a higher perception of an altered smell than patients with chronic illness who have a different sensitivity to a "non-debilitating" symptom. In elder HCWs, a more increased muscle or joint pain persistence at ten months after COVID-19 infection was found compared to younger ones. Pre-existing musculoskeletal problems in subjects over 55 or the progressive reduction in muscle strength and less resilience after physical exertion associated with ageing could account for this finding [17].

Perceived work ability among our study's population decreased from the established score of 10 before COVID-19 infection to a median score of 8 at the time of infection recovery, with lower WA scores in cases with known chronic disease and nursing assistants. At the time of the questionnaire administration, with the previously described substantial decrease in many long-COVID symptoms' prevalence, we found a significant improvement in the WA score in all hospitalized HCWs. In the literature, we have not found other studies that specifically investigated WA perception in patients/workers hospitalized for COVID-19 infection. A survey by Andrade M. et al. [18] aimed to explore the implications of the COVID-19 pandemic on psychosocial aspects and work ability among Brazilian workers: they studied a cohort of workers at baseline and twelve months follow-up, categorizing data also depending on the previous COVID-19.

The Authors unexpectedly found that WA was unaffected by the pandemic in 75% of the workers and, at a 12-month follow-up, no difference in WA scores was found between infected and uninfected workers. The Authors explained these results based on a large proportion of involved workers composed of public servants with job stability and a high "smart working" rate: these protective factors may have contributed to these results on perceived WA. HCWs involved in our study, conversely, carry out an activity characterized by greater job demand: this assumption can explain our results, which, in contrast with the finding of Andrade M. et al., highlighted a reduction in WA after hospitalization for COVID-19 in the overall population and particularly in nursing assistants.

There is a lack of published research on the impact of long-COVID on fitness at the return to work. Among the limited current literature concerning this point, Pauwels et al. [19] reviewed the relevant published studies on the impact of long COVID syndrome on patients' return to work. After screening 2,545 publications, the Authors identified only seven relevant studies on this topic. They concluded that the return to work for individuals with long-COVID is complex and diverges for each individual concerning the specific persistent symptoms. On the other hand, the Authors highlighted that working is generally good for health and should be considered a practical part of the rehabilitation program for workers suffering from long-COVID. In this way, they suggested that occupational physicians develop a close and trustful relationship with all stakeholders to facilitate a safe return to work for subjects with long-COVID syndrome. According to the guidance published by the Faculty of Occupational Medicine, a gradual return to work for patients with long-COVID symptoms is recommended, adjusting workloads and work rhythms to the health conditions of the involved workers. [20]

In our studied population, HCWs returned to work after an average time of 172.3±149.3 SD days from the infection onset. As required by the regulations issued by the Italian Ministry of Health [10], all hospitalized workers affected by COVID-19 underwent a clinical evaluation by the Occupational Physician at the time of return to work with the expression of fitness to work judgment: at this time our study highlighted, with the persistence of symptoms related to long-COVID-19 and the reduction in the average WA score, a decrease in fully fit to work judgements and an increase in the fit to work decisions with restrictions, with a rise of limitations related to night shift work and physical exertion. Due to the clinical conditions, about two-thirds of hospitalized HCWs also underwent examination and clinical management in an outpatient clinic specializing in long-COVID syndrome. In four cases (two more than baseline), a worsening of chronic diseases conditioning a possible greater susceptibility to infections required the issuance by the occupational physician of a fitness to work judgment with temporary restriction on exposure to significant biological risk, according to the instructions of the Italian Ministry of Health related to the protection of "fragile" workers [7].

At the subsequent health occupational examinations, until today, a decrease in the restrictions' rate was observed: in particular, we observed a reduction, but still non-significant, of restrictions' rate related to both night shift work and physical exertions. It's to note that out of the four cases with fitness to work judgement with limitation on biological risk exposure at the time of return to work, the evidence of improved control of the known chronic pathologies allowed the Occupational Physician to remove this restriction at subsequent medical examinations in two of them. The increase in the rate of judgements with restrictions was expected to encourage workers' gradual return to work with long-COVID by modulating the workloads and rhythms of work, as indicated by international guidelines [20]. In this context, the rise of limitations related to night-shift work can be explained by the known effect that the alteration of the circadian rhythm could have on subjects' well-being, particularly in HCWs with psychological and sleep problems [21].

Finally, the slow reduction in the rate of HCWs with limited fitness to work may be linked to both the characteristics of the work (e.g. workload, rhythms of work and the known psychological impact of working in the healthcare system) and the persistence of psychological symptoms (e.g., anxiety and depression) affecting perceived physical fitness, physical pain and even general health perception [22].

Some limitations could affect obtained results and require further confirmatory studies. Primarily, this study focused on a relatively small number of cases with a high prevalence of individuals with one or more chronic diseases. As a result, we potentially oversampled HCWs at a very high risk of complications (not only related to COVID-19 and hospitalization). The absence of a control group did not allow for the identification of predisposing factors for the development of long-COVID syndrome in hospitalized HCWs. Finally, the time elapsed between infection and questionnaire administration may have partially affected the accuracy of data related to symptoms' duration and WA score at the time of COVID-19 recovery.

5. Conclusions

Our study highlighted a high prevalence of post-COVID symptoms in HCWs hospitalized for Sars-CoV-2 infection with a longer persistence over time of symptoms related to mental and psychological well-being. Along with the persistence of long-COVID symptoms, we found a decrease in perceived WA at the time of COVID-19 recovery and an increase in fit-to-work judgements with restrictions at the time of return to work. Due to these clinical conditions, about two-thirds of hospitalized HCWs also underwent examination and clinical management in outpatient clinics specialized in long-COVID syndrome. Empowerment of perceived WA and a slight reduction of fit-to-work judgements with restrictions were found at an average of 18 months after infection, indicating how the gradual improvement of both the physical and psychological conditions of hospitalized HCWs leads to a progressive recovery of their WA and fit-ness to work. Further studies are necessary to evaluate the long-term effects of COVID-19 in larger populations of HCWs hospitalized due to acute COVID-19 and in HCWs with a mild-moderate course of the disease to guarantee the best health protection of HCWs with per-sistent physical and psychological disorders after COVID-19.

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References

1. Cui J, Li F, Shi ZL. Origin and evolution of pathogenic coronaviruses. *Nat Rev Microbiol*. 2019;17(3):181-192. Doi:10.1038/s41579-018-0118-9
2. WHO Coronavirus (COVID-19) Dashboard. Available at: https://covid19.who.int/ (Last accessed: March 2022).
3. Sohrabi C, Alsafi Z, O'Neill N, et al. World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19) [published correction appears in *Int J Surg*. 2020 May;77:217]. *Int J Surg*. 2020;76:71-76. Doi:10.1016/j.ijsu.2020.02.034
4. Sharma A, Ahmad Farouk I, Lal SK. COVID-19: A Review on the Novel Coronavirus Disease Evolution, Transmission, Detection, Control and Prevention. *Viruses*. 2021;13(2):202.Published2021Jan29.Doi:10.3390/v13020202
5. Michelen M, Manoharan L, Elkheir N, et al. Characterising long COVID: a living systematic review. *BMJ Glob Health*. 2021;6(9):e005427. Doi:10.1136/bmjgh-2021-005427
6. Wolff D, Nee S, Hickey NS, Marschollek M. Risk factors for Covid-19 severity and fatality: a structured literature review. *Infection*. 2021;49(1):15-28. Doi:10.1007/s15010-020-01509-1
7. Italian Ministry of Health. Notice no. 14915 of 20 April 2020 "Indicazioni operative relative alle attività del medico competente nel contesto delle misure per il contrasto e il contenimento della diffusione del virus Sars-CoV-2 negli ambienti di lavoro e nella collettività". Available at: https://www.trovanorme.salute.gov.it/norme/renderNormsanPdf?anno=2020&codLeg=73956&parte=1%20&serie=null (last accessed: July 2022).
8. Mendola M, Tonelli F, Garletti FS, et al. COVID-19 impact and vaccine effectiveness among healthcare workers of a large University Hospital in Lombardy, Italy. *Med Lav*. 2021;112(6):453-464. Published 2021 Dec 23. Doi:10.23749/mdl.v112i6.11983
9. Sanchez-Ramirez DC, Normand K, Zhaoyun Y, Torres-Castro R. Long-Term Impact of COVID-19: A Systematic Review of the Literature and Meta-Analysis. *Biomedicines*. 2021;9(8):900. Published 2021 Jul 27. Doi:10.3390/biomedicines9080900

10. Italian Ministry of Health. Notice no. 15127 of 12 April 2021 “Indicazioni per la riammissione in servizio dei lavoratori dopo assenza per malattia Covid-19 correlata”. Available at: https://www.trovanorme.salute.gov.it/norme/renderNormsanPdf?anno=2021&codLeg=79702&parte=1%20&serie=null (Last accessed: Jun 2022).
11. Mariani C, Borgonovo F, Capetti AF, et al. Persistence of Long-COVID symptoms in a heterogenous prospective cohort. *J Infect*. 2022;84(5):722-746. Doi:10.1016/j.jinf.2022.01.024
12. Huang L, Li X, Gu X, et al. Health outcomes in people 2 years after surviving hospitalisation with COVID-19: a longitudinal cohort study [published online ahead of print, 2022 May 11]. *Lancet Respir Med*. 2022;S2213-2600(22)00126-6. Doi:10.1016/S2213-2600(22)00126-6
13. Bellan M, Soddu D, Balbo PE, et al. Respiratory and Psychophysical Sequelae Among Patients With COVID-19 Four Months After Hospital Discharge. *JAMA Netw Open*. 2021;4(1):e2036142. Published 2021 Jan 4. Doi:10.1001/jamanetworkopen.2020.36142
14. Hellemons ME, Huijts S, Bek LM, et al. Persistent Health Problems beyond Pulmonary Recovery up to 6 Months after Hospitalization for COVID-19: A Longitudinal Study of Respiratory, Physical, and Psychological Outcomes. *Ann Am Thorac Soc*. 2022;19(4):551-561. Doi:10.1513/AnnalsATS.202103-340OC
15. Crook H, Raza S, Nowell J, Young M, Edison P. Long covid-mechanisms, risk factors, and management [published correction appears in *BMJ*. 2021 Aug 3;374:n1944]. *BMJ*. 2021;374:n1648. Published 2021 Jul 26. Doi:10.1136/bmj.n1648
16. Pappa S, Sakkas N, Sakka E. A year in review: sleep dysfunction and psychological distress in healthcare workers during the COVID-19 pandemic. *Sleep Med*. 2022;91:237-245. Doi:10.1016/j.sleep.2021.07.009
17. Costa G, Sartori S. Ageing, working hours and work ability. *Ergonomics*. 2007;50(11):1914-1930. Doi:10.1080/00140130701676054
18. Andrade MA, Castro CSM, Batistão MV, Mininel VA, Sato TO. Occupational Profile, Psychosocial Aspects, and Work Ability of Brazilian Workers During COVID-19 Pandemic: IMPPAC Cohort. *Saf Health Work*. 2022; 13(1):104-111. Doi:10.1016/j.shaw.2021.11.004
19. Pauwels S, Boets I, Polli A, Mylle G, De Raeve H, Godderis L. Return to work after long COVID: Evidence at 8th March 2021. (2021) Available at: https://www.hse.gov.uk/coronavirus/assets/docs/return-to-work-after-long-covid.pdf (Last accessed: Jun 2022).
20. Faculty of Occupational Medicine Guidance: Guidance for healthcare professionals on return to work for patients with long-COVID. Available at: https://www.fom.ac.uk/wp-content/uploads/longCOVID_guidance_04_small.pdf (Last accessed: Jun 2022).
21. Qanash S, Alwafi H, Barasheed S, et al. Impact of night shifts on sleeping patterns, psychosocial and physical well-being among healthcare professionals: a cross-sectional study in a tertiary hospital in Saudi Arabia. *BMJ Open*. 2021;11(9):e046036. Published 2021 Sep 2. Doi:10.1136/bmjopen-2020-046036
22. Saarijärvi S, Salminen JK, Toikka T, Raitasalo R. Health-related quality of life among patients with major depression. *Nord J Psychiatry*. 2002;56(4):261-264. Doi:10.1080/08039480260242741

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Long-term COVID symptoms, work ability and fitness to work in healthcare workers hospitalized for Sars-Cov-2 infection

SUPPLEMENTARY FILE

QUESTIONNAIRE
Post COVID symptoms and work ability in Healthcare Workers hospitalized for COVID-19 infection

Date: _______________

- Personal data

Surname and Name	
Date of birth (dd/mm/yy)	
Job category	
Department (at the time of COVID-19 infection)	

- Section 1 - Post-COVID symptoms at recovery from COVID-19 infection

Positive NPS date: ___________________ Negative NPS date: ____________________

Length of hospitalization for COVID-19 days: _____________

Symptom	***Present at COVID-19 recovery (YES/NOT)***	***Time for resolution (days; if it is not resolved sign "PRESENT")***
Cough		
Dyspnea at rest		
Exertional dyspnea		
Arthralgia/myalgia		
Palpitation/tachycardia		
Chest pain		
Anosmia		
Ageusia		
Asthenia		
Headache		
Loss of memory		
Telogen effluvium		
Sleep disorders		
Anxiety/depression		
Other		

Data specification ***YES = symptom present*** ***NOT= absence of the symptom*** ***PRESENT: symptom already present***

After hospitalization, did you go to medical evaluation at outpatient clinics experienced in Long-COVID, due to the persistence of symptoms related to COVID-19 infection?

☐ YES ☐ NOT

- Section 2 - Post-COVID symptoms at the time of questionnaire administration

Symptoms	***Present at the time of questionnaire administration***	***Clinical course (B-S-W)***
Cough		
Dyspnea at rest		
Exertional dyspnea		
Arthralgia/myalgia		
Palpitation/tachycardia		
Chest pain		
Anosmia		
Ageusia		
Asthenia		
Headache		
Loss of memory		
Telogen effluvium		
Sleep disorders		
Anxiety/depression		
Other		

Data specification ***YES = present*** ***NOT= absent*** ***B= it getting better*** ***S = clinically stable*** ***W = it getting worse***

- **Section 3 - Screening on perceived work ability (WA)**

1. Considering your WA before infection as 10, please give a score from 0 to 10 to your WA at the time of recovery from COVID-19 infection (negative NPS):

0 1 2 3 4 5 6 7 8 9 10

2. Considering your WA before infection as 10, please give a score from 0 to 10 to your WA at this moment (time of questionnaire administration):

0 1 2 3 4 5 6 7 8 9 10

3. (If WA score right now improved compared with the score at the time of COVID-19 recovery) How long did it take to get this improvement?

- ○ < 3 months
- ○ 3-6 months
- ○ 6-9 months
- ○ 9-12 months
- ○ >12 months

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Ocular health among industrial workers: a prevalence study of foreign body injury, refractive error, dry eye, pterygium and pingueculae

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Keywords: Dry eye; occupational health; pingueculae; pterygium; wounds; injuries

Abstract

Background: *Workplaces play a critical role in developing ocular diseases, owing to the risk of accidents. This study aimed to evaluate the ocular health of industrial workers by determining the prevalence of foreign body injury, refractive error, dry eye, and pterygium/pingueculae, as well as the factors influencing these diseases.* **Methods:** *This study involved on-site examinations of workers from an industrial area hosting marble processing factories and metal sectors. Data such as refractive error, foreign body injury-related corneal nephelium, pterygium/pingueculae presence, and Schirmer test-assisted dry eye evaluation were all collected.* **Results:** *The average age of workers was 35.78±10.05 years, with a female-to-male ratio of 20:220. The majority of workers had completed primary school (56.3%), smoked >1 cigarette/day (57.6%), and did not use any assistive devices for bodily functions (88.3%). On average, working hours/week were 55.07±8.79, and working years were 5.99±7.00. Dry eyes were found in 31(22%), and 35(34%) marble and metal workers, respectively (p=0.042). 11(7.9%) marble workers and 29(28%) metal workers had foreign body ocular injury-related corneal nephelium (p=0.0001). Furthermore, pterygium/pingueculae were revealed in 17 marble workers (12.3%) and three metal workers (3%) (p=0.009).* **Conclusions:** *Ocular health is essential, and routine ocular health screening in industrial workers, as well as workplace safety measures, should be implemented to prevent potential occupational accidents.*

1. Introduction

Uncorrected refractive errors, cataract, age-related macular degeneration, glaucoma, and diabetic retinopathy are among the top five causes of visual impairment worldwide, according to the World Health Organization (WHO). Whatever the cause, the fact that nearly one billion people worldwide have a treatable but incurable visual impairment is astounding [1]. The prevalence of these diseases varies from country to country. While cataract causes more visual impairment in low- and middle-income countries, conditions such as diabetic retinopathy, glaucoma, and age-related macular degeneration are more prevalent in high-income countries [2].

Focusing on both the individual and social implications of disease outbreaks is critical. According to the WHO, visual impairments double the risk of

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falling, whereas depression, anxiety, and motor function loss triple the risk [1]. Visual impairments have an impact on employment and accidents [3]. Workplaces play a critical role in this context due to the possibility of developing accidents and potentially associated ocular diseases. It has been reported that ocular injuries account for 3-10% of all occupational injuries [4-8].

Aside from accidents, working conditions have been linked to an increase in the prevalence of diseases such as dry eye [9], pterygium [10], and cataract [11], emphasizing the importance of workers' ocular health protection and improvement. The value of occupational risk assessments in determining the necessary precautions cannot be overstated in this regard.

As a result, the current study was designed to assess the ocular health of industrial workers by determining the prevalence of foreign body injury, refractive error, dry eye, pterygia/pingueculae, and the associated influencing factors.

2. Methods

2.1. Study design and participants

This cross-sectional study enrolled 9,000 industrial workers from the Aegean region of Afyonkarahisar province in Turkey between April and May 2021. This province's industrial area has long been known for its internationally valuable marble and metal industries. While those in the marble sector worked on quarry marble, those in the metal sector worked on marble cutting machines. The sample size was calculated to be 215 based on the expected value of 40.4% for refractive errors [12], which is the highest expected value for ocular disease prevalence, using the Epi Info Program, with an 8% margin of error, 1.5 design effects, and five clusters planned to be selected. Five factories were randomly chosen from the industrial area to arrive at this figure, and two hundred and forty factory volunteers participated in the study.

2.2. Ocular assessment

A senior ophthalmologist (IEA) performed a comprehensive ocular examination on all participants between 09:00 AM and 12:00 AM to minimize any potential diurnal and climatic condition-related ocular physiological changes, particularly in the aspect of a possible dry eye condition. Also, personal protective equipment such as an N95 mask, visor, apron, gloves, and so on was used during the examination to prevent SARS-CoV-2 transmission. The other study authors gathered demographic information and distributed a workplace health questionnaire (MD, YŞ, AT).

A complete anamnesis was performed, including noting any other diseases or medications and visual acuity using the Snellen chart (6m) before measuring refractive error in glasses and contact lens users. An anterior segment examination was performed using a hand slit lamp (Reichert, NY, USA) to detect cataracts, pterygium, pingueculae, and dry eye. The Schirmer test was performed after instilling local anesthesia into the cornea. Participants with values less than 5 mm and a tear break-up time (TBUT) test of greater than 10 seconds were classified as having dry eyes. Dilated fundoscopy was performed using a 90D Volk in cases with visual acuity below 20/20, and any ocular pathology was recorded.

2.3. Statistical analysis

the statistical analysis was conducted using the Statistical Program in Social Sciences (SPSS) 23.0 package. Continuous variables were reported as mean and standard deviation, while categorical variables were reported as numbers and percentages. The χ^2 test was used to compare categorical variables and the possible relationship between workplace risk factors and ocular diseases such as dry eye, refractive error, foreign body injury status, pterygium, and pingueculae. Yates' correction or Fisher's exact test was used when necessary.

3. Results

The average age of workers was 35.78±10.05 years, with a female-to-male ratio of 20:220. Working hours per week averaged 55.07±8.79, and working years averaged 5.99±7.00. The majority of workers had finished primary school (56.3%), smoked more than one cigarette per day (57.6%),

Table 1. The socio-demographic characteristics of industrial workers.

Parameters	Marble sector, n. (%)	Metal sector n. (%)	Total n. (%)	χ^2	P value
Gender					
Female	9(6.5)	11(10.8)	20(8.3)	1.395	0.238
Male	129(93.5)	91(89.2)	220(91.7)		
Education level					
Illiterate and Literate	2(1.4)	6(5.9)	8(3.3)	16.616	<0.001*
Primary school graduates	35(25.4)	24(23.5)	59(24.6)		
High school graduates	56(40.6)	20(19.6)	76(31.7)		
University graduates	45(32.6)	52(51.0)	97(40.4)		
Smoking Status					
None	35(25.4)	36(35.3)	71(29.6)	2.975	0.226
More than one cigarette/day	83(60.1)	55(53.9)	138(57.5)		
Quit smoking	20(14.5)	11(10.8)	31(12.9)		
Chronic disease status					
Absent	122(88.4)	89(87.3)	211(87.9)	0.073	0.787
Present	16(11.6)	13(12.7)	29(12.1)		
Assistive devices for body functions					
None	119(86.2)	93(91.2)	212(88.3)	3.011	0.223
Glasses	15(10.9)	9(8.8)	24(10.0)		
Others	4(2.9)	0(0.0)	4(1.7)		
Total	138(100.0)	102(100.0)	240(100.0)		

**p<0.05, n=Number of participants, %=Percentage.*

and did not use any assistive devices for bodily functions (88.3%). Table 1 summarizes the socio-demographic characteristics of industrial workers.

Most industrial workers were employed in production (marble and metal sectors) units (68.3%). 24.6% of the employees were not directly involved in production but were working in management, marketing and technical units. Only 22.5% worked the night shift. 36.3% reported workplace exposure to flying, moving or falling objects. 14.6% had been exposed to corrosive-corrosive chemicals (e.g., silica, fluorine) at work. The remaining workplace units and associated risk factors are shown in Table 2.

Most factories in the industrial area had an occupational physician – 195(81.3%). Despite this, the vast majority of industrial workers, 231(96.2%), were not subjected to regular ocular examinations. Despite having an eye problem, 25(10.4%) workers could not be visited by an ophthalmologist for various reasons, including difficulties obtaining hospital rendezvous and permission to leave the workplace for outpatient clinics. Participants had an 18.3% refractive error, a 27.5% dry eye, a 16.7% pterygium/pingueculae, and a 8.3% corneal foreign body injury (Figure 1).

Most participants were emmetropes (81.7%), with no dry eye (72.5%), pterygium/pingueculae (83.3%), or history of corneal foreign body injury (91.7%) (Table 3 and Figure 1).

There were no statistically significant differences between refractive error and occupational sector (p=0.147). Dry eye was detected in 22% of the marble sector and 34% of the metal sector workers (p=0.042). Metal workers had a higher rate of foreign body injury-related corneal nephelium (28.4%) than marble workers (7.9%) (p=0.0001). However,

Table 2. Industrial workers' workplace units and risk factors.

Parameters	Marble sector n. (%)	Metal sector n. (%)	Total n. (%)	χ^2	P value
Units					
Administration, marketing and technical	40(29.0)	19(18.6)	59(24.6)	3.405	0.182
Welding	9(6.5)	8(7.8)	17(7.1)		
Production in marble and metal sectors	89(64.5)	75(73.5)	164(68.3)		
Nigh shift status					
Yes	96(69.6)	90(88.2)	186(77.5)	11.724	0.001*
No	42(30.4)	12(11.8)	54(22.5)		
Workplace exposure to flying, moving, or falling objects					
No	89(64.5)	64(62.7)	153(63.8)	0.078	0.781
Yes	49(35.5)	38(37.3)	87(36.3)		
Exposure to corrosive-corrosive chemicals in the workplace (e.g., silica, fluorine)					
No	125(90.6)	80(78.4)	205(85.4)	6.949	0.008*
Yes	13(9.4)	22(21.6)	35(14.6)		
Construction machinery use with a colored signal or warning lamp					
No	101(73.2)	69(67.6)	170(70.8)	0.872	0.35
Yes	37(26.8)	33(32.4)	70(29.2)		
Welding Machine Usage					
No	116(84.1)	71(69.6)	187(77.9)	7.117	0.008*
Yes	22(15.9)	31(30.4)	53(22.1)		
Wearing glasses with visors (Personal Protective Equipment)					
No	75(54.3)	49(48.0)	124(51.7)	0.935	0.334
Yes	63(45.7)	53(52.0)	116(48.3)		
Total	138(100.0)	102(100.0)	240(100.0)		

**p<0.05, n=Number of participants, %=Percentage.*

marble workers (12.3%) were more likely to have pterygium/pingueculae than metal workers (3%) (Table 3).

4. Discussion

The present study was conducted in occupational settings, and therefore it may be more effective than hospital-based studies in revealing eye accidents, injuries, and diseases. Indeed, occupational accidents are under-reported in developing countries, including Turkey. As a result, the current study findings take on greater significance. The presence of foreign body injury-related corneal nephelium could indicate unreported accidents.

Heinrich accident pyramid reported 29 accidents with minor injuries and 300 near-misses per accident, with one serious injury and death [13]. By accepting 40 foreign body injuries as minor accidents, this situation can be interpreted as indicating 1-2 serious injuries or fatal accidents and 413 near misses. Therefore, existing preventive measures are either insufficient or not correctly implemented. Indeed, primary eye protection reduces the risk of eye-related accidents by 90% [14]. Despite this precautionary measure, the main issue here is that employers and employees generally disregard this risk. It is worth noting that, of the sectors studied, those working in the metal sector had a higher rate of eye injuries caused by foreign objects than those working in the marble sector. Based on the literature, the metal industrial sector appears to be the most hazardous for eye injuries, consistent with the current study findings [15].

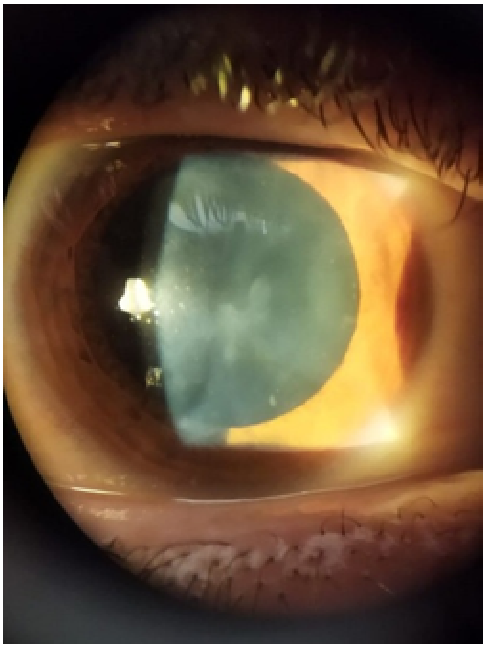

Figure 1. Corneal nephelium caused by multiple foreign body trauma in a 45-year-old male worker at a marble cutting machine factory.

Another significant finding in the current study was that 16.2% of the industrial workers did not know whether their workplace had an on-site physician: 2.5% of workers stated that they don't have an occupational physician. However, the workplaces where the study was conducted were classified as high-risk and served by a responsible physician. As a result, the occupational medical unit is underutilized in a sector with severe ocular problems. The workplace physician's list of ocular diseases should be screened, and it should be determined whether workers take necessary precautions. The current study, on the other hand, revealed that the occupational physician did not perform ocular screening procedures regularly and that an ophthalmologist had not examined 62% of workers in more than a year. The employer and the employees appeared to place too little emphasis on ocular health, and the occupational physician did not plan periodic examinations based on job requirements. Given the nature of the job, it is presumed that ocular diseases should be included in workplace screening, and training interventions should be planned to raise the awareness of workers in hazardous jobs.

Pterygium and pingueculae are two other diseases that the workplace may influence. Their development has been linked to UV rays, age, high

Table 3. The relationship between industrial workers' occupational sector and ocular health conditions.

	Occupational sector				
Parameters	**Marble Sector n. (%)**	**Metal Sector n. (%)**	**Total n. (%)**	**χ^2**	**P value**
Refractive error					
Present	21(47.7)	23(52.3)	44(100.0)	2.106	0.147
Absent	117(59.7)	79(40.3)	196(100.0)		
Dry eye					
Present	31(47.0)	35(53.0)	66(100.0)	4.131	0.042*
Absent	107(61.5)	67(38.5)	174(100.0)		
Corneal foreign body injury					
Absent	127(63.5)	73(36.5)	200(100.0)	17.678	<0.001*
Present	11(27.5)	29(72.5)	40(100.0)		
Pterygium/Pingueculae					
Absent	121(55.0)	99(45.0)	220(100.0)	6.752	0.009*
Present	17(85.0)	3(15.0)	20(100.0)		

**p<0,05, n=Number of participants, %=Percentage.*

cholesterol metabolism, dust exposure, elastotic degeneration, alcohol, and dry eyes [16]. A 52% prevalence of pingueculae has been reported [16], much higher than the rate of 8.3% found in the current study. However, the population was also older, with a mean age of 63.4±14.5 years, compared to 35.78±10.05 of our study subjects, which could account for a low rate of pterygium and pingueculae detection.

The prevalence of pterygium/pingueculae was around 25% in a study of quarry workers in Ghana [17]. One of the most important risk factors for the pterygium/pingueculae is UV radiation [18]. Our study was carried out in factories in the industrial zone. Both marble workers and metal workers were working indoor. Therefore, UV radiation was not considered the main risk for either group. The lower frequency found in our study might be due to younger age and low UV exposure. The marble sector workers had a higher frequency of pterygium and pingueculae than those from the metal sector. This increase could be attributed to dust generated during the manufacturing process of the marble industry, which influences the formation of pterygium and pingueculae. Given this disparity, interventions to reduce ambient dust are only partially effective. Environmental measures, for example, could effectively reduce the dust effect and the formation of pterygium and pingueculae.

Refractive errors, including astigmatism, myopia, and hyperopia, are the most common vision problem worldwide [1]. In the refractive error meta-analysis [12], the estimated pool prevalence for myopia was 26.5%, 30.9% for hyperopia, and 40.4% for astigmatism, with significant differences across countries. Genetic and environmental factors may have contributed to the development of this difference. A substantial proportion of working-age adults have an undiagnosed refractive error, according to a cohort study conducted in England [3]. Consistently, we found that 18.3% of workers had refractive errors. While 10% of those with refractive errors wore glasses, 8.3% did not seek corrective measures for their visual defect. Age and educational level could be critical variables in refractive errors [19]. The younger age group, as well as the concentration of education at the primary and secondary levels, are thought to contribute to the lower incidence of refractive errors.

Dry eye is linked to decreased eye comfort, poor quality of life [20], and poor work performance [21]. Dry eyes affect between 5% and 35% of the population [22]. A meta-analysis of studies on workers who used screens found that the prevalence was 39.1% in studies investigating symptom-based dry eye and 25.4% in studies investigating tear film anomalies [23]. The method used in these studies could have played a significant role in the prevalence discovered [24, 25]. The current study employed the Schirmer and TBUT tests, and the prevalence of dry eye in employees was 27.5%. It backs up previous research on the tear film. Dry eye can be caused by various factors, including age, gender, particle exposure, environmental conditions such as climatic conditions, work conditions [visual-demanding work], and medications such as antihistamines and steroids [21]. Khorshed et al. [24] study with 250 workers in the marble quarry found that 51.2% had dry eyes. Compared to Khorshed et al., the current study found a lower rate of dry eye. The present study evaluated the occupational sectors associated with marble processing in the industry may have revealed this difference. Khorshed et al. evaluated the workers directly involved in marble extraction in a marble quarry.

Overall, dry eye was more prevalent in metal than in marble workers. A study in the Netherlands [9] to investigate the relationship between population-based dry eye and occupation types discovered that the metal sector was the most dangerous business group for dry eye. It is worth noting that exposure to dust, chemicals, toxins, and the overall hazardous working environment are prevalent in these industries.

The current study has a significant limitation: it only included workers from the marble and metal industries. Specific ocular health concerns may exist for automotive, biomedical, and other automotive workers. In this context, multi-centred field studies with a larger workforce and other business lines related to this issue would be clinically and occupationally valuable. Furthermore, workers were presumed to have always worked the same job throughout their professional lives. Workers with extensive work experience may have previously worked in different business lines and suffered eye injuries. However, the risk of eye injury based on the workers' working years was not considered. It is unknown whether new workers value safety precautions more than experienced workers. Inexperienced workers may sustain more eye injuries. Nonetheless, because it is a direct field study conducted by an ophthalmologist under the supervision of public health experts, our study adds to the literature in an unprecedented way. More research on this topic, however, is needed.

5. Conclusions

The majority of workers had completed primary school, smoked more than one cigarette per day, and did not use any bodily function assistive devices. The metal sector had a higher rate of eye injuries caused by foreign objects than the marble sector, indicating its high potential for visual injuries. The same industry had a higher prevalence of dry eye. The fact that occupational physicians did not regularly perform ocular screening procedures and that an ophthalmologist had not examined more than 60% of workers in more than a year demonstrates how little attention was paid to ocular health conditions. Further large-scale multi-center research involving different industrial sectors, in addition to marble and metal, could provide clinically and occupationally relevant outcomes in the long term, providing a complete picture of ocular health status.

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

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References

1. World Health Organization. World Report on Vision. Geneva: World Health Organization, 2019.
2. Bourne RRA, Flaxman SR, Braithwaite T, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Glob Heal*. 2017;5(9):e888-e897. Doi:10.1016/S2214-109X(17)30293-0
3. Rahi JS, Peckham CS, Cumberland PM. Visual impairment due to undiagnosed refractive error in working-age adults in Britain. *Br J Ophthalmol*. 2008; 92(9):1190-1194. Doi:10.1136/bjo.2007.133454
4. Gobba F, Dall'Olio E, Modenese A, et al. Work-related eye injuries: a relevant health problem. Main epidemiological data from a highly-industrialized area of Northern Italy. *Int J Environ Res Public Health*. 2017;14(6):604. Doi:10.3390/ijerph14060604
5. McCall BP, Horwitz IB, Taylor OA. Occupational eye injury and risk reduction: Kentucky workers' compensation claim analysis 1994-2003. *Inj Prev*. 2009;15(3): 176-182. Doi:10.1136/ip.2008.020024
6. Zghal-Mokni I, Nacef L, Kaoueche M, et al. Epidemiology of work-related eye injuries. *Tunis Med*. 2007;85(7):576-579.
7. Cao H, Li L, Zhang M. Epidemiology of patients hospitalized for ocular trauma in the Chaoshan Region of China, 2001-2010. Wedrich A, ed. PLoS One. 2012;7(10):e48377. Doi:10.1371/journal.pone.0048377
8. Pandita A, Merriman M. Ocular trauma epidemiology: 10-year retrospective study. *N Z Med J*. 2012; 125(1348):61-69.
9. Bazeer S, Jansonius N, Snieder H, Hammond C, Vehof J. The relationship between occupation and dry eye. *Ocul Surf*. 2019;17(3):484-490. Doi:10.1016/j.jtos.2019.04.004
10. Lee J, Kim U-J, Lee Y, et al. Sunlight exposure and eye disorders in an economically active population: data from the KNHANES 2008-2012. *Ann Occup Environ Med*. 2021;33. Doi:10.35371/aoem.2021.33.e24
11. Della Vecchia E, Modenese A, Loney T, et al. Risk of cataract in health care workers exposed to ionizing radiation: a systematic review. *Med Lav*. 2020;111(4): 269-284. Doi:10.23749/mdl.v111i4.9045
12. Hashemi H, Fotouhi A, Yekta A, et al. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. *J Curr Ophthalmol*. 2018;30(1):3-22. Doi:10.1016/j.joco.2017.08.009

13. Heinrich HW. Industrial Accident Prevention: A Scientific Approach. NY, USA: McGraw-Hill; 1941.
14. Peate WF. Work-related eye injuries and illnesses. *Am Fam Physician*. 2007;75(7):1017-1022.
15. Serinken M, Turkcuer I, Cetin E, Yilmaz A, Elicabuk H, Karcioglu O. Causes and characteristics of work-related eye injuries in western Turkey. *Indian J Ophthalmol*. 2013;61(9):497. Doi:10.4103/0301-4738.119435
16. Viso E, Gude F, Rodríguez-Ares MT. Prevalence of pinguecula and pterygium in a general population in Spain. *Eye*. 2011;25(3):350-357. Doi:10.1038/eye.2010.204
17. Ovenseri-Ogbomo G, Ocansey S, Boadi-Kusi SB. Oculo-visual findings among industrial mine workers at Goldfields Ghana Limited, Tarkwa. *Ophthalmol Eye Dis*. 2012;4:OED.S9204. Doi:10.4137/OED.S9204
18. Modenese A, Gobba F. Occupational exposure to solar radiation at different latitudes and pterygium: a systematic review of the last 10 years of scientific literature. *Int J Environ Health Res*. 2018;15(1):37. Doi:10.3390/ijerph15010037
19. Wang M, Cui J, Shan G, et al. Prevalence and risk factors of refractive error: a cross-sectional study in Han and Yi adults in Yunnan, China. *BMC Ophthalmol*. 2019;19(1):33. Doi:10.1186/s12886-019-1042-0
20. Paulsen AJ, Cruickshanks KJ, Fischer ME, et al. Dry eye in the Beaver Dam Offspring Study: Prevalence, risk factors, and health-related quality of life. *Am J Ophthalmol*. 2014;157(4):799-806. Doi:10.1016/j.ajo.2013.12.023
21. Wolkoff P. Dry eye symptoms in offices and deteriorated work performance – A perspective. *Build Environ*. 2020;172:106704. Doi:10.1016/j.buildenv.2020.106704
22. The Epidemiology of Dry Eye Disease: Report of the epidemiology subcommittee of the international dry eye workShop (2007). *Ocul Surf*. 2007;5(2):93-107. Doi:10.1016/S1542-0124(12)70082-4
23. Courtin R, Pereira B, Naughton G, et al. Prevalence of dry eye disease in visual display terminal workers: a systematic review and meta-analysis. *BMJ Open*. 2016;6(1):e009675. Doi:10.1136/bmjopen-2015-009675
24. Khorshed EAE, El-Naggar SA, El-Gohary SS, Awad AMB, Ahmed AS. Occupational ocular health problems among marble workers at Shaq El Tho'ban industrial area in Egypt. *Environ Sci Pollut Res*. January 2022. Doi:10.1007/s11356-021-18410-5

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Prevalence of work-related musculoskeletal symptoms among young orthopedics during the surgical practice: an intervention study

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Keywords: Ergonomics; prevention; physiotherapy

Abstract

Background: *Work-related muscle-skeletal symptoms (WRMS) represent a substantial social and economic impact on the way of work and have a high incidence in surgeons. In the literature, several studies address the impact of WRMS in surgeons performing gynecological, laparoscopic, and robotic surgery, but there are no studies in the field of orthopedic surgery. This pilot study aims to assess the effectiveness of a preventive program to reduce pain.* **Methods:** *All workers filled in a standardized questionnaire, and postoperative pain in the operating room was quantified using a numeric scale (NAS). The intervention group followed ergonomic principles in the operating room supervised by a physiotherapist and specific physical exercises before and after surgery. Data were analyzed using the statistical program STATA rel. 14.0.* **Results:** *Twenty-one surgeons were assigned to intervention groups and thirty-three to controls. At baseline, the two groups were homogeneous for anthropometric factors, and controls were older and with higher work seniority. Pain perception resulted in high in both groups in many body districts. At follow-up, after three months, the intervention group significantly reduced pain perception in all body districts for the lumbar back, knees, ankles and feet (p<0.05). In the control group, pain perception increased in all body districts investigated.* **Conclusions:** *We found a high prevalence of WRMS in young orthopedic surgeons, and we demonstrated the effectiveness of a preventive program through targeted ergonomic education and exercises for the most affected body districts.*

1. Introduction

Nowadays, work-related muscle-skeletal symptoms (WRMS) represent a growing problem as a cause of absenteeism from work, reduction of activity, transfer to another job and disability [1]. In the Netherlands, Germany and the United Kingdom, WRMS account for 28% of lost days worked by health workers [2]. In Italy, the National Institute for Occupational Accident Insurance [3] reports that in 2017 there were about 58,000 complaints of occupational diseases, 65% affect the muscle-skeletal system [3].

Healthcare professionals are exposed to the risk of developing WRMS up to three times higher than the general population [4], depending on the type of activity carried out by the professional, the workload and the position taken during work. For

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example, a Portuguese study has shown a correlation between the symptoms perceived by nurses in prolonged standing activities and the maintenance of incongruous positions [5]. Ergonomists have assessed surgeons' environments and working conditions as equal to or even worse than some industrial workers [6].

The presence of WMSDs in surgeons seems to be underestimated [7]. Several studies and literature reviews emerge [8] that deal with the detection of the existence and prevalence of WRMS symptoms in surgeons performing gynecological surgery [9, 10], microsurgery [11], general surgery [12], plastic surgery [8], neurosurgery [13] and assisted robots [14]. These studies recommend special attention to the ergonomic education of surgeons [15] by including this education already during the training course. Few clinical studies propose symptom reduction interventions with exercises during surgery [16] or before and after surgery [17], but orthopedic surgeons are not considered.

The purpose of this intervention study is to propose an ergonomic educational intervention combined with stretching exercises to prevent WRMS in orthopedic surgeons.

2. Materials and Methods

The study had a prospective design comparing results obtained before and after an intervention to evaluate its effectiveness. The same design was applied in a control group continuing the activity requested by the job as usual. Fifty-four orthopedic surgeons from two different Italian hospitals in the Friuli Venezia Giulia region were recruited and agreed to participate in the study. Twenty-one orthopedic surgeons from Cattinara Hospital were recruited into the intervention group. In contrast, thirty-three orthopedic surgeons from Santa Maria della Misericordia Hospital in Udine were selected as a control group.

In July 2019, during the first assessment, the Italian version of the Nordic questionnaire [18], SF 12 [19] and numeric analogic score (NAS) [20] were administered twice: before and after the surgery in the operating theatre; detecting the present pain in the different body districts. A further questionnaire based on previous studies [21] was proposed to investigate the postural structure and the knowledge and application of ergonomic measures in the operating theatre. The questionnaire on joint pain investigated anthropometric information, job, presence of pathologies, use of drugs for musculoskeletal pathologies, physical activity, and the presence of joint pain in the various body districts (cervical spine, upper limbs, dorsal spine, lumbar spine, lower limbs) in the last month according to the Numerical Rating Scale (1 no pain, 10 unbearable pain) [20]. The SF 12 questionnaire (Short Form) investigated the health status perceived by the subjects in the last four weeks. [19]. The SF 12 is the reduced version of SF 36 covering physical activity, role and physical health, role and emotional state, and mental health. The remaining scales, covering physical pain, general health, vitality and social activities, are presented here in a reduced form with only one question each. Some studies on European populations show that the synthetic indices of SF 12 correlate with the corresponding SF 36 with a range of values between 0.93 and 0.97 [22]. The calculation of the scores was performed by referring to the cited manual.

In addition, an *ad-hoc* questionnaire based on previous studies [21] was prepared, including questions on postural set-up in the operating theatre and awareness and application of ergonomic prevention measures. All participants filled the four questionnaires at the baseline and after a three-month follow-up. At the three-month follow-up, the questionnaire was supplemented with questions regarding compliance with the program of self-treatment exercises.

During the three months, a physiotherapist went to the operating theatre of the study group to record video and photos of surgeons' positions during the interventions; both first and second operators (if present) were followed. These data were included in a table to detect incongruous postures taken during a shift.

The intervention group underwent an educational program based on ergonomic guidelines in the operating room and simple self-treatment exercises; these exercises should be performed before and after surgical sessions or twice a day if not in the operating room. Inclusion criteria were an agreement to participate, be an orthopedic surgeon, and work in Trieste and Udine's orthopedic facilities. Exclusion criteria: previous surgery at osteoarticular level, history of trauma, orthopedic or rheumatological diagnoses, and neurological pathologies.

The statistical package STATA 14.0 (Stata Corporation, Texas, TX) was used to analyze the data. Continuous data were summarized as median (25-75° percentiles) due to non-normal distribution assessed using the Shapiro-Wilk test and compared with the Mann-Whitney test. Symptom scores before and after treatment were investigated with the Wilcoxon test. Categorical data were compared using the Chi-square test. Factors associated with pain in different body districts were examined during the follow-up using the Generalized Equations Estimation (GEE) and reported as OR (Odds Ratios) and 95% Confidence Intervals. Statistical significance was placed at p<0.05.

3. Results

Twenty-one surgeons participated in the intervention group (IG) and thirty-three in the control group (CG), and the majority were men in both groups (66.7% and 84.9%, respectively), as shown in Table 1.

There were no differences between the two groups considering the anthropometric features, but IG resulted in older and higher work seniority. Almost all surgeons performed open surgery, while arthroscopic interventions were more common in CG (p=0.01). Surgeries performed daily, and weekly were similar. Drug intake for MS was reported by 23.8% and 31.2% in IG and CG, respectively; no one said to use opioids. A surgeon reported work absence due to MS. Musculoskeletal symptoms in the previous twelve months were declared by the majority of subjects with a higher prevalence of low back pain (66.7% in IG and 42.4% in CG), neck pain (57% in IG and 24.2% in CG, p<0.01) and dorsal pain (42.9% in IG and 15.1% in CG, p=0.02).

Table 2 reported MS symptoms in IG and CG after surgery before and after the intervention: 47.6% and 24.2% in IG and CG, respectively, reported dorsal pain, 42.9% and 45.1% in IG and CG, respectively, reported low back pain and 39.1% and 27.3% in IG and CG, respectively, reported neck pain. After the three months of follow-up, we have

Table 1. Characteristics of the population studied.

Variable	Intervention Group (IG) n=21	Control Group (CG) n=33	p
Age, years median (25°-75° percentiles)	30 (29-33)	33 (30-37)	0.020
Women n. (%)	7 (33.3)	5 (15.1)	0.117
Weight kg median (25°-75° percentiles)	73 (68-82)	72 (65-84)	0.703
Height cm median (25°-75° percentiles)	178 (169-182)	177 (171-183)	0.696
BMI median (25°-75° percentiles)	23.7 (21.8-25.3)	21.9 (22-25.8)	0.894
Residents n. (%)	20 (95.2)	26 (78.8)	0.040
Work seniority years Median (25°-75° percentiles)	3 (2-4)	7 (5-12)	0.020
Surgery performed n. (%)			
Open	21 (100)	32 (97)	
Arthroscopic	9 (42.9)	25 (78.8)	0.421
Robotic	0	3 (9.4)	0.010
Endovascular	0	0	0.149

Table 1 (*Continued*)

Variable	Intervention Group (IG) n=21	Control Group (CG) n=33	p
Surgery per day median (25°-75° percentiles)	2 (2-3)	3 (2-3)	0.09
Surgery per week median (25°-75° percentiles)	9 (6-10)	10 (6-15)	0.353
Surgery duration minutes median (25°-75° percentiles)	60 (60-90)	70 (102-120)	0.003
Drugs intake n. (%)	5 (23.8)	10 (31.2)	0.604
NSAID	5 (23.8)	10 (31.2)	0.604
Opioids	0	0	0.206
Muscle relaxant	1 (4.8)	0	
For days median (25°-75° percentiles)	2.5 (1.5-4.5)	5 (4-7)	0.060
Leaded gown	21 (100%)	29 (97.9%)	0.097
Absence from work due to WRMSD	1 (4.8%)	0	0.206
Sport hours weekly median (25°-75° percentiles)	3 (1-4)	4 (2-6)	0.098
Orthopedic diseases n. (%)	0	1 (3.1)	0.421
Pain n. (%)			
Neck	12 (57.1)	8 (24.2)	0.010
Shoulders	7 (33.3)	7 (21.2)	0.321
Elbow	2 (9.5)	1 (3.0)	0.312
Wrists-Hands	6 (28.6)	5 (15.5)	0.230
Dorsal back	9 (42.9)	5 (15.5)	0.020
Lumbar back	14 (66.7)	14 (42.4)	0.083
Leg	1 (5.9)	3 (9.7)	0.642
Knees	3 (14.3)	7 (1.2)	0.524
Ankles-Feet	2 (11.8)	4 (12.9)	0.902

Table 2. Musculoskeletal symptoms in the previous seven days reported after the surgery at the baseline and follow-up.

Pain	Groups	Baseline	Three-month follow up
Neck	Intervention	8 (39.1%)	7 (33.3%)
	Controls	9 (27.3%)	15 (45.4%)
	P-value	0.404	0.377
Shoulders	Intervention	8 (38.1%)	6 (28.6%)
	Controls	11 (33.3%)	15 (45.4%)
	P-value	0.120	0.132
Elbows	Intervention	2 (9.52%)	1 (5.88%)
	Controls	1 (3.03%)	4 (12.90%)
	P-value	0.311	0.440
Wrist	Intervention	4 (19%)	5 (23.1)
	Controls	3 (9.1%)	14 (42.4)
	P-value	0.298	0.163
Hands	Intervention	6 (28.57%)	4 (19.5%)
	Controls	5 (15.15%)	11 (33.3%)
	P-value	0.232	0.232

Table 2 (*Continued*)

Pain	Groups	Baseline	Three-month follow up
Dorsal back	Intervention	10 (47.62%)	8 (38.1%)
	Controls	8 (24.2%)	15 (45.4%)
	P-value	0.083	0.594
Lumbar back	Intervention	9 (42.9%)	8 (38.1%)
	Controls	15 (45.4%)	17 (51.5%)
	P-value	0.052	0.270
Knees	Intervention	4 (19.5%)	2 (9.5%)
	Controls	11 (33.3%)	19 (57.6%)
	P-value	0.254	0.010
Ankle	Intervention	4 (12.1%)	2 (9.5%)
	Controls	1 (4.6%)	10 (30.9%)
	P-value	0.072	0.072
Feet	Intervention	2 (9.5%)	5 (23.8%)
	Controls	5 (15.5%)	10 (30.3%)
	P-value	0.548	0.269

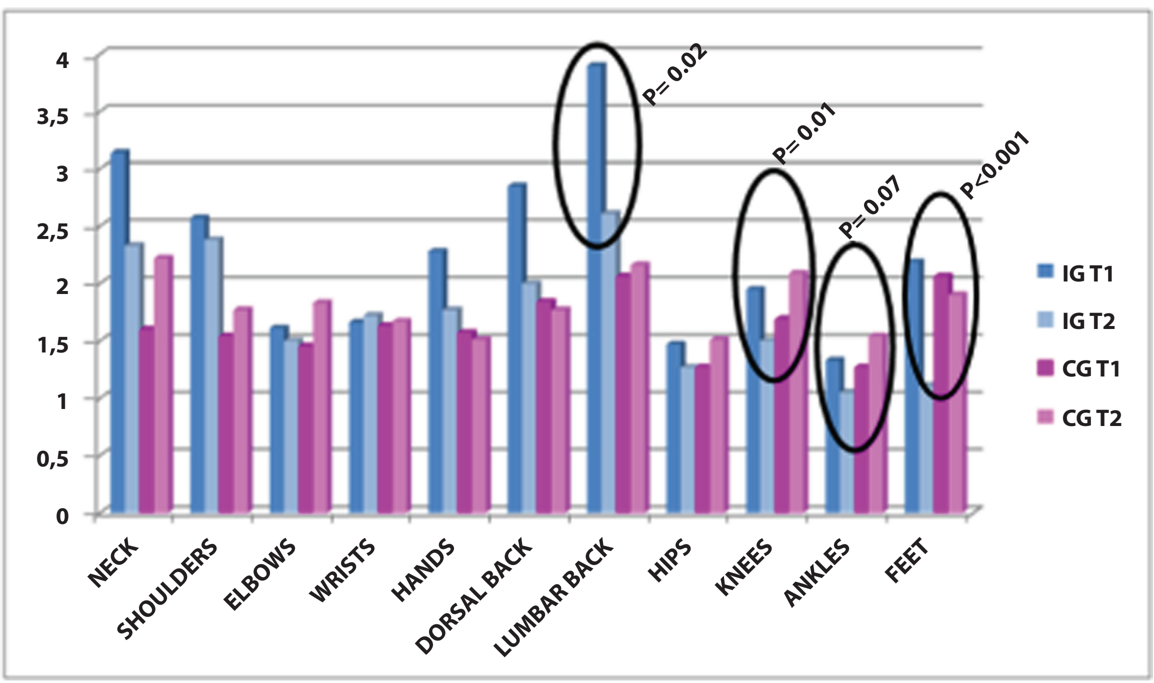

Figure 1. Postoperative NAS values of the two groups at T1 (baseline) and T2 (after three months) in the intervention group (IG) and control group (CG). Wilcoxon signed rank test between lumbar back and feet pain before and after intervention in IG (P=0.02 and <0.001, respectively). Mann-Whitney test between knees and ankles pain after intervention between IG and CG P=0.01 and P=0.07, respectively.

a reduction in the number of workers that reported symptoms in all body districts except in wrist in IG, while in CG, we found an increase in subjects that reported symptoms.

Figure 1 shows symptoms score (NAS) after surgery in the two groups before and after the follow-up in body districts. At follow-up, after three months, the intervention group significantly

Table 3. Factors associated with musculoskeletal symptoms investigated using the GEE (Generalized Equations Estimation) during the follow-up. Data are reported as OR (Odds ratio) and CI (confidence intervals) at 95%.

	OR	95%CI	P
Intervention vs Controls	0.37	0.1-1.6	0.190
Age	1.04	0.99-1.2	0.577
Women	3.2	0.9-33.0	0.328
Surgeries/week	1.03	0.9-1.2	0.671

reduced pain perception in all body districts for the lumbar back, knees, and ankles ($p<0.05$). In the control group, pain perception increased in all body districts investigated.

We evaluated factors associated with WRMD during the follow-up using the Generalized Equations Estimation (GEE) statistics (Table 3), finding a non-significant reduction of symptoms in IG and higher symptoms in women, probably due to the small number of subjects involved in the study.

4. Discussion

WRMS are significant health problems in various areas of work, including surgery. The first aim of this study was to quantify the extent of musculoskeletal disorders afflicts young orthopedic surgeons during their work performance. The surgical activity involves postural habits known to be risk factors for WRMS, including the maintenance of incorrect postures, frequently repeated movements of the upper limbs and prolonged static postures (postures maintained for more than 4 seconds).

Despite the limited numbers of our population, our study confirmed the higher prevalence of WRMS in orthopedic surgeons, mainly in younger subjects, in accord with other studies that correlate more WRMS to fewer years of experience [23]. The lumbar spine (66.7%), neck (57.1%), dorsal spine (42.9%) and shoulders (33.3%) are the most affected areas, as found by other studies [16, 24].

At the baseline, IG reported a higher prevalence of neck and dorsal back pain compared to CG and a NAS higher in all body sites. However, the CG was older than IG. Moreover, our study reported a prevalence of WRMS lower than that of a randomized controlled trial in Italy involving surgeons [17].

At three months follow-ups, we noted symptom scores in all body sites except wrists in IG and increased CG significantly for lumbar back and feet (pre-post IG), knees and ankles (post-intervention between IG and CG), and feet.

The importance of knowledge of ergonomics and how this can affect the onset of WRMS is also highlighted in studies, in which it is noted that already during the training as residents, it is necessary to implement ergonomic knowledge to prevent musculoskeletal disorders [25]. In the analysis of inappropriate positions taken during surgery, the most involved operators are the second and third, as the role of the first surgeon is played by the most experienced doctor, who adjusts the surgical field according to his needs. Instead, available guidelines suggest adjusting the operating table according to the height of the tallest operator and not the oldest [10, 26].

This study presents some limitations: the limited number of the sample, the variability in the execution of the operations (often unforeseeable, for example, in the traumatic field), and the time frame of only three months that has allowed for short-term improvements. It is necessary to continue the follow-up the verify the effectiveness of mid- and long-term prevention and adherence to the suggested preventive protocol.

Another limitation could be the older age of CG. However, the prevalence of symptoms and NAS was higher in IG than in CG despite the young but different ages (median age of 30 *vs* 33, respectively). The high prevalence of symptoms was not expected in young subjects.

5. Conclusion

This study has highlighted the high prevalence of WRMS in young orthopedic surgeons and that a preventive intervention, in collaboration with the physiotherapist, can reduce postoperative pain symptoms, especially in the lumbar spine and lower limbs. These results indicate the importance of increasing the knowledge and the application of ergonomics among orthopedic surgeons.

Institutional Review Board Statement: The approval of the Ethics Committee was not requested for the study as the assessments carried out are included in the health surveillance procedures.

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

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

References

1. Yasobant S, Rajkumar P. Work-related Musculoskeletal Disorders Among Health Care Professionals: A Cross-Sectional Assessment of Risk Factors in a Tertiary Hospital, India. *Indian J Occup Environ Med*. 2014: 18,75-81. DOI: 10.4103/0019-5278.146896
2. Luger T, Maher CG, Rieger MA, et al. Work-break schedules for preventing musculoskeletal symptoms and disorders in healthy workers. *Cochrane Database Syst Rev*. 2019:23:CD012886. DOI: 10.1002/14651858.CD012886.pub2
3. Relazione Annuale del Presidente, giugno 2018, Roma; www.inail.it, Accessed December 20, 2021.
4. Naidoo RN, Haq SA, Naidoo RN, et al. Occupational use syndromes. *Best Pract Res Clin Rheumatol*. 2008 :22, 677-91. DOI: 10.1016/j.berh.2008.04.001
5. Ribeiro T, Serranheira F, Loureiro H, et al. Work related musculoskeletal disorders in primary health care nurses. *Appl Nurs Res*. 2017:33,72-77. DOI: 10.1016/j.apnr.2016.09.003
6. Epstein S, Sparer EH, Tran BN, et al. Prevalence of Work-Related Musculoskeletal Disorders Among Surgeons and Interventionalists: A Systematic Review and Meta-analysis. *JAMA Surg*. 2018:21,153-155. DOI: 10.1001/jamasurg.2017.4947
7. Gilbert CR, Thiboutot J, Mallow C, et al. Assessment of Ergonomic Strain and Positioning During Bronchoscopic Procedures: A Feasibility Study. *J Bronchology Interv Pulmonol*. 2020:27,58-67.
8. Epstein S, Tran BN, Capone AC, et al. Work-Related Musculoskeletal Disorders among Plastic Surgeons: A Systematic Review. *J Reconstr Microsurg*. 2018: 34,553-562. DOI: 10.1097/LBR.0000000000000615
9. Kim-Fine S, Woolley SM, Weaver AL, et al. Work-related musculoskeletal disorders among vaginal surgeons. *Int Urogynecol J*. 2013:24,1191-200.
10. Catanzarite T, Tan-Kim J, Menefee SA, et al. Ergonomics in gynecologic surgery. *Curr Opin Obstet Gynecol*. 2018:30,432-440. DOI: 10.1007/s00192-012-1958-x
11. Howarth AL, Hallbeck S, Mahabir RC, et al. Work-Related Musculoskeletal Discomfort and Injury in Microsurgeons. *J Reconstr Microsurg*. 2019:35,322-328. DOI: 10.1055/s-0038-1675177
12. Stomberg MW, Tronstad SE, Hedberg K, et al. Work-related musculoskeletal disorders when performing laparoscopic surgery. *Surg Laparosc Endosc Percutan Tech*. 2010:20,49-53. DOI: 10.1097/SLE.0b013e3181cded54
13. Gadjradj PS, Ogenio K, Voigt I, et al. Ergonomics and Related Physical Symptoms Among Neurosurgeons. *World Neurosurg*. 2020: 134,e432-441. DOI: 10.1016/j.wneu.2019.10.093
14. Pandey SK, Sharma V, Pandey SK, et al. Robotics and ophthalmology: Are we there yet? *Indian J Ophthalmol*. 2019:67,988-994. DOI: 10.4103/ijo.IJO_1131_18
15. Vijendren A, Yung M, Sanchez J et al. "he ill surgeon: a review of common work-related health problems amongst UK surgeons. *Langenbecks Arch Surg*. 2014:399,967-79. DOI: 10.1007/s00423-014-1233-3
16. Hallbeck MS, Lowndes BR, Bingener J, et al. The impact of intraoperative microbreaks with exercises on surgeons: A multi-center cohort study." *Appl Ergon*. 2017: 60,334-341. DOI: 10.1016/j.apergo.2016.12.006
17. Giagio S, Volpe G, Pillastrini P, et al. A Preventive Program for Work-related Musculoskeletal Disorders Among Surgeons: Outcomes of a Randomized Controlled Clinical Trial. *Ann Surg*. 2019:270,969-975. DOI: 10.1097/SLA.0000000000003199
18. Gobba F, Ghersi R, Martinelli S, et al. Italian translation and validation of the Nordic IRSST standardized questionnaire for the analysis of musculoskeletal symptoms. *Med Lav*. 2008:99,424-43. PMID: 19086615
19. Ware JE Jr. Patient-based assessment: tools for monitoring and improving healthcare outcomes. *Behav Health Tomorrow*. 1996:5,88-87. PMID: 10158047
20. Price DD, McGrath PA, Rafii A, et al. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. *Pain*. 1983:17,45-56. DOI: 10.1016/0304-3959(83)90126-4
21. Wauben LS, van Veelen MA, Gossot D, et al. Application of ergonomic guidelines during minimally invasive surgery: a questionnaire survey of 284 surgeons. *Surg Endosc*. 2006:20,1268-74. DOI: 10.1007/s00464-005-0647-y
22. Ware J Jr, Kosinski M, Keller SD. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. *Med Care*. 1996:34,220-33. DOI: 10.1097/00005650-199603000-00003
23. Grant KMK, Vo T, Tiong LU, et al. The painful truth: work-related musculoskeletal disorders in Australian surgeons. *Occup Med* (Lond). 2020:12,60-63. DOI: 10.1093/occmed/kqz155
24. Szeto GP, Ho P, Ting AC, et al. Work-related musculoskeletal symptoms in surgeons. *J Occup Rehabil*. 2009: 19, 175-84. DOI: 10.1007/s10926-009-9176-1
25. Gadjradj PS, Ogenio K, Voigt I, et al. Ergonomics and Related Physical Symptoms Among Neurosurgeons. *World Neurosurg*. 2020:134,e432-e441. DOI: 10.1016/j.wneu.2019.10.093
26. Berquer R, Smith WD, Davis S. An Ergonomic Study of the Optimum Operating Table Height for Laparoscopic Surgery. *Surg Endosc*. 2002: 16,416-21. DOI: 10.1007/s00464-001-8190-y

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The simultaneous exposure to heat and whole-body vibration on some motor skill functions of city taxi drivers

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Key words: Combined exposure; heat; whole-body vibration; body balance; grip strength; city drivers

Abstract

Background: *Driving requires sensory-motor abilities in unpredictable and complex driving scenarios. This experimental study aimed to investigate the combined effects of exposure to whole-body vibration and heat on motor skill functions of city taxi drivers.* **Methods:** *This study was conducted using a driving simulator on 30 male taxi drivers. The drivers were exposed to five exposure conditions set by a single or combined exposure of two air temperatures (24 and 30 °C) and two vibration levels (0.5, 1 m/s^2). Motor skill functions, including body balance, hand grip strength, and perceived fatigue, were measured using a force plate, dynamometer, and Borg CR-10 questionnaire.* **Results:** *The separate exposure to heat did not modify balance and hand grip strength, but its combined exposure to vibration affected balance and grip strength. The effect sizes of heat, vibration, and heat + vibration on balance were respectively 0.003, 0.23, and 0.441. Vibration exposure made the most significant mean differences in hand grip strength compared with the other scenarios. The separate effect of heat on drivers' perceived fatigue was comparable to vibration. The combined exposure to heat and vibration aggravated the perceived fatigue associated with exposure to heat and vibration alone.* **Conclusion:** *Vibration mainly affects the driver's postural equilibrium, handgrip strength, and fatigue. The heat exposure alone did not have any remarkable effects on the balance responses and handgrip strength; however, it significantly increased the drivers' perceived fatigue. Exposure to heat can aggravate the effects of vibration on motor skills with a synergistic interaction.*

1. Introduction

Using vehicles as taxis in urban life is integral to the lifestyle and a source of drivers' whole-body vibration (WBV) [1]. The vibrations transmitted from the road surface to the vehicle get in touch with the driver through the foot, seat, and backrest [2]. Exposure to WBV can cause health problems in

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the cardiovascular, respiratory, gastrointestinal, spinal, and peripheral nervous systems, and it may also cause a disturbance to the vision and hearing systems [3, 4]. Hence, long-term exposure to whole-body vibration in taxi drivers can cause adverse effects such as reduced perception, annoyance, disturbance of vision and delicate motor tasks, spinal cord injury, and damage to the digestive and reproductive systems. It can reduce blood flow to the lower back and causes cell damage and local fatigue [5], which may cause low back pain [6] and postural imbalance [7].

It should be noted that motor skills are defined as the fundamental movement characteristics of humans and are very important in job performance. Strength, endurance, and speed are primary skills, while mobility and coordination are complementary. In this regard, Savage et al. mentioned that human balance disturbance is one of the most common complications of WBV exposure, which sometimes leads to falls [7]. A fall accident is a non-traffic-related occupational injury, especially at high vibration frequencies, due to body imbalance of drivers [4]. Human postural equilibrium or balance is essential for human motor skills and is very important for daily activities [8] so standing and walking depend on it [4]. Balance is a complex process achieved from the integrated information of visual, vestibular, and somatosensory systems [9]. When these sensory systems are disturbed, the body's balance control mechanisms change and the balance decreases [10]. Studies have shown that vibration can reduce the balance by interfering with the proprioceptive system [4, 11, 12]. It should be noted that the force plate used to measure balance will be able to record the horizontal and vertical reaction forces. The center of pressure (COP) coordinates are determined, and sway from the pressure center is recorded as COP displacement [13].

Handgrip strength is an essential characteristic of the hand in different activities, especially driving, and reduced strength can indicate muscle fatigue due to exposure to vibration. Widia and Dawal showed strong relationships between muscle activity, grip strength, interval time and vibration level. Muscle activity and ratio decrease of grip strength increase as the vibration level and exposure duration increase [14]. Drivers require high motor-sensory skills. Hence, proper handgrip strength and suitable postural stability are essential for safe driving [4].

The dissatisfaction levels of extreme air temperature have even some veto power over the existing outdoor noise levels from traffic loads during driving. Due to the nature of taxi driving in outdoor areas, drivers are exposed to heat stress in the warm seasons, aggravated by global warming [15]. Spaul et al. have shown combined exposure to heat and WBV can even reduce the effectiveness of body cooling mechanisms [16, 17]. Exposure to heat and whole-body vibration (WBV) may be the risk factors for drivers' physical and mental fatigue, which can result in poor performance or *postural* instability [18, 19]. Son et al. showed that workers' balance ability is affected by physical workload and heat exposure [20].

The related literature emphasized the interactions among environmental factors and recommended more detailed research. It can be seen that exposure to any of the physical factors alone can affect the physical and mental performance of drivers [21]. There are limited studies on the combined effects of vibration and heat exposure during driving activities, especially among taxi drivers. This study empirically investigated the effects of separate and combined exposure to vibration and heat on some motor skills among taxi drivers under simulated driving conditions.

2. Methods

2.1 Subjects

In this experimental study, 30 healthy male taxi drivers participated voluntarily, and a clear explanation of the testing process was given to them. Eligible drivers filled out a demographic questionnaire which included age, height, weight, history of the disease, and the Pittsburgh Sleep Quality Index (PSQI) questionnaire assessing sleep quality over a 1-month time interval. The mean ± SD of age and BMI of the participants were 34.56±5.93 years and 22.57±2.06 kg/m^2, respectively.

The drivers had not engaged in any possible medications related to motor skills. The drivers had to get at least 7 hours of sleep the night before each session and not use caffeine or other stimulants.

All participants were paid to ensure their motivation. The Hamadan University of Medical Sciences Ethics Committee approved this study (Code: IR.UMSHA.REC.1400.036.). All drivers were informed of the research, and consent forms were obtained. The inclusion criteria for volunteers to make the study as accurate as possible are as follows:

- Drivers should not be older than 45 years;
- Weight was kept in the range of 75 to 85 as it can interfere with the received vibration levels;
- The Pittsburgh Sleep Quality Index questionnaire score should be below 6;
- Drivers should be healthy and be in the standard BMI range (18-23);
- Drivers should not use specific drugs or caffeine, or any other stimulants;
- Drivers should not have sleep problems and have at least 7 hours a day;
- Drivers should not suffer from daltonism (Ishihara test) and have correct visual acuity (visual acuity score=20/20) using the visual screening device (Optec 5000/5000P Series).

2.2 Experimental design

The research was performed using a within-subjects design, where all drivers were considered their controls. A repeated-measures design was conducted to investigate the effect of exposure of 30 minutes to heat or WBV in different scenarios. As shown in *Figure 1*, the drivers exposed for 30 minutes to five different scenarios on separate days under simulated driving conditions: (i) heat exposure (air temperature: 30° c, WBV acceleration: 0 m/s^2), (ii) WBV_1 exposure (air temperature: 24° c, WBV acceleration: 0.5 m/s^2), (iii) WBV_2 exposure (air temperature: 24° c, WBV acceleration: 1 m/s^2), (iv) combined heat and WBV_1 (air temperature: 30° c, WBV acceleration: 0.5 m/s^2), and (v) combined heat and WBV_2 (air temperature: 30° c, WBV acceleration: 1 m/s^2). The WBV intensities of 0.5 and 1 m/s^2 were selected based on ISO 2631exposure limit recommendation. They were also chosen according to the real data obtained from taxi drivers exposed to WBV in fields. The grip strength and balance test and Borg scale fatigue were tested before and after each scenario. Different scenarios were performed randomly for each driver to eliminate the sequence effect. Moreover, the interval between each experiment was two days to eliminate the effects of previous exposure.

2.3 Driving simulation condition

The simulated driving system was derived from city car driving software (v1.5.9.2) that simulates visual driving. It was linked to a vibration simulator (Car racing VR-Sarisa model) with Xbox 360 controller. This car simulator works with a pneumatic system mechanism, and it can produce vibration in different adjustable acceleration and frequency spectrums. It is powered by two air compressors that can generate vibrations in different regulated frequencies and accelerations. The vibration was set at two levels of 0.5 m/s^2 and 1 m/s^2 and monitored continuously by a vibration meter (SVANTEK, SV106A). *Table 1* shows the vibration acceleration values of the driving simulator system. The vibration of vehicles such as the studied taxi car frequently varies from 1 to 50 Hz, and the most noticeable vibrations occur on the Z-axis [22, 23]. It should be noted that the output frequency of the driving simulator was 5 to 20 Hz.

The driving simulator was located in the air-conditions simulator chamber shown in *Figure 2*. Air-conditions simulator chamber can able to provide different air temperature conditions. The chamber's dimensions are 4 × 3.5 × 2.7 m (L×W×H), and is made of pre-made injected polyurethane panels with a density of 40 kg / m3, and is covered with alloy sheets that produce -25° to 50°c air temperature condition in the chamber. The WBGT-meter (CASELLA -HB3279-03) was used to monitor air temperature, and it got constant at 30°c and 24° c. The digital light meter (INS-DX-200) and Sound-level meter (LUTRON SL-4011 (Were used to keep brightness and background noise at the optimal limit of 300 Lux and 50 to 55 dB, respectively.

2.4 Motor skill functions measurement

For measuring body balance, Subjects' COP was measured in ML and AP axes in two different vision conditions, including Eyes-Open (EO) and

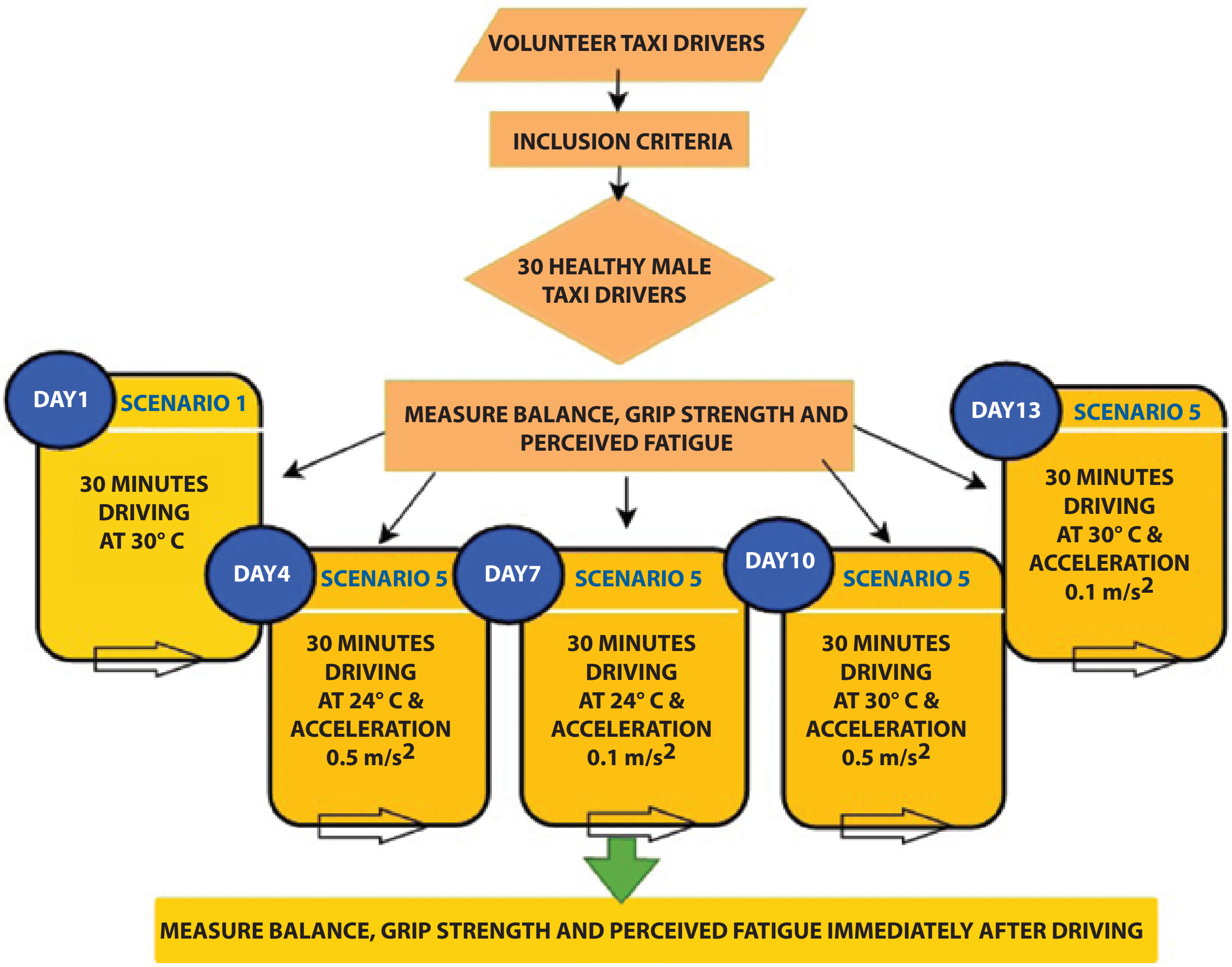

Figure 1. Diagram of the study experiment setup.

Table 1. Characteristics of vibration accelerations induced by the driving simulator.

Condition (1)	x	y	z	sum	Condition (2)	x	y	z	sum
a_{rms} (m/s^2)	0.01	0.09	0.49	0.50	a_{rms} (m/s^2)	0.08	0.11	0.98	1.00
$MTVV^a$	0.11	0.28	2.17		$MTVV^a$	0.30	0.57	2.21	
a_{peak}	0.23	0.47	2.71		a_{peak}	0.82	1.35	4.81	
VDV^b (m/s$^{1.75}$)	0.24	0.85	4.88		VDV^b (m/s$^{1.75}$)	3.66	12.82	73.20	

a= the maximum transient vibration value, calculated at a one-second interval.
b= the fourth power vibration dose value.

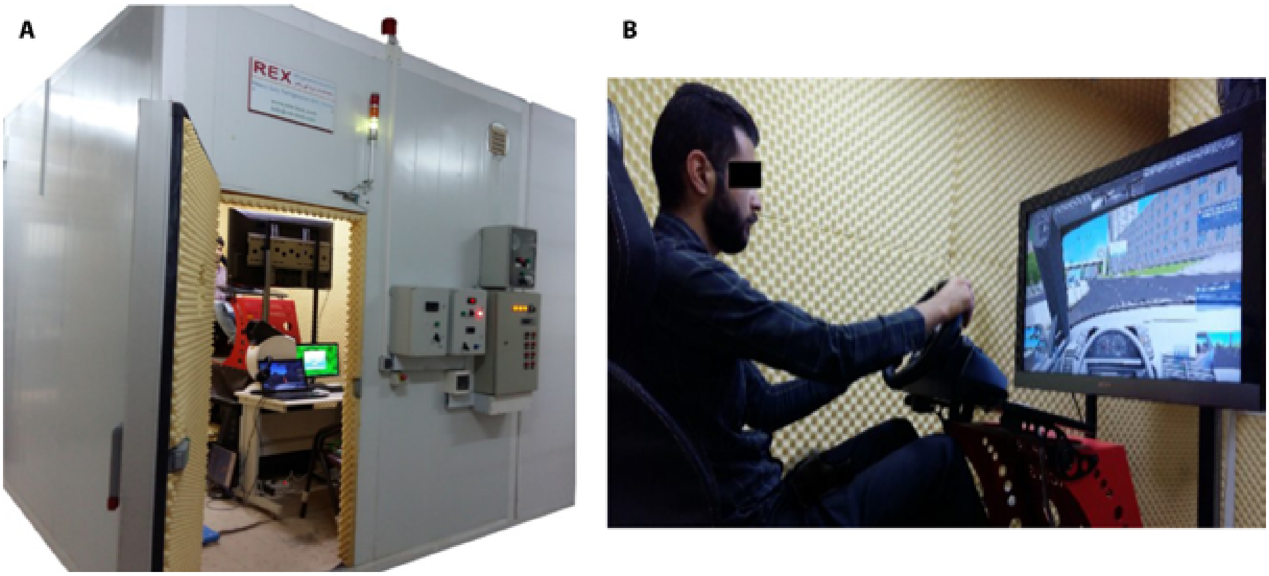

Figure 2. The air-condition simulator chamber (a) and the driving simulator (b).

Eyes-Closed (EC), before and after exposure in each session. The force plate is placed on a rigid surface to prevent unwanted movements. The subjects stood barefoot in a Romberg position (stand straight and motionless with hands to the sides of the body and in a neutral position) on the Kistler 9286BA force platform (Winterthur, Switzerland) for 30 seconds while they were looking at a specific target at a distance of one meter from their eyes height [24]. Body balance was measured three times with eyes open and three times with closed eyes, and an average of these was reported. The stand location on the force plate must be the same for everyone, so a T-shaped sheet was installed on the force plate, and people stood on the marked area. The force plate was connected to Kistler 9865 amplifier, and recorded data were transformed to BioWare software (Software for Data Acquisition of Force Plates) by an analogue to digital converter Kistler 5691A Data Logger. The sampling frequency was 100 Hz, and to increase the measurement accuracy, 10s first data were deleted, and the 20s final data were extracted. Finally, 4,000 coordinate points of COP (2,000 point x, 2,000 point y) were used to calculate the root-mean-square of COP anterior-posterior (y)/ medial-lateral (x) displacement by using formulas in excel [12]{Cornelius, 1994 #12;Pollard, 2017 #28}. Many parameters can be calculated from formulas to describe the balance, all of which are suggestive [11]. A graph of the COP displacement recorded by the BioWare software in different directions is shown in *Figure 4*.

Jamar hydraulic hand dynamometer was used to measure hand grip strength before and after each scenario. The mean score of handgrip strength was obtained by three times measured. Each time, a dynamometer fitting the anatomy of the individual's hand was calibrated to zero. The volunteers had to keep the upper arm close to the body, at a 90-degree angle, grabbing the dynamometer for a few seconds with maximum force. The kilogram number on the dynamometer indicates gripe strength [25, 26].

Finally, the Borg scale (CR-10) was used to determine the perceived fatigue of the drivers [27, 28]. Each of the numbers on this scale expresses a degree of perceived fatigue such that a value of zero means nothing at all, a matter of five means moderate fatigue, and a value of 10 means unbearable fatigue. Fatigue perceived by the individual was used to assess fatigue before and after each scenario.

2.5 Statistical analysis

After confirming the normality of the data by using the Kolmogorov-Smirnov test, paired sample

T-test was used to determine the effects of exposure in different scenarios. When Mauchly's test rejected the Sphericity Assumed, a Greenhouse-Geisser correction was used to obtain p-values. The repeated measure ANOVA was employed to compare the scenarios in pairs and to report effect size (ES). LSD post hoc test was used to compare the means between groups in pair scenarios. All statistical analyses were performed using the SPSS 22 package.

3. Results

The comparison between the root-mean-square (RMS) of COP in anterior-posterior (AP) and Medial-Lateral (ML) displacement before and after different exposure and vision conditions by paired t-test is shown in *Table 2*. In the open eyes condition, there were significant mean differences in COP-AP and COP–ML in all exposure conditions except for heat and WBV_1 scenarios. In the closed eyes condition, the significant displacement increment of COP-AP and COP-ML were observed in all scenarios, except for the heating scenario (p=0.24 and p= 0.64). Generally, it was observed that WBV_2 and heat +WBV_2 had more significant effects on drivers' body balance compared with the other conditions.

Table 2 also shows the effect sizes of COP-AP and COP–ML RMS data in all exposure conditions. The heat exposure scenario cannot affect balance lonely. Still, the combined exposure to heat with WBV1 and WBV2 can affect the displacement increment of COP more effectively than the single WBV exposure scenario.

In open eyes condition, the effect sizes of heat, WBV_2, and heat+WBV_2 on COP-AP were 0.003, 0.23, and 0.441, respectively. The effect sizes of heat, WBV_2, and heat+WBV_2 on COP-ML were 0.01, 0.04, and 0.54, respectively. These responses are the same about closed eye conditions.

The combined effects of heat and vibration were more than the sum of these separated effects. *Table 3* shows the significant differences for RMS data of COP in all directions and all exposure scenarios and open and closed eyes vision conditions.

Table 4 also shows the pairwise comparison of RMS data of COP in EO (AP and ML directions) and EC (AP and ML direction) in different exposure conditions.

The mean differences in hand grip strength in all scenarios are shown in *Table 5*.

A significant reduction in grip strength after exposure in all scenarios except in heat and WBV_1 scenarios (p=0.08 and p=0.13, respectively). Based on the acquired effect size, WBV_2 scenario makes the greatest mean differences in hand grip strength compared with the other scenarios. It is also observed that the effect sizes of heat, WBV_2, and heat+WBV_2 on hand grip strength are 0.004, 0.012, and 0.019, respectively. It can be stated that exposure to heat has increased the effect of vibration on hand grip strength. As shown in Tables 4 and 5, it can also be seen the separate effect sizes of exposure whole-body vibration on drivers' postural equilibrium and grip strength were considerable compared with the heat exposure in the domain of the studied scenarios.

The effects of different scenarios on the perceived fatigue scores were presented in *Table 6*. The results showed that all drivers experienced fatigue in all scenarios ($p<0.001$). According to the acquired effect size, the combined scenarios (Heat+WBV_1=0.73, Heat+WBV_2=0.98) have more effect on perceived fatigue than the single exposure scenarios (Heat=0.31, WBV_1=0.21, WBV_2= 0.55).

As shown in *Table 6*, the separate effect sizes of exposure to heat on drivers' perceived fatigue was comparable to vibration at the domain of the studied scenarios. Moreover, the effect of exposure to heat on the perceived fatigue was considerable compared the hand grip strength at the domain of the studied scenarios.

4. Discussion

Occupational exposure to environmental factors can act in quite complex ways to produce their combined effects on body responses. It is observed that the studies about the separate and combined effects of occupational exposure to environmental factors have become very important.

This study confirmed that separate exposure of drivers to vibration caused a significantly increased COP displacement in the different directions. Some

Table 2. The significant mean difference of COP in (AP) and (ML) directions in all exposure conditions.

	Eyes Open						Eyes Closed					
	AP(y)			ML(x)			AP(y)			ML(x)		
Scenarios	**Mean±SD**	**Sig**	**ES**	**Mean±SD**	**Sig**	**ES**	**Mean±SD**	**Sig**	**ES**	**Mean±SD**	**Sig**	**ES**
Heat	0.24±1.13	0.23	0.003	-.03±0.84	0.80	0.010	-0.22±1.04	0.24	0.006	0.09±1.11	0.64	0.004
WBV_1	0.12±0.93	0.48	0.036	0.23±0.93	0.21	0.113	0.32±0.66	**0.013***	0.021	0.47±0.92	**<0.01***	0.170
WBV_2	0.65±0.91	**<0.01***	0.230	0.41±0.75	**0.04***	0.04	0.51±0.95	**0.02***	0.213	0.64±0.70	**<0.01***	0.574
Heat + WBV_1	0.48±0.85	**0.04***	0.078	0.35±0.91	**0.04***	0.252	0.47±0.65	**<0.01***	0.115	0.47±1.00	**<0.01***	0.413
Heat+ WBV_2	1.13±0.78	**<0.01***	0.441	0.62±0.89	**<0.01***	0.54	1.03±0.95	**<0.01***	0.268	0.92±0.79	**<0.01***	0.668

[a] *Mean: The difference between COP in different directions before and after each exposure condition.*
[b] **: indicates statistically significant.*
[C] *WBV: whole body vibration (at two acceleration levels; WBV1: 0.5 m/s^2 and WBV2:1 m/s^2).*

Table 3. The significant differences for RMS data of COP in all directions and in all exposure scenarios.

Directions	Mean Difference	SD	F	p
COP-AP	-0.378	0.38	-13.23	< 0.001*
COP-ML	-0.447	0.77	-7.72	< 0.001*

research revealed that whole-body vibration exposure can impair human body balance [4, 29, 30]. This impairment actually can reduce the function of central postural control mechanisms, especially at the high vibration acceleration [31]. Yung et al. demonstrated that the single exposure to low to high levels of vibration may increment to some extent in human postural sway [32].

The separate exposure to heat has no significant reduction effect on body balance in any direction and vision condition, however, the combined exposure to heat and vibration can affect on body postural stability more effectively than the single WBV exposure scenario. The acquired effect sizes data showed that the combined effects of heat and vibration on body balances were more than the sum of these separated effects. It can be said that the synergist effects can be seen in the interaction of heat and vibration on the body balance. Previous studies on the combined effects of vibration and heat on body balance were not found. However, Golhosseini et al. determined simultaneous exposure to WBV and noise can increase the equilibrium effects more than a single exposure to WBV [33]. Raffler et al. also showed WBV and awkward posture have more effect than single factor exposure on low back pain [5]. It is also observed that combined exposure to vibration and noise can make disturbance on visual cognitive process [34].

A significant difference of the body balance in open and closed eyes vision conditions so that it can be indicated the role of sight in body balance. It should be noted that, the acceleration of 1 m/s^2 can upset a person's proper balance, but acceleration of 0.5 m/s^2, has no direct significant effect on balance, but when vision as sensory ability is eliminated, the same low vibration level (acceleration 0.5 m/s^2) can also upset the balance. Black et al. also indicated that visual sensory impairment is associated with body imbalance and falls [35].

The mean differences in perceived fatigue among drivers in all scenarios were statistically significant ($p<0.001$). In accordance with the current finding, Fujii et al. demonstrated that activity at high air temperatures can increase fatigue [19]. Moreover, Ferreira-Souza et al. mentioned that exposure to vibration can induce fatigue among drivers [36]. The results confirmed that the synergism interaction also occurs in the driver's perceived fatigue at simultaneous exposure to heat and vibration so that the size effect of heat and WBV on the fatigue is greater than the sum of each factor. The finding represented that the separate effect size of exposure to heat on drivers' perceived fatigue was very considerable in the domain of the studied scenarios. Heat stress, as a physical stressor, can affect the body's physiological responses, and the resulting consequences appear as fatigue over time.

The separate effect of exposure to heat is not significant on grip strength. However, in the combined exposure condition, the effect of vibration on grip strength was aggravated. The low acceleration level of vibration could not also statistically affect the handgrip strength, but the combined exposure to heat were significant ($p<0.001$). It should be noted that the low grip strength can indicate muscle fatigue [37] resulting a decline in physical function [21]. Albert et al. reported that the physical function is an important task in a driving vehicle and lack of this is associated with unsafe driving [38].

The main limitation of this study is the short-term exposure as compared with actual working hours of driving activities. More studies in the field seem necessary to fully validate this finding in the long-term exposure of drivers. Moreover, the interaction of this physical factors on some psycho-physiological responses of the city taxi drivers can be studied using the advanced clinical methods in future. It should be noted that the findings are limited to the experiment configurations of air temperatures and vibration levels as the most common real exposure levels of drivers.

Occupational health program should be carried out to help prevent adverse health effects among taxi

Table 4. Pairwise comparisons of COP in (AP) and (ML) directions in all exposure conditions.

			Heat		WBV1		WBV2		Heat+ WBV1		Heat+ WBV2	
Vision	**Direction**	**Scenarios**	**Δ Mean**	**Sig.**	**Δ Mean**	**Sig.**	**Δ Mean**	**Sig.**	**Δ Mean**	**Sig.**	**Δ Mean**	**Sig.**
Eyes-Open	(AP)	Heat	-	-	0.33	1	-0.32	1	-0.2	1	0.78*	0.041*
		WBV1	-0.33	1	-	-	-0.65	0.16	-0.55	0.23	-1.11	<0.001*
		WBV2	0.32	1	0.65	0.165	-	-	0.122	1	-0.45	0.03
		Heat+ WBV1	0.2	1	0.53	0.23	-0.122	1	-	-	-0.57	0.04
		Heat+ WBV2	0.78	0.04	1.11	<0.001*	0.45	0.03	0.57	0.04	-	-
	(ML)	Heat	-	-	-0.155	1	-0.51	0.22	-0.37	0.22	-0.65	0.18
		WBV1	0.155	0.12	-	-	0.35	0.79	0.21	1	-0.5	0.13
		WBV2	0.51	0.21	0.35	0.79	-	-	0.14	1	-0.14	1
		Heat+ WBV1	0.37	0.54	021	1	-0.14	1	-	-	-0.28	0.45
		Heat+ WBV2	0.65	<0.001*	0.5	0.13	0.145	1	0.28	0.45	-	-
Eyes-Closed	**(AP)**	Heat	-	-	0.55	0. 01*	0.71	0.01*	-0.51	0. 01*	-1.24	<0.001*
		WBV1	0.55	0.01	-	-	0.158	0.14	0.37	0.71	-0.69	<0.001*
		WBV2	0.71	0.001	0.158	0.14	-	-	0.195	0.25	-0.53	<0.001*
		Heat+ WBV1	0.516	0.012	-0.03	0.71	-0.195	0.255	-	-	-0.73	<0.001*
		heat+ WBV2	1.24	<0.001*	0.69	<0.001*	0.53	<0.001*	0.73	<0.001*	-	-
	(ML)	Heat	-	-	-0.26	1	-0.616	0.06	0.247	0.44	-0.83	0.01
		WBV1	0.26	1	-	-	-0.34	0.48	-0.36	1.62	-0.56	0.21
		WBV2	-0.616	0.006	0.34	0.48	-	-	0.24	0.44	-0.217	0.92
		Heat+ WBV1	0.369	0.62	0.1	1	-0.24	0.117	-	-	-0.46	0.11
		Heat+ WBV2	0.88	<0.001*	0.56	0.21	0.21	0.92	0.46	0.11	-	-

*Δ Mean: The difference between COP in different directions before and after each exposure condition; *: indicates statistically significant differences.*
WBV: whole body vibration (at two acceleration levels; WBV1: 0.5 m/s^2 and WBV2:1 m/s^2).

Table 5. The significant mean differences of handgrip strength in all exposure conditions.

Exposure conditions	Mean±Std.	Sig.	Effect size
Heat	1.83±2.42	0.08	0.004
WBV$_1$	0.76±2.23	0.137	0.00
WBV$_2$	2.73±2.09	<0.001*	0.012
Heat+ WBV$_1$	2.13±1.75	<0.001*	0.008
Heat+ WBV$_2$	3.3±2.11	<0.001*	0.019

*Mean: The difference between COP in different directions before and after each exposure condition; *: indicates statistically significant WBV: whole body vibration (at two acceleration levels; WBV1: 0.5 m/s^2 and WBV2:1 m/s^2).*

Table 6. The significant mean differences of perceived fatigue in all exposure conditions.

Exposure conditions	Mean± Std.	Sig.	Effect Size
Heat	2.97±.77	<0.001*	0.31
WBV$_1$	1.4±1.38	<0.001*	0.21
WBV$_2$	4.4±.99	<0.001*	0.55
Heat+ WBV$_1$	4.16±.80	<0.001*	0.73
Heat+ WBV$_2$	6.17±1.27	<0.001*	0.98

*Mean: The difference between COP in different directions before and after each exposure condition; *: indicates statistically significant WBV: whole body vibration (at two acceleration levels; WBV1: 0.5 m/s^2 and WBV2:1 m/s^2).*

drivers. The mechanical vibration transmitted from car seat to drivers must be reduced using preventive maintenance as much as possible. Instructing drivers regarding adverse health effects of environmental factors while driving is also necessary.

5. Conclusion

It is confirmed that the separate exposure of drivers to vibration have main effect and the separate exposure to heat have crossed effect on driver's postural equilibrium. The heat exposure alone cannot lead to remarkable effects on the balance responses; however, it can increase the effect of vibration on the balance. The combined effects of exposure to heat and vibration represented synergist interactions on balance or equilibrium, as an essential functional skill of drivers. The separate effect of exposure to heat is not significant on grip strength, however, the effect of vibration on grip strength was aggravated during simultaneous exposure to heat. The findings also represented that the separate effect size of exposure to heat on drivers' 'erceived fatigue was very considerable at the domain of the studied scenarios. It is recommended that future studies focus on the validation of this experimental design in field.

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References

1. Duarte MLM, de Melo GC. Influence of pavement type and speed on whole body vibration (WBV) levels measured on passenger vehicles. *J Braz Soc Mech Sci Eng.* 2018;40(3):1-12.
2. Nassiri P, Koohpaei A, Zeraati H, Shalkouhi PJ. Train passengers comfort with regard to whole-body vibration. *J Low Freq Noise V A.* 2011;30(2):125-36.

3. Shi W, Li M, Guo J, Zhai K. Evaluation of road service performance based on human perception of vibration while driving vehicle. *J Adv Transp*. 2020. Doi: https://doi.org/10.1155/2020/8825355
4. Mani R, Milosavljevic S, Sullivan SJ. The effect of occupational whole-body vibration on standing balance: A systematic review. *Int J Ind Ergon.* 2010;40(6):698-709.
5. Raffler N, Rissler J, Ellegast R, Schikowsky C, Kraus T, Ochsmann E. Combined exposures of whole-body vibration and awkward posture: a cross sectional investigation among occupational drivers by means of simultaneous field measurements. *Ergonomics*. 2017; 60(11):1564-75.
6. Bovenzi M, Schust M, Mauro M. An overview of low back pain and occupational exposures to whole-body vibration and mechanical shocks. *Med Lav*. 2017;14;108(6):419-433.
7. Savage R, Billing D, Furnell A, Netto K, Aisbett B. Whole-body vibration and occupational physical performance: a review. *Int Arch Occup Environ Health*. 2016;89(2):181-97.
8. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. *J Gerontol*. 1991;46(3):M69-M76.
9. Johansson R, Magnusson M. Human postural dynamics. *Crit Rev Biomed Eng*. 1991;18(6):413-37.
10. Vouriot A, Gauchard GC, Chau N, et al. Sensorial organisation favouring higher visual contribution is a risk factor of falls in an occupational setting. *Neurosci Res*. 2004;48(3):239-47.
11. Cornelius KM, Redfern MS, Steiner LJ. Postural stability after whole-body vibration exposure. *Int J Ind Ergon*. 1994;13(4):343-51.
12. Pollard J, Porter W, Mayton A, Xu X, Weston E. The effect of vibration exposure during haul truck operation on grip strength, touch sensation, and balance. *Int J Ind Ergon*. 2017;57:23-31.
13. Prieto TE, Myklebust JB, Hoffmann RG, Lovett EG, Myklebust BM. Measures of postural steadiness: differences between healthy young and elderly adults. *IEEE Trans Biomed Eng*. 1996;43(9):956-66.
14. Widia M, Dawal SZ. The Effect of Vibration on Muscle Activity and Grip Strength Using an Electric Drill. *Adv Electron Forum*. 2013;10:318-323.
15. Makowiec-Dąbrowska T, Gadzicka E, et al. Climate conditions and work-related fatigue among professional drivers. *Int J Biometeorol*. 2019;63(2):121-8.
16. Spaul W, Spear R, Greenleaf J. Thermoregulatory responses to heat and vibration in men. *Aviat Space Environ Med*. 1986;57(11):1082-7.
17. Kjellstrom T, Freyberg C, Lemke B, Otto M, Briggs D. Estimating population heat exposure and impacts on working people in conjunction with climate change. *Int J Biometeorol*. 2018;62(3):291-306.
18. Troxel WM, Helmus TC, Tsang F, Price CC. Evaluating the impact of Whole-Body Vibration (WBV) on fatigue and the implications for driver safety. *Rand Health Q*. 2016;5(4):10-20.
19. Fujii H, Fukuda S, Narumi D, Ihara T, Watanabe Y. Fatigue and sleep under large summer temperature differences. *Environ Res*. 2015;138:17-21.
20. Son SY, Tokizawa K, Yasuda A, Sawada CI. Physiological responses and balance ability are affected by physical workload and heat exposure in workers. *Extreme Physiol Med*. 2015; 4: 25-29.
21. Bohannon RW. Muscle strength: clinical and prognostic value of handgrip dynamometry. *Curr Opin Clin Nutr Metab Care*. 2015;18(5):465-70.
22. Mansfield N. Vibration and shock in vehicles: new challenges, new methods, new solutions. 1st International Comfort Congress, Salerno, Italy, 7-8 June 2017.
23. Zeng X, Kociolek AM, Khan MI, Milosavljevic S, Bath B, Trask C. Whole body vibration exposure patterns in Canadian prairie farmers. *Ergonomics*. 2017; 60(8):1064-73.
24. Lê T-T, Kapoula Z. Role of ocular convergence in the Romberg quotient. *Gait Posture*. 2008;27(3):493-500.
25. Ramlagan S, Peltzer K, Phaswana-Mafuya N. Hand grip strength and associated factors in non-institutionalised men and women 50 years and older in South Africa. *BMC Res Notes*. 2014;7(1):8.
26. Thuresson M, Äng B, Linder J, Harms-Ringdahl K. Intra-rater reliability of electromyographic recordings and subjective evaluation of neck muscle fatigue among helicopter pilots. *J Electromyogr Kinesiol*. 2005; 15(3):323-31.
27. Borg G. An introduction to Borg's RPE-scale: Mouvement Publications; 1985.
28. Borg E. On perceived exertion and its measurement: Psykologiska institutionen; 2007.
29. Lu SY, Liu CC, Lee CL, Lin YH. Vertical vibration frequency and sitting posture effects on muscular loads and body balance. *Int J Ind Ergon.* 2019;74:102860.
30. Ahuja S, Davis J, Wade LR, editors. Postural stability of commercial truck drivers: Impact of extended durations of whole-body vibration. *Proc Hum Factors Ergon Soc Annu Meet.* 2005: SAGE Publications Sage CA: Los Angeles, CA.
31. Le Clair K, Riach C. Postural stability measures: what to measure and for how long. *Clin Biomech*. 1996;11(3):176-8.
32. Yung M, Tennant LM, Milosavljevic S, Trask C. The multisystem effects of simulated agricultural whole body vibration on acute sensorimotor, physical, and cognitive performance. *Ann Work Expo Health*. 2018;62(7):884-98.
33. Golhosseini SMJ, Aliabadi M, Golmohammadi R, al. Combined effects of exposure to noise and vibration on human postural equilibrium under simulated driving conditions. *Sound Vib*. 2022;56(1):37-49.
34. Niazmand-Aghdam N, Ranjbarian M, Khodakarim S, Mohammadian F, Dehghan SF. The effects of

combined exposure to road traffic noise and whole body vibration on types of attention among men. *Med Lav*. 2021;112(5):360.
35. Black A, Wood J. Vision and falls. *Clin Exp Optom*. 2005;88(4):212-22.
36. Ferreira-Souza L, Gama M, Coelho-Oliveira A, Sá-Caputo D, Bernardo-Filho M. Could Whole-body vibration lead the professional drivers to fatigue? A Narrative Review. *Ergonomics*. 2021;11:272.
37. Little MA, Johnson Jr BR. Grip strength, muscle fatigue, and body composition in nomadic Turkana pastoralists. *Am J Phys Anthropol.* 1986;69(3):335-44.
38. Albert G, Lotan T, Weiss P, Shiftan Y. The challenge of safe driving among elderly drivers. *Healthc Technol Lett*. 2018;5(1):45-8.

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Developing a Decision Aid Tool for selecting pen-paper observational ergonomics techniques: a quasi-experimental study

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Keywords: Observational techniques; risk assessment; Decision Aid Tool; musculoskeletal disorders; ergonomics

Abstract

Background: *A significant error that may occur during ergonomic risk assessment and invalidate assessment reliability corresponds to technique selection. This study aimed to develop a new tool called the Decision Aid Tool (DAT) to reduce pen-paper observational technique selection errors.* **Methods:** *This quasi-experiment before-after study was performed in three phases. In the first phase, the participants' skills in technique selection were examined by showing them twenty videos of different single-task jobs. In the second phase, the DAT was designed using pen-paper observational techniques. Finally, in the third phase, 115 occupational health specialists included in the study through purposive sampling of experts evaluated the tool's efficacy.* **Results:** *The results of the first phase showed that 62% of participants made an error in selecting the proper technique. The mean and standard deviation scores from the first and third phases were 11.4±6.59 and 39.01±1.89, respectively. The mean scores increased significantly after using DAT, and 97.5% of participants could correctly select task techniques.* **Conclusions:** *The efficacy of DAT was confirmed in a quasi-experimental before-and-after study. Using DAT increases the participants' ability to choose the correct technique. The DAT can be functional for practitioners to select the pen-paper observational techniques correctly under the purpose of assessment, the body areas, and the characteristics of the task to be assessed.*

1. Introduction

Ergonomic workplace assessment plays a crucial role in preventing and reducing the risk of work-related musculoskeletal disorders (WMSDs). Many tools identify and assess factors associated with the increased risk of WMSDs. These tools include direct, observational-based, and worker self-report methods, each with certain advantages and disadvantages [1-4]. Direct methods refer to those using sensors attached directly to the subject to measure certain variables. Electromyography

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(EMG) recording of muscle action, goniometers, optical scanning, sonic system, electromagnetic system, and accelerometer-based systems are the most used direct measurement methods. These methods are more accurate than observational and worker self-report methods. However, the problem lies in the high cost of these methods and the need for special equipment and skilled technical staff, which limit their use in the workplace. Worker self-report methods have low validity and reliability when ergonomic interventions are aimed in real work environments [3, 5, 6].

Observation-based methods are usually more straightforward for practitioners to implement and apply to a wide range of tasks at a relatively lower cost. These methods are better suited to the needs of practitioners, so they are currently considered the first and most common methods used by occupational safety and health (OSH) practitioners [1, 3, 5-7]. Many techniques used to assess the risk of WMSDs are based on direct observation of workers while performing their tasks. Each method has been developed for a specific purpose. The techniques differ depending on the characteristics of the task, body areas, and the risk factors that should be assessed. These differences make selecting and applying the methods challenging for practitioners [5, 6, 8]. Takala et al. reviewed thirty-two pen-paper observational techniques and concluded that, despite the large number available, none is perfect, nor could any of them cover all purposes [6].

The selection of a technique should be based on the purpose of risk assessment, characteristics of the task, body areas, and risk factors to be assessed. Therefore, despite the simplicity of pen-paper observational techniques, a certain level of knowledge and skill is required for their proper use. Otherwise, errors may occur in using these techniques, which can distort the risk assessment results [5-8]. A study that identified common mistakes in pen-paper observational techniques in twenty Spanish-speaking countries reported that practitioners made errors in 30.3% of their assessments [5]. Some studies have stated that practitioners rarely know about more than a minimal selection of ergonomics techniques. There are geographical differences between countries and continents using various ergonomic risk assessment methods [4, 6, 7, 9].

Two types of errors that may occur during ergonomic risk assessment and invalidate the reliability of the appraisal are technique selection errors and application errors. Errors in selecting the technique invalidate assessment reliability and indicate that the practitioner does not know how to choose the correct approach. The mistakes in ergonomic risk assessment arise from improper application of methods and lead to over- or under-estimate the risk. The method selection may be appropriate, but a lack of skill and knowledge of its rationale can lead to an improper risk assessment [5, 7].

When selecting a technique, the practitioner should consider its validity, reliability, applicability, strengths, and weaknesses [6]. Each pen-paper observational process has drawbacks, and no technique includes all the tasks. However, if the method is used correctly, it can play an essential role in a comprehensive ergonomics program [8]. Therefore, selecting the proper technique is a significant step in the risk management of musculoskeletal disorders in the workplace [5, 7, 10].

One of the factors that increase the error in technique selection is the frequent use of one or several limited techniques to assess all types of tasks [2, 3, 6]. Studies on the frequency of pen-paper observational methods in the United States, Canada, Iran, and twenty Spanish-speaking countries have shown that practitioners often use limited techniques to evaluate various tasks [1, 2, 7]. In a study by Tajvar et al., Iranian practitioners used only four methods in 68.4% of their assessments. Moreover, 53.3% of the practitioners' risk assessments were erroneous in the technique selection process [7]. Inadequate knowledge of practitioners about the types of ergonomic risk assessment techniques, the lack of a decision aid tool to choose the correct method, and the lack of serious supervision over the technique selection process have led practitioners to use a limited number of techniques to assess different tasks [1-3, 5].

This study aimed to develop a new tool called the Decision Aid Tool (DAT) to assist in the choice of the proper technique in the risk management of WMSDs, thereby reducing method selection errors and geographic differences between countries/continents. This new tool allows practitioners to select the proper pen-paper observational techniques based on the task type, the purpose of assessment, and the body areas to be assessed.

2. Methods

This study was conducted in three phases. (i) The participants' skills in selecting the correct pen-paper observational technique were examined in the first phase. (ii) In the second phase, DAT was designed, and in the third phase (iii), the efficacy of this new tool was evaluated. All participants participated voluntarily and signed a written informed consent form. This study received the approval code #IR.SUMS.REC.1399.858 from the ethics committee of Shiraz University of Medical Sciences.

2.1 First phase

The study's first phase aimed to assess participants' skills in selecting the correct pen-paper observational techniques. Initially, twenty videos of different single-task jobs were prepared purposefully in real work environments with the worker involved in work. In selecting these twenty videos, it was tried to cover all types of tasks, including agricultural, service-providing, industrial, and office tasks. For each video, a scenario was written highlighting the job, the purpose of the assessment, and the assessed body areas. Next, the participants were asked to watch each video, consider the scenario written for that video based on their knowledge and experience, and select the technique(s) that they found appropriate for assessing the risk of each task shown in each video. Each participant could choose one or more methods for each job displayed in the videos.

The research team, with three experienced ergonomists (more than ten years of experience in applying ergonomic risk assessment techniques), carefully reviewed the authentic scientific sources related to pen-paper observational methods. They finally considered these techniques' features, strengths, and weaknesses and then selected those that felt appropriate for each of the twenty videos. The choices made by the research team were used to assess the participants' skills in choosing the proper method. The participants were Iranian specialists in the field of occupational health with bachelor's degrees, selected through purposive sampling. After conducting the pilot study and considering 1.96 for $Z_{(1-\alpha/2)}$, 0.84 for $Z_{(1-\beta)}$, 3.7 for δ_d^2, and d^2=0.26, the sample size was determined to be 112. Inclusion criteria were as follows: (i) having at least one year of work experience, (ii) assessing ergonomic risk in the last six months, and (iii) participating in the first and third phases of the study. Those who did not participate in the two phases were excluded.

After preparing a list of eligible participants and providing them with the necessary information about the study's objectives, 152 participants agreed to participate. Among them, 16 participants were excluded due to failure to complete the checklist in the first phase, and 21 were later excluded because they did not meet the checklist requirements in the third phase. The remaining 115 occupational health specialists participated in the study. In the first phase, they were asked to select the technique(s) that they found appropriate for assessing the risk of each task shown in the videos and enter their selections into a checklist. The checklist was then compared with that completed by the research team. According to Table 1, each participant was given a score to indicate their skill in selecting the correct technique. Participants were given a score between 0 and 2, depending on how they chose the method to assess each task shown in the twenty videos. A wrong choice of the technique(s) is due to a conceptual error invalidating the assessment's reliability. These errors occurred when practitioners selected method(s) to assess the ergonomic risk of

Table 1. Classification of participants' scores in selecting pen-paper observational techniques.

Skill level classification	Score	Technique selection level
Good	2	The practitioner selected all the techniques correctly (absolutely correct).
Intermediate	1	The participant selected only some of the techniques correctly (relatively correct).
Weak	0	The participant selected the technique incorrectly (incorrect).

a task without considering its limitations and applicability, i.e. when the chosen method is designed for evaluating another risk factor or body area. For example, using the NIOSH lifting equation to assess pushing/pulling tasks or using the strain index technique to assess the whole body is wrong [2, 3]. Each participant's score ranged between 0 and 40 for 20 tasks. Finally, the scores were converted into percentages, and the ability of each participant to select the proper technique was classified into four levels: very weak (0-24%), weak (25-49.9%), good (50-74.9%), and very good (75-100%).

2.2 Second phase

The purpose of the second phase was to develop a new tool to help practitioners to select pen-paper observational techniques. Accordingly, the research team examined the features, strengths, and limitations of various pen-paper observational methods from authoritative scientific sources. It then developed DAT according to the characteristics of each technique [5-8, 11-17]. This tool was designed so a practitioner can find a suitable method(s) by answering a few questions. The practitioners are first asked to determine the type of job to be assessed. They should perform a job analysis before the technique selection process. When the task is set, specific questions should be answered about the purpose of assessment, the body areas, and how the task is to be performed.

The classification of tasks includes MMH, non-MMH, and special-purpose tasks. Depending on how they are performed, MMH tasks are divided into three categories, including lifting/lowering, carrying, and pushing/pulling loads. The variability of lift task characteristics during manual lifting jobs makes it hard to assess the risk of WMSDs. Therefore, for lifting tasks, four types of sub-tasks are defined: single, composite, variable, and sequential tasks. Once the sub-task type is specified, the practitioner can select the appropriate technique. Single-task manual lifting corresponds to lifting only once or when there is no significant variance from lift to lift. In composite tasks, the type and weight of loads are the same, but the load is lifted in different dimensions. In variable tasks, lifting and lowering the load are associated with a change in the load weight and horizontal distance and vertical height. Sequential manual lifting involves tasks in which a worker rotates between a set of single, composite, and variable lifting tasks. Moreover, the worker rotates between different workstations during shifts [5, 6, 8-10, 18-20].

For non-MMH tasks, depending on the purpose of assessment and the assessed body areas, practitioners can select the appropriate technique(s). Recently, certain techniques have been developed to evaluate the ergonomics of some jobs or tasks, such as computer work, assembly, patient transportation, and agriculture, defined in this study as special-purpose techniques; we tried to use these techniques in the development of DAT. [21-24].

2.3 Third phase

The purpose of the third phase was to evaluate the efficacy of DAT. This study phase was performed three months after the completion of the first phase with the same participants. In this phase, participants were first instructed on selecting a technique using DAT. They were then asked to re-perform the technique selection for the same twenty tasks in the first phase using DAT. Finally, the checklist completed in this phase was scored according to Table 1. For the twenty studied tasks, the score ranged between 0 and 40. Then, the scores were converted into percentages, and the ability of participants to select appropriate techniques was expressed in the following four levels: very weak (0-24.99%), weak (25-49.99%), good (50-74.99%), and very good (75-100%). Finally, to evaluate the efficacy of the new tool, the average technique selection scores in the first phase (before using DAT) and the third phase of the study (after applying DAT) were compared. Figure 1 summarizes the steps involved in each phase of the study.

2.4 Statistical analysis

To evaluate the efficacy of DAT, a paired-samples T-test was used. For this purpose, the data's normality was first tested using the quantile-quantile (QQ) plot diagram and Kolmogorov-Smirnov statistical test. Then, the mean scores obtained from the

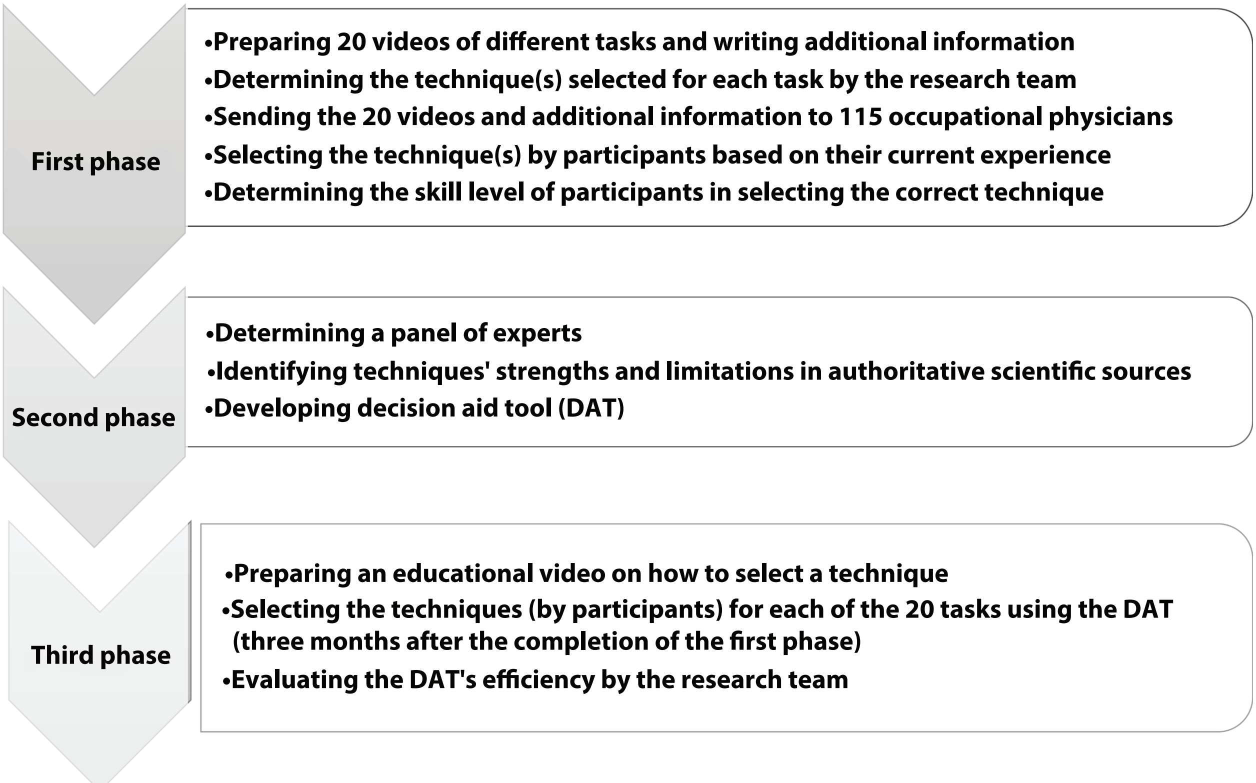

Figure 1. Summary of the steps in each phase of the study.

Table 2. Demographic details of participants (N=115).

Demographic characteristic	Category	Frequency	Percent
Gender	Male	48	41.7
	Female	67	58.3
Age (year)	30≥	51	44.3
	31≤	64	55.7
Work experience (year)	1-5	54	47
	6-10	32	27.8
	11≤	29	25.2

technique selection process were compared before and after applying DAT. All statistical analyses were performed using SPSS version 20.

3. Results

3.1 First phase

A total of 115 OSH specialists with an average age of 33.1±4.83 years participated in this study. Demographic details of the participants are summarized in Table 2.

Comparing the techniques selected by participants in the first phase and those chosen by the research team showed that only 19% of the participants could select the correct methods for all tasks demonstrated in the videos. Moreover, 62% of the participants chose the techniques incorrectly, and 19% identified only some of them correctly (considered relatively correct). The mean and standard deviation scores obtained from the first phase were 11.4±6.59. The maximum score that a participant could earn was 40.

After assessing the participants' skills in selecting the technique, it was found that 48.7% of the participants had a very weak level of skill; 33.9% had a weak level of skill; 12.2% had a good level, and only 5.2% had a very good level of skill. Table 3 shows the selection status of pen-paper observational techniques for twenty tasks presented in videos before applying DAT.

3.2 Second phase

Pen-paper observational techniques' characteristics, strengths, and limitations were carefully studied, twenty-eight techniques were chosen, and DAT was developed (see Figure S1). This tool was designed to help practitioners select the correct methods by specifying the type of task, the purpose of assessment, and the body areas to be assessed. Table S2 summarizes the selection criteria and limitations of the pen-paper observational techniques used in this study. In developing DAT, attempts were made to cover all types of tasks. First, tasks were divided into three general categories: MMH tasks, jobs with specific techniques (special purpose tasks), and non-MMH tasks. This tool assessed the body areas of the upper limbs (fingers, wrists, forearms, elbows, shoulders, arms, and neck), waist, and lower limbs.

Table 3. Pen-paper observational techniques for twenty tasks presented in videos before and after applying DAT: MAW = Maximum Acceptable Weight.

		Selection status of techniques					
		Before (%)			After (%)		
Video #	Purpose of assessment	Incorrect	Relatively correct	Correct	Incorrect	Relatively correct	Correct
#1	MAW for MMH-single task	73.9%	24.3%	1.7%	21.7	-	78.3
#2	MAW for pushing/pulling	80%	18.3%	1.7%	-	-	100
#3	MAW for handling with both hands	79.1	20	0.9	-	-	100
#4	MAW, for handling with on one hand	89.6	9.6	0.9	-	-	100
#5	MAW for lifting with 2 or more people	93	6.1	0.9	-	-	100
#6	Carrying patient	60	-	40	-	-	100
#7	MWA for MMH-composite tasks	73	20	7	13.9	-	86.1
#8	MAW for MMH-variable tasks	77.4	17.4	5.2	14.8	-	85.2
#9	Assessment of whole body for MMH	46.1	53	0.9	-	-	100
#10	Screening lifting tasks by 2 or more	79.1	-	20.9	-	-	100
#11	Assessment of wrist in repetitive tasks	52.2	26.1	21.7	-	-	100
#12	Assessment of hand activity and peak force	67	-	33	-	-	100
#13	Assessment of repetitive movements of upper extremities	50.4	-	49.6	-	-	100
#14	Assessment of upper limb repetitive actions	53.9	27	19.1	-	-	100
#15	Screening pushing/pulling tasks	83.5	-	16.5	-	-	100
#16	Assessment of a single body side	5.2	17.4	77.4	-	-	100
#17	Assessment of lower limb	27	73	-	-	-	100
#18	Assessment of Computer work	16.5	-	83.5	-	-	100
#19	Assessment of Agricultural work	100	-	-	-	-	100
#20	General assessment of whole body	33	67	-	-	-	100

Table 4. Comparison between the mean scores of technique selection obtained before and after using DAT.

Phase of study	Mean	Std. Deviation	Mean Difference	95% CI of Mean Lower	95% CI of Mean Upper	t statistics	p-value
Before	11.40	6.59	27.60	26.49	28.72	48.98	<0.001
After	39.01	1.89					

Note: Paired samples T-test was used to evaluate the efficacy of DAT.

After determining the type of task, the practitioner should specify the purpose of the assessment; e.g., for jobs involving MMH, the practitioner should specify whether the purpose of the evaluation is to determine the maximum acceptable weight, screen MMH tasks, or assess the whole body. If the objective was to determine the maximum allowable weight or to screen MMH tasks, then it was necessary to specify how to handle the load manually by lifting/lowering, carrying, and pushing/pulling the load. Concerning non-MMH tasks, the practitioner could select the appropriate technique after determining the purpose and the body areas to be evaluated. If the job to be considered was defined as non-MMH, and the objective was to assess the upper limb, then the practitioner must specify the upper limb segment.

In assessing the whole body, the practitioner should select the type of technique according to the purpose of the assessment. If the aim is to evaluate the left and right sides of the body separately, the methods developed for this purpose should be used (e.g., RULA and REBA). RULA/REBA assess the upper/entire body providing a final RULA/REBA score (an overall risk level). However, if there is a significant difference between the two sides, two separate assessments could be appropriate [25, 26]. Accordingly, other techniques (e.g., OWAS or WERA) should be used instead [25-28]. There are particular techniques for assessing ergonomic risk in some tasks or jobs, such as agriculture, patient transportation, and work with computers, which are defined in this study as special-purpose techniques. There are many such techniques, and we have mentioned only three of them in the design of DAT. (Figure S1).

3.3 Third phase

The mean and standard deviation of the scores obtained after the third phase were 39.01±1.89. A comparison of methods by participants in the third phase with those selected by the research team showed that 97.5% of the participants who used DAT correctly identified the technique(s) for the twenty studied tasks. Only 2.5% of participants in the third phase made an error selecting the method for lifting jobs. Table 3 shows the selection status of pen-paper observational techniques for twenty tasks presented in videos after applying DAT.

The results showed a statistically significant difference between the technique selection scores obtained before and after applying DAT. The mean score increased by 27.6 after the participants used DAT in selecting the technique (Table 4).

4. Discussion

This study was designed to develop a new DAT tool to reduce errors in selecting pen-paper observational techniques. This study was conducted in three phases. The purpose of the first phase was to assess the participants' skills in selecting pen-paper observational methods. The second phase aimed to develop DAT, and the purpose of the third phase was to evaluate the efficacy of DAT.

The results of the first phase showed that 62% of participants made an error in selecting the correct technique for twenty tasks presented in the studied videos. These results are consistent with a previous study by Tajvar et al., who showed that a high percentage of Iranian practitioners (53.3%) made an error in selecting the correct technique [7]. Moreover, it was found that the skill level of 48.7% of participants was very weak, and that of 33.9% of them was weak. Although all participants had a bachelor's degree in occupational health and more than one year of experience in applying ergonomic risk assessment techniques, most did not have sufficient knowledge and skill to select the correct method.

Most practitioners are familiar with a few techniques but don't know the new ones [6]. The frequency of applying pen-paper observational methods in the United States, Canada, Iran, and twenty Spanish-speaking countries has also shown that practitioners often use a limited number of techniques to assess various tasks [1, 2, 7].

There are several reasons for this information gap, e.g. language limitations [5-7]. Ergonomic risk assessment techniques are usually presented in English in scientific journals and media. Most non-English practitioners with low English proficiency have difficulty accurately translating or understanding these techniques [6, 7]. Therefore, if the practitioners' performance is not closely monitored, they may prefer to use the same limited number of methods they have already learned to assess various tasks [7].

Each technique has its limitations and is designed for specific purposes, and its use for assessing all types of tasks is inappropriate and can lead to selection error [6]. Tajvar et al. reported that 53.3% of risk assessments performed by Iranian practitioners were based on wrong techniques because critical factors, such as the assessment's purpose, the task type, and the body parts to be assessed, had been overlooked. These practitioners used only four techniques in 68.4% of their assessments [7]. It is suggested to plan the translation, dissemination, and training for non-English speaking countries to update practitioners' information.

There is a need to ensure practitioners have enough knowledge and skill in pen-paper observational techniques. Updating scientific resources, modifying the educational curriculum, creating stricter regulations regarding the qualification of practitioners and monitoring their performance, and purposefully holding retraining workshops are some of the measures that can increase the knowledge and skills of the practitioners. As suggested by David, practitioners would benefit from developing a decision aid tool that would allow them to make an informed selection [1]. Therefore, the research team concluded that perhaps a Decision Aid Tool could help the practitioners to select appropriate technique(s) according to the objectives of the assessment, body areas, and the type of task to be assessed. With such a tool, it can be expected that the possibility of error in the choice of technique will be significantly reduced, and occupational health and safety inspectors can monitor the performance of the practitioners better and more accurately.

The second phase aimed to develop a new Decision Aid Tool to reduce practitioners' errors in selecting pen-paper observational techniques. In this regard, the research team carefully examined the features, strengths, and limitations of various pen-paper observational methods in authoritative scientific sources. This tool is designed so that practitioners can select appropriate techniques by answering a few specific questions.

Evaluating the tool's efficacy showed a significant difference between the technique selection mean scores before and after applying DAT; the mean scores increased significantly after using DAT. It can be concluded that using DAT increases the participants' ability to select the correct technique(s). Because the technique selection in DAT was based on specific instructions, the error probability of technique selection was significantly reduced, and the risk assessment results were more reliable.

The results of the third phase showed that 97.5% of participants were able to correctly select the techniques for the tasks shown in the videos after using DAT. However, in the first phase, only 19% of participants could choose the correct methods. Among participants in the third phase, only 2.5% made errors in technique selection, corresponding to the choice of the proper technique for lifting tasks. To assess the maximum acceptable weight in load lifting, the practitioner must first identify the type of lifting task, which includes simple, complex, variable, and sequential tasks. If the practitioner fails to correctly recognize the lifting task type, a technique selection error may occur. Therefore, the main reason for making errors can be the participants' inability to distinguish tasks.

4.1 Limitations of the study

According to the study's objectives in the development of DAT, twenty-eight pen-paper observational techniques that existed in Persian sources or have been used by Iranian researchers were used. Many other methods may be used in different countries and can be included in this tool. They can be added to this tool, but due to the unfamiliarity of Iranian practitioners with them, we could not use them in this study. In addition, newer and more up-to-date techniques may emerge over time. Therefore, this tool presents only a few of many pen-paper observational methods and will need to be updated.

5. Conclusion

The high error rate of practitioners in selecting ergonomic risk assessment techniques is a matter of concern. The present study aimed to design a new Decision Aid Tool (DAT) to reduce the error rate in technique selection. In this tool, twenty-eight pen-paper observational techniques that have been published in authentic scientific sources were used. The efficacy of DAT was confirmed in a quasi-experimental before-and-after study. Therefore, DAT can be instrumental in choosing the pen-paper observational techniques per the purpose of assessment, body areas, and characteristics of the task to be assessed. Furthermore, this new tool can also reduce geographic differences between countries/continents in pen-paper observational techniques.

Supplementary Materials: Figure S1: Decision aid tool, Table S1: Abbreviation for pen-paper observation techniques with their expanded names and Table S2: the selection criteria and limitations of the pen-paper observational methods.

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Informed Consent Statement: All participants participate voluntarily and sign a written informed consent form.

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References

1. David GC. Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occup Med.* 2005;55(3):190-9. Doi: https://doi:10.1093/occmed/kqi082
2. Diego-Mas JA, Poveda-Bautista R, Garzon-Leal DC. Influences on the use of observational methods by practitioners when identifying risk factors in physical work. *Ergonomics.* 2015;58(10):1660-70. Doi: https://doi.org/10.1080/00140139.2015.1023851
3. Lowe BD, Weir PL, Andrews DM. NIOSH, National Institute Occupational Safety and Health. (2014). Observation-based posture assessment: review of current practice and recommendations for improvement. Publication No. 2014–131. Available on line at: https://stacks.cdc.gov/view/cdc/24085
4. Lowe BD, Dempsey PG, Jones EM. Ergonomics assessment methods used by ergonomics professionals. *Appl Ergon.* 2019;81(102882. Doi: https://doi.org/10.1016/j.apergo.2019.102882
5. Diego-Mas JA, Alcaide-Marzal J, Poveda-Bautista R. Errors using observational methods for ergonomics assessment in real practice. *Hum Factors.* 2017;59(8):1173-87. Doi: https://doi.org/10.1177%2F0018720817723496
6. Takala EP, Pehkonen I, Forsman M, et al. Systematic evaluation of observational methods assessing biomechanical exposures at work. *Scand J Work Environ Health.*2010;3-24.
7. Tajvar A, Daneshmandi H, Dortaj E, et al. Common errors in selecting and implementing pen-paper observational methods by Iranian practitioners for assessing work-related musculoskeletal disorders risk: a systematic review. *Int J Occup Saf Ergon* . 2021;1-7. Doi: https://doi.org/10.1080/10803548.2021.1905993
8. Roman-Liu D. Comparison of concepts in easy-to-use methods for MSD risk assessment. *Appl Ergon* .2014;45(3):420-7. Doi: https://doi.org/10.1016/j.apergo.2013.05.010
9. Pascual SA, Naqvi S. An investigation of ergonomics analysis tools used in industry in the identification of

work-related musculoskeletal disorders. *Int J Occup Saf Ergon.* 2008;14(2):237-45. Doi: https://doi.org/10.1080/10803548.2008.11076755
10. Choobineh A, Rahimifard H, Jahangiri M, Mahmoodkhani S. Musculoskeletal injuries and their associated risk factors in office workplaces. *Iran Occup Health.* 2012; 8(4):70-81
11. Andreas G-WJ, Johanssons E. Observational methods for assessing ergonomic risks for work-related musculoskeletal disorders. A scoping review. *Rev Cienc Salud.* 2018;16(SPE):8-38.
12. Colombini D, Occhipinti E, Alvarez-Casado E, Waters TR. Manual lifting: A guide to the study of simple and complex lifting tasks, CRC Press, 2012.
13. Kadikon Y, Rahman MNA. Manual material handling risk assessment tool for assessing exposure to. *J Eng Appl Sci.* 2016;100(10):2226-32.
14. Karwowski W: International Encyclopedia of Ergonomics and Human Factors, -3 Volume Set, CRC Press, 2006.
15. Karwowski W, Szopa A, Soares MM. Handbook of standards and guidelines in human factors and ergonomics, CRC Press, 2021.
16. Stanton NA, Hedge A, Brookhuis K, Salas E, Hendrick HW. Handbook of human factors and ergonomics methods, CRC Press, 2004.
17. Chiasson MÈ, Imbeau D, Aubry K, Delisle A. Comparing the results of eight methods used to evaluate risk factors associated with musculoskeletal disorders. *Int J Ind Ergon.* 2012;42(5):478-88.
18. Dempsey PG, McGorry RW, Maynard WS. A survey of tools and methods used by certified professional ergonomists. *Appl Ergon.* 2005;36(4):489-503. Doi: https://doi.org/10.1016/j.apergo.2005.01.007
19. Marras WS. Fundamentals and assessment tools for occupational ergonomics, CRC Press, 2006.
20. Waters T, Lu ML, Occhipinti E. New procedure for assessing sequential manual lifting jobs using the revised NIOSH lifting equation. *Ergonomics.*2007;50(11):1761-70. Doi: https://doi.org/10.1080/00140130701674364
21. Battevi N, Menoni O, Ricci MG, Cairoli S. MAPO index for risk assessment of patient manual handling in hospital wards: a validation study. *Ergonomics.* 2006; 49(7):671-87. Doi: https://doi.org/10.1080/00140130600581041
22. Kong YK, Lee SJ, Lee KS, Kim GR, Kim DM. Development of an ergonomics checklist for investigation of work-related whole-body disorders in farming–AWBA: Agricultural whole-body assessment. *J Agric Saf Health.* 2015;21(4):207-15. Doi: https://doi:10.13031/jash.21.10647
23. Schaub K, Caragnano G, Britzke B, Bruder R. The European assembly worksheet. *Theor Issues Ergon Sci.* 2013;14(6):616-39. Doi: https://doi.org/10.1080/1463922X.2012.678283
24. Sonne M, Villalta DL, Andrews DM. Development and evaluation of an office ergonomic risk checklist: ROSA–Rapid office strain assessment. *Appl Ergon.* 2012; 43(1):98-108. Doi: https://doi.org/10.1016/j.apergo.2011.03.008
25. Hignett S, McAtamney L. Rapid entire body assessment (REBA). *Appl Ergon.*2000;31(2):201-5. Doi: https://doi.org/10.1016/S0003-6870(99)00039-3
26. McAtamney L, Corlett EN. RULA: a survey method for the investigation of work-related upper limb disorders. *Appl Ergon.*1993;24(2):91-9. Doi: https://doi.org/10.1016/0003-6870(93)90080-S
27. Karhu O, Härkönen R, Sorvali P, Vepsäläinen P. Observing working postures in industry: Examples of OWAS application. *Appl Ergon.*1981;12(1):13-7. Doi: https://doi.org/10.1016/0003-6870(81)90088-0
28. Abd Rahman MN, RANI MRA, Rohani JM. WERA: an observational tool develop to investigate the physical risk factor associated with WMSDs. *J Hum Ergol.* 2011;40(1_2):19-36. Doi: https://doi.org/10.11183/jhe.40.19

Original article

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Appendix A-FigureS1:

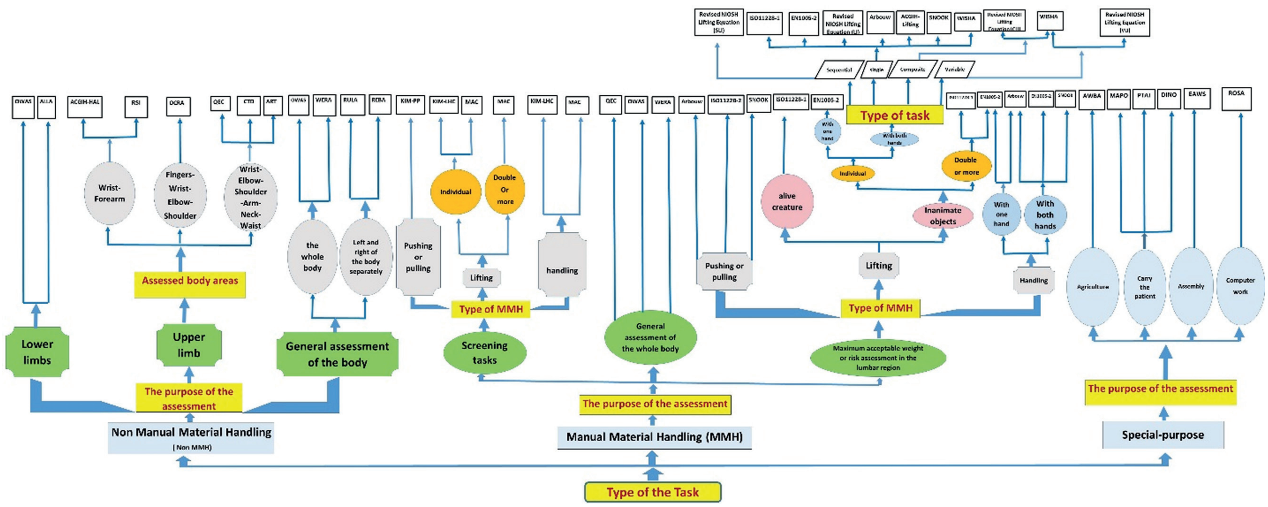

Figure S1: Decision Aid Tool.

ACGIH-HAL: American conference of governmental industrial hygienists-Hand activity level, ART: Assessment of repetitive tasks of the upper limbs, QEC: Quick exposure check, OWAS: Ovake working posture analyzing system, KIM-PP: Key indicator method for pulling and pushing, KIM-LHC: Key indicator method for lifting, holding and carrying, MAC: Manual handling assessment charts, DINO: Direct nurse observation, MAPO: Movement and assistance of hospital patient, Revised NIOSH Equation(CLI): Revised National institute for occupational safety and health lifting equation(Composite Lifting Index), Revised NIOSH Equation(VLI): Revised National institute for occupational safety and health lifting, equation (Variable Lifting Index), Revised NIOSH Equation(SLI): Revised National institute for occupational safety and health lifting equation(Sequential Lifting Index), CTD: Cumulative trauma disorder risk assessment model for the upper extremities, OCRA: Occupational repetitive action index, PTAI: Patient transfer assessment instrument, REBA: Rapid entire body assessment, ROSA: Rapid office strain assessment, RULA: Rapid upper limb assessment, WERA: Workplace ergonomic risk assessment, WISHA: Washington industrial safety and health act lifting analysis, ALLA: Agricultural lower limb assessment, AWBA: Agricultural Whole-Body Assessment, ACGIH-Lifting TLV: American conference of governmental industrial hygienists lifting threshold limit values, EAWS: Ergonomic assessment worksheet, EN 1005-2: European Standard 1005-2, ISO 11228-1: International Organization for Standardization 11228-1, ISO 11228-2: International Organization for Standardization 11228-2, RSI: Revised Strain Index.

Appendix B-Table S1

Table S1: Abbreviation for pen-paper observation techniques with their expanded names.

#	Abbreviation	Expanded name	Reference
1	ACGIH-HAL	American conference of governmental industrial hygienists-Hand activity level	American Conference of Governmental Industrial Hygienists (ACGIH). TLVs and BEIs. Cincinnati: American Conference of Governmental Industrial Hygienists; 2000.
2	ART	Assessment of repetitive tasks of the upper limbs	Ferreira J, Grey M, Hunter L, Birtles M, Riley D. (2009). Development of an assessment tool for repetitive tasks of the upper limbs (ART). UK: Health & Safety Executive.
3	QEC	Quick exposure check	David G, Woods V, Li G, Buckle P. The development of the Quick Exposure Check (QEC) for assessing exposure to risk factors for work-related musculoskeletal disorders. *Appl Ergon*. 2008;39 (1), 57-69.
4	OWAS	Ovake working posture analyzing system	Karhu O, Kansi P, Kuorinka I. Correcting working postures in industry: a practical method for analysis. *Appl Ergon*. 1977;8 (4), 199-201.
5	KIM-PP/KIM-LHC	Key indicator method for pulling and pushing/Key indicator method for lifting, holding and carrying	Steinberg U. New tools in Germany: development and appliance of the first two KIM (lifting, holding and carrying, pulling and pushing) and practical use of these methods. *Work*. 2012; 41(Supplement 1),3990-3996.
6	SNOOK	Liberty Mutual Manual Materials Handling Tables	Snook SH, Ciriello VM. The design of manual handling tasks: revised tables of maximum acceptable weights and forces. *Ergonomics*. 1991;34(9), 1197-1213.
7	MAC	Manual handling assessment charts	Tapley SE. Reliability of manual handling assessment charts (MAC) developed for health and safety inspectors in the UK: A field study. *HSE*. 2002;UK.
8	DINO	Direct nurse observation	Johnsson C, Kjellberg K, Kjellberg A, Lagerström M. A direct observation instrument for assessing patient transfer technique (DINO). *Appl Ergon*. 2004;35(6),591-601.
9	MAPO	Movement and assistance of hospital patient	Battevi N, Menoni O, Ricci MG, Cairoli S. MAPO index for risk assessment of patient manual handling in hospital wards: a validation study. *Ergonomics*. 2006;49(7),671-687.
10	Revised NIOSH Equation(CLI)	Revised national institute for occupational safety and health lifting equation (Composite Lifting Index)	Waters TR, Putz-Anderson V, Garg A, Fine LJ. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*. (1993);36(7):749-776.
11	Revised NIOSH Equation(VLI)	Revised national institute for occupational safety and health lifting equation (Variable Lifting Index)	Waters T, Occhipinti E, Colombini D, Alvarez-Casado E, Fox R. Variable Lifting Index (VLI) A New Method for Evaluating Variable Lifting Tasks. *Hum Factors*. 2016;58(5),695-711.

Table S1 (*Continued*)

#	Abbreviation	Expanded name	Reference
12	Revised NIOSH Equation(SLI)	Revised national institute for occupational safety and health lifting equation (Sequential Lifting Index)	Waters T, Lu ML, Occhipinti E. New procedure for assessing sequential manual lifting jobs using the revised NIOSH lifting equation. *Ergonomics*. 2007;50(11), 1761-1770.
13	CTD	Cumulative trauma disorder risk assessment model for the upper extremities	Seth V, Weston RL, Freivalds A. Development of a cumulative trauma disorder risk assessment model for the upper extremities. *Int J Ind Ergon*. 1999;23(4), 281-291.
14	OCRA	Occupational repetitive action index	Occhipinti E. OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. *Ergonomics*. 1998;41(9),1290-1311.
15	PTAI	Patient transfer assessment instrument	Karhula K, Rönnholm T, Sjögren T. A method for evaluating the load of patient transfers. Occupational Safety and Health Administration. Occupational safety and health publications, 2009;83.
16	REBA	Rapid entire body assessment	Hignett S, McAtamney L. Rapid entire body assessment (REBA). *Appl Ergon*. 2000;31(2),201-205.
17	ROSA	Rapid office strain assessment	Sonne M, Villalta DL, Andrews DM. Development and evaluation of an office ergonomic risk checklist: ROSA-Rapid office strain assessment. *Appl Ergon*, 2012;43(1),98-108.
18	RULA	Rapid upper limb assessment	McAtamney L, Corlett EN. RULA: a survey method for the investigation of workrelated upper limb disorders. *Appl Ergon*. 1993;24(2),91-99.
19	WERA	Workplace ergonomic risk assessment	Rahman MNA, Rani MRA, Rohani JM. WERA: an observational tool develop to investigate the physical risk factor associated with WMSDs. *J Hum Ergol.* 2011;40(1_2),19-36.
20	Arbouw	The Arbouw guidelines	Karwowski W. International Encyclopedia of Ergonomics and Human Factors, 3 Volume Set, CRC, Press, 2006,1471-1484.
21	ALLA	Agricultural lower limb assessment	Kong YK, Lee SY, Lee KS, Kim DM. Comparisons of ergonomic evaluation tools (ALLA, RULA, REBA and OWAS) for farm work. *Int J Occup Saf Ergon* 2018;24(2), 218-223.
22	AWBA	Agricultural whole-body assessment	Kong YK, Lee SJ, Lee KS, Kim GR, Kim DM. Development of an ergonomics checklist for investigation of work-related whole-body disorders in farming-AWBA: Agricultural whole-body assessment. *J Agric Saf Health*. 2015;21(4),207-215.
23	ACGIH-Lifting TLV	American conference of governmental industrial hygienists lifting threshold limit values	American Conference of Governmental Industrial Hygienists (ACGIH) (2004), Threshold Limit Values for Chemical Substances and Physical Agents & Bioloigical Exposure Indices, Cincinnati, OH.
24	EAWS	Ergonomic assessment worksheet	Schaub K, Caragnano G, Britzke B, Bruder R. The European assembly worksheet. *Theor Issues Ergon Sci*. 2013;14(6),616-639.

Table S1 (*Continued*)

#	Abbreviation	Expanded name	Reference
25	EN 1005-2	European Standard 1005-2	Colombini D, Occhipinti E, Alvarez-Casado E, Waters TR. Manual lifting: A guide to the study of simple and complex lifting tasks, CRC Press, 2012.
26	ISO 11228-1	International Organization for Standardization 11228-1	ISO. 2003. ISO 11228-1. Ergonomics-Manual handling-Lifting and carrying.
27	ISO 11228-2	International Organization for Standardization 11228-2	ISO. 2007a. ISO 11228-2. Ergonomics-Manual handling-Pushing and pulling.
28	RSI	Revised Strain Index	Arun Garg J, Moore S, Kapellusch JM. The Revised Strain Index: an improved upper extremity exposure assessment model. *Ergonomics*. 2017;60 (7), 912-922.

Appendix C-Table S2:

Table S2: The selection criteria and limitations of the pen-paper observational techniques.

	Selection criteria			
Technique	**Types of job/task**	**The purpose of the assessment**	**Body parts assessed**	**Limitations of the technique**
ACGIH-HAL	Tasks that involve the same, or very similar repetitive hand, wrist, or forearm exertions	to determine unacceptable levels of hand activity and force	Wrist-forearm	Only consider repetition and force applied to monotonous handwork performed for four or more hours per day.
ART	Repetitive tasks	To assess tasks that require repetitive moving of the upper limbs	Neck, lower back, and upper limb	Does not consider the lower limb. it is not intended for display screen equipment (DSE) assessments.
QEC	A wide range of tasks	to quickly assess exposure to WMSD risks for a wide range of tasks	Wrist-elbow-shoulder-arm-neck-waist	Not suitable when tasks are highly varied. The method only allows for looking at the worst possible work positions for each body part involved in a task. Does not consider the lower limb.
OWAS	A wide range of tasks	To assess stressful work postures	The whole body and lower limb	Does not separate right and lift upper extremities.posture coding crude for shoulders. does not consider repetition or duration of the sequential postures. assessments of neck and elbows/wrist are missing.
KIM-PP	Pushing or pulling load	Risk assessment of physical workload in pushing or pulling a load on the screening level	Trunk	Only suitable for screening pushing/pulling tasks. it provides a general risk level but cannot predict workers' injuries.
KIM-LHC	Lifting, holding or carrying a load	Risk assessment of physical workload in lifting, holding or carrying a load on the screening level	Trunk	Only suitable for screening lifting, holding, or carrying tasks and provides a general level of risk, but it cannot predict injuries to workers.
MAC	Lifting (and lowering), carrying, and team handling a load	To aid occupational health and safety inspectors assess the most common risk factors in lifting (and lowering), carrying, and team handling operations.	Back	Is not appropriate for tasks that involve pushing/pulling and is not designed to assess risks associated with workplace upper limb disorders.
DINO	Patient transfer tasks	To assess the work technique of nursing personnel during patient transfers	Back and shoulders	Only applicable for the risk assessment of patient manual handling in hospital yards. Non-applicability in some hospital wards e.g. resuscitation and psychiatry. It neglects all the other risk determinants (frequency, environment, work organization, etc.)

Table S2 (*Continued*)

Technique	Selection criteria: Types of job/task	Selection criteria: The purpose of the assessment	Selection criteria: Body parts assessed	Limitations of the technique
MAPO	Patient manual handling	To assess the risk exposure level of patient manual handling in hospital wards	Low back	Only applicable for the risk assessment of patient manual handling in hospital yards. variables such as psychosocial factors and overtime hours are not included in the risk assessment of patient manual handling.
Revised NIOSH Equation(CLI)	Lifting/ lowering load(single-task)	To determine the recommended weight limit of a load base on lifting/ lowering characteristics and to estimate the relative magnitude of physical stress for a task or a job	Low back	This technique cannot be used for: one-handed lifting/lowering, lifting/ lowering tasks that are done for more than eight hours, lifting/lowering while seated or kneeling, lifting/lowering in restricted workspaces, lifting/lowering of unstable objects, people, or animals, carrying/pushing/pulling tasks (including use of a wheelbarrow or shovel), lifting/ lowering on slippery surfaces, lifting/ lowering in unfavorable environments and Lifting/lowering with high speed motion (faster than about 30 inches/ second).
Revised NIOSH Equation(VLI)	Lifting/ lowering load(variable-tasks)			
Revised NIOSH Equation(SLI)	Lifting/ lowering load(sequential-tasks)			
CTD	Industrial jobs based on task and hand motion parameters	To predict CTD incidence rates or a relative risk potential for the upper extremities.	Wrist-elbow-shoulder-arm-neck-waist	Is not applicable for jobs with cycle times under four seconds.
OCRA	Tasks that involve repetitive movements of the upper limbs	To identify a procedure for calculating a concise index of exposure to the risks of WMSDs associated with repetitive movements of the upper limbs.	Fingers, wrist-elbow-shoulder	The use is time-consuming. Well-trained observers needed.
PTAI	Patient transfers	To evaluate the load of patient transfers	Upper limb, trunk, lower back, and lower limb	Only applicable for evaluating the load of patient transfers in the healthcare sector.
REBA	Tasks that involve the types of unpredictable working postures found in health care and other service industries.	To quick postural analysis for whole-body activities, both static and dynamic.	The whole body	The right and left hands have to be assessed separately and there is no method to combine this data, duration, and frequency of items not included. This method is not recommended for assessing tasks that are primarily manual material handling tasks. The method is not suitable for assessing jobs that involve a number of different and varying tasks.

Table S2 (*Continued*)

Technique	Selection criteria: Types of job/task	The purpose of the assessment	Body parts assessed	Limitations of the technique
ROSA	Computer work	To quickly quantify risks associated with computer work and to establish an action level for change based on reports of worker discomfort.	The whole body	Only applicable for computer work in the office environment.
Arbouw	Lifting and carrying, pushing /pulling, static postures, and repetitive work	To develop guideline instrument for assessing physical workload	Lower back	Relative time-consuming but does not give very detailed information.
RULA	Tasks where the worker uses primarily the upper limbs to complete the task.	To provide a method of screening a working population quickly, for exposure to a likely risk of work-related upper limb disorders.	Upper limb /the whole body	The right and left hands have to be assessed separately and there is no method to combine this data. Does not consider the duration of exposure. It is appropriate for tasks that typically, the worker is seated or standing without much movement when performing the task.
WERA	The wide range of job/task	To assess the physical risk factors associated with work-related musculoskeletal disorders	The whole body	As with most techniques, do not consider psychosocial factors and the interaction of the risk factors.
SNOOK	Lifting, Lowering, Pushing, Pulling, Carrying tasks	To provide guidelines for predicting the maximum weights and workloads that are acceptable to different percentages of the male and female industrial population.	Low back	Does not consider any trunk rotation/ twisting that may take place while performing the task. This method is not suitable for use when the task involves one-handed lifting, lowering, carrying, pushing, or pulling. The method is also not useful for tasks that involve throwing or catching objects.
ALLA	Tasks that involve the types of postures for farm work	To assess lower limb postures for farm work	Lower limb	Only applicable for the risk assessment of the lower limb. As with most techniques do not consider psychosocial factors and the interaction of the risk factors.
AWBA	Agriculture	To assess various postures in agricultural work	The whole body	Only applicable for the risk assessment of agricultural work. Does not consider psychosocial factors and the interaction of the risk factors.

Table S2 (*Continued*)

	Selection criteria			
Technique	Types of job/task	The purpose of the assessment	Body parts assessed	Limitations of the technique
ACGIH-Lifting TLV	Tasks that involve Lifting /lowering a load	To provide guidance on acceptable weight limits for lifting tasks.	Low back	This technique is not applicable for use with other material handling tasks such as carrying, pushing, and/or pulling and should not be used if any of the following is true: - the trunk/twists rotate more than 30 degrees to either side; - more than 360 lifts per hour are required; - lifting is done for more than eight hours a day; - a constrained body posture is used when lifting (kneeling, restricted head room, seated, crouching); - one-handed lifting is required; - lifting is done in high heat and/or humidity; - the objects being lifted are unstable (containers with shifting center of mass, people, animals); - the object being lifted has poor hand holds or grasping points; - theworkers" footing is unstable (slippery floor, unstable ground/or surface).
EAWS	Assembly tasks	To assess physical workload in cyclic work	The whole body	Cannot be used for ergonomic job rotation planning as the sequence and the load characteristic of the tasks (e.g. aggravation of fatigue or recovery aspects) are not considered. The application is complex and requires intensive training.
EN 1005-2	Tasks that involve the manual handling of machinery, component parts of machinery, and objects processed by the machine (input/ output) of 3 kg or more, for carrying less than 2 m.	To assess manual handling of machinery and component parts of machinery.	Lower back	Does not cover the holding of objects (without walking), pushing or pulling of objects, hand-held machines, or handling while seated.
ISO 11228-1	Tasks that involve Lifting and Carrying a load	To set recommended limits for the mass of objects being manually handled.	Lower back	Does not include holding objects, pushing or pulling objects, lifting with one hand, or manual handling while seated.

Table S2 (*Continued*)

	Selection criteria			
Technique	**Types of job/task**	**The purpose of the assessment**	**Body parts assessed**	**Limitations of the technique**
ISO 11228-2	Tasks that involve Pushing and Pulling a load	To determine whole-body pushing and pulling force limits, according to specific characteristics of the population and the task.	The whole body	Only applicable for tasks that involve Pushing and Pulling a load.
RSI	Repetitive "hand intensiv" tasks	To assessa distal upper extremity physical exposure	The wrist, forearm	Only applicable for simple,mono-task jobs where the constituent variables do not change substantially between different exertions during a task cycle and the worker does not rotate between different tasks during a work shift.

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Updated estimates of excess total mortality in Italy during the circulation of the BA.2 and BA.4-5 Omicron variants: April-July 2022

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Keywords: COVID-19; Omicron; excess deaths; mortality

Abstract

Background: *The impact of new lineages and sub-lineages of Omicron on total and excess mortality is largely unknown. This study aims to provide estimates of excess mortality during the circulation of the Omicron variant in Italy updated to July 2022.* **Methods:** *Over-dispersed Poisson regression models, fitted separately for men and women, on 2011-2019 mortality data were used to estimate the expected number of deaths during the COVID-19 pandemic. The excess deaths were then obtained by the difference between observed and expected deaths and computed at all ages and at working ages (25-64 years).* **Results:** *Between April and June 2022, we estimated 9,631 excess deaths (+6.3%) at all ages (4,400 in April, 3,369 in May, 1,862 in June) and 12,090 in July 2022 (+23.4%). At working ages, the excess was 763 (+4.9%) in April-June 2022 and 679 (+13.0%) in July 2022.* **Conclusions:** *Excess total mortality persisted during the circulation of different lineages and sub-lineages of the Omicron variant in Italy. This excess was not limited to the elderly population but involved also working age individuals, though the absolute number of deaths was small. The substantial excess found in July 2022 is, however, largely attributable to high temperatures. At the end of the year, this may translate into 30 to 35,000 excess deaths, i.e. over 5% excess mortality. COVID-19 related deaths reversed the long-term trend toward increasing life expectancy, with the relative implications in social security and retirement schemes.*

1. Introduction

Italy was among the countries most severely hit by the Coronavirus disease 2019 (COVID-19) pandemic with more than 45,000 excess deaths estimated during the first wave in February-May 2020 [1] and more than 177,000 officially-registered COVID-19 deaths since the beginning of the pandemic to the end of September 2022 [2].

Most deaths occurred in 2020, when vaccines were not available, and in 2021 during the circulation of the Delta variant with suboptimal vaccine coverage. In December 2021, a new variant of SARS-CoV-2, B.1.1.529 (Omicron), started to circulate in the country, and in early January 2022 it became the dominant variant [3]. The circulation of Omicron has been accompanied by a surge in the number of cases (5 million cases registered in January and

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over 17 million to the end of September 2022). This, however, was followed by a smaller increase in hospitalizations and COVID-19 deaths as compared to previous waves [2]. In the following months, different lineages and sub-lineages of Omicron circulated in Italy (from the original lineage BA.1 to the latest ones BA.4-5) [4], whose impact on total mortality remain to be quantified.

In this study, we update previous estimates on excess total mortality in Italy covering the months of April-July 2022, with a focus on mortality at working ages.

2. Methods

The study is based on national daily mortality data from January 1, 2011 to July 31, 2022 and population data for the calendar years 2011-2022 [5,6].

We estimated the number of excess deaths by the difference between the observed deaths and the number of deaths that would have been expected had the pandemic not occurred. The expected number of deaths were estimated separately for men and women using two over-dispersed Poisson regression models. The models included a linear term for calendar year (to account for temporal trends in mortality), age groups (to capture the demographic changes over the period), a smooth function of week of the year (to capture seasonal variations) as predictors, and the natural logarithm of the population as offset term. A natural spline was used as a smooth function, with number of knots chosen on the basis of the quasi-Akaike Information Criterion (QAIC). Up to 10 equally spaced knots were tested.

Excess deaths were reported at all ages and at working ages (25-64 years) and presented both in absolute terms (i.e. difference between observed and expected deaths) and relative terms (i.e. percent relative differences). To avoid the inclusion of individuals who may still be in education and those who are retired, we defined the working-age population as individuals aged 25-64 years. Excess deaths were provided with 95% Confidence Intervals (CI) obtained through a Monte Carlo simulation. We sampled 10,000 iterations from a multivariate normal distribution for each set of the model's coefficients using the parameter estimates and the variance-covariance matrix. For each iteration, we computed the difference between the observed and the expected deaths and 95%CI were obtained using normal approximation.

To evaluate the excess mortality due to high temperature in July 2022, we related mean temperatures for the months of July of the period 2015-2022 in six urban areas from northern and central Italy (Turin, Milan, Florence, Bologna, Rome and Naples) to the number of deaths registered in the same areas and in the corresponding periods.

3. Results

Between April and June 2022, 226,232 deaths were registered in Italy; 22,166 (9.8%) of them among individuals of working ages. We estimated an excess mortality over the whole period of 21,721 (+10.6%) deaths at all ages and 1,442 (+7.0%) at working ages (Table 1). Observed deaths were higher than expected in all the four months, although most of the excess was observed in the month of July 2022. Between April and June 2022, we estimated 9,631 excess deaths (+6.3%) at all ages (4,400 in April, 3,369 in May, 1,862 in June) and 12,090 in July 2022 (+23.4%). At working ages, the excess was 763 (+4.9%) in April-June 2022 (123 in April, 338 in May, 302 in June) and 679 (+13.0%) in July 2022.

Figure 1 shows the excess deaths in relative terms, i.e. as percent of the expected number of deaths, estimated at all ages and at working ages. In April, the estimate was lower for individuals of working ages as compared to that obtained for the whole population (+2.3% *vs* +8.4%). In May, the estimates were close to +6.5%, while in June the value was higher at working ages than at all ages (+6% *vs* +3.8%). In July, excess mortality substantially increased, up to +13.0% at working ages and +23.4% at all ages.

Our estimates of total excess deaths were close to the officially-registered COVID-19 deaths in the months of April (4,124 deaths), May (3,190 deaths) and June (1,656 deaths), whereas COVID-19 deaths accounted for only 31% of the total excess we estimated in the month of July 2022 (3,733 COVID-19 deaths *vs* 12,090 excess deaths).

Figure 2 shows the relationship between the average temperatures and the number of deaths registered in the municipalities of Turin, Milan, Bologna,

Table 1. Observed, expected deaths and excess total mortality in Italy between April and July 2022 at working ages (25-64 years) and at all ages by month.

Age group	2022	Observed deaths	Expected deaths[1]	Difference	95%CI
Working ages	April	5,400	5,277	123	99 to 146
	May	5,529	5,191	338	314 to 361
	June	5,332	5,030	302	279 to 324
	July	5,905	5,226	679	655 to 702
	April-July	22,166	20,724	1,442	1,359 to 1,522
All ages	April	56,512	52,112	4,400	4,221 to 4,578
	May	54,520	51,151	3,369	3,191 to 3,546
	June	51,471	49,609	1,862	1,683 to 2,040
	July	63,729	51,639	12,090	11,912 to 12,267
	April-July	226,232	204,511	21,721	21,140 to 22,299

CI: Confidence Interval.
[1]Estimated from 2011-2019 mortality and population data, separately by sex, through an over-dispersed Poisson regression model including a linear term for calendar year (to account for the temporal improvement in mortality), age groups as categorical variable (to capture the demographic changes over the period), a smooth function of week of the year with 7 equally spaced knots (to capture seasonal variations), and the natural logarithm of the population as offset term. Values were rounded up to the smallest integer.

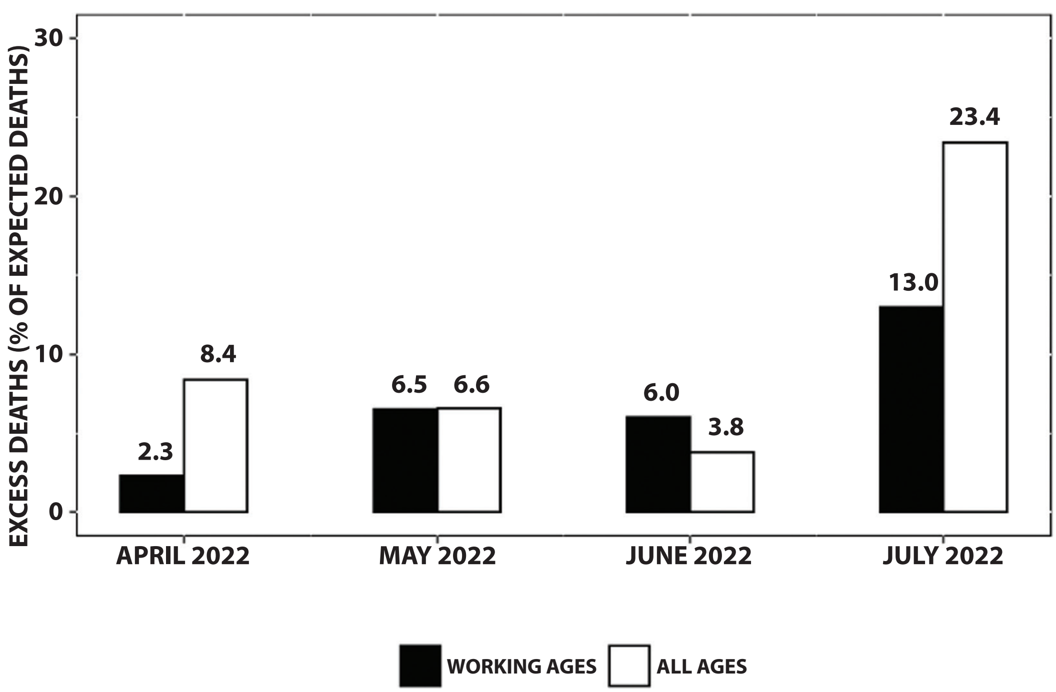

Figure 1. Excess total mortality in Italy (expressed as percent of the expected deaths) between April and July 2022 at working ages (25-64 years) and at all ages by month.

Florence, Rome and Naples in the months of July for the calendar years 2015-2019. The high temperatures in July 2022 and 2015 can explain to a 15-20% excess deaths in the six urban areas considered.

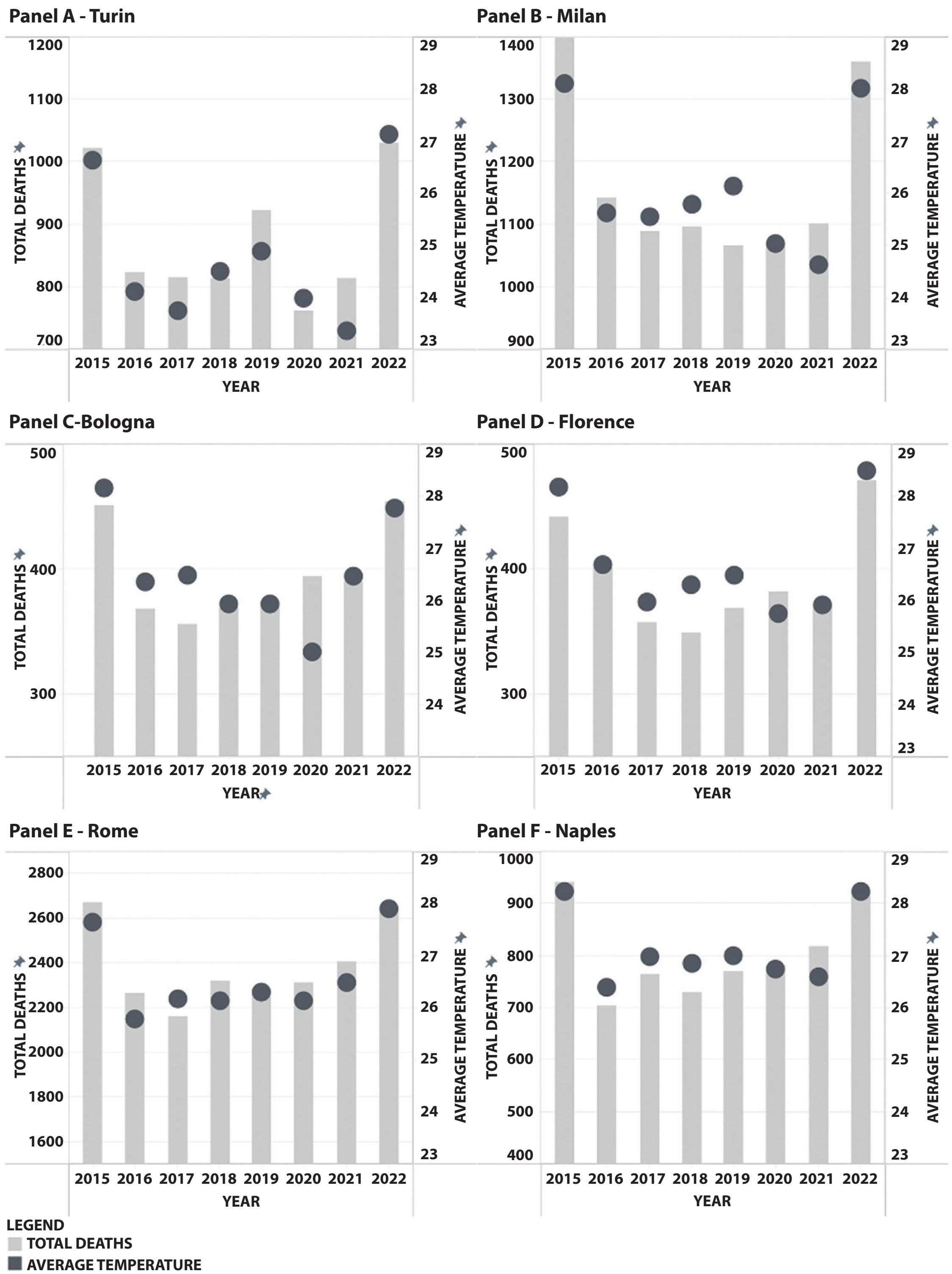

Figure 2. Relationship between average temperatures (°C) and number of deaths registered in the municipalities of Turin, Milan, Bologna, Florence, Rome and Naples in the months of July of the calendar years 2015-2022. Data on average temperatures were downloaded at: http://www.ilmeteo.it

4. Discussion

Between April and July 2022, we estimated an average 6% higher total mortality, whereas in July 2022 the excess was +23%. In the working age population, we observed a similar pattern with excesses in the range of 2 to 6% in April-June 2022, which increased to 13% in July 2022.

We reported only a modest excess mortality (+2.5%) at all ages during the initial period of Omicron predominance in Italy (February-March 2022), and no excess at working ages [7]. That finding likely resulted from the combination of a less severe disease induced by Omicron [8,9] and a high level of natural and vaccine-induced protection of the Italian population [10]. However, in spring and summer 2022, when new variants appeared and quickly became predominant, the number of deaths returned higher than expected. This may reflect the waning of vaccine efficacy, since the (booster) vaccination campaign levelled off at the end of the previous winter. However, the reasons behind that remain largely undefined, and in the absence of cause-of-death data in Italy, can be only hypothesized.

The numbers of hospitalization in intensive care units due to COVID-19 did not increase between February and July 2022 [2], indicating that those deaths did not occur in the acute phase of the disease, but may be related to possible sequalae of COVID-19 [11,12]. In fact, a remarkable increased risk of cardiovascular events has been observed among individuals infected by SARS-CoV-2, including young and middle-aged adults [13,14]. Long-term (i.e. over 300 days) cardiac pathology, mainly inflammatory (moderate myocarditis) has been reported in subjects with mild initial COVID-19 illness and no previous cardiac disease. [15]. Moreover, an indirect effect of COVID-19 on other diseases as a consequence of delayed diagnosis and suboptimal care has to be considered [16]. In support of these hypotheses, there are emerging data on increasing mortality from causes other than COVID-19, including heart disease, diabetes and Alzheimer disease/dementia [17,18].

The remarkable excess observed in the month of July 2022 can be largely attributed to the high ambient temperatures registered in that month in Italy. This is evident from the substantial gap between the estimated excess deaths and the deaths attributed to COVID-19 in July, which was not observed in the previous months. In July 2015, there was a similar increase in ambient temperature in several main Italian cities, and in that year around 12,000 excess deaths were registered compared to the previous year.

Other countries are still observing excess total mortality during the circulation of Omicron. The Office for National Statistics reported no excess in the UK between January and mid-March 2022, but from the second half of March to the end of July 2022, 20,600 (6,000 in July) more deaths than expected were observed, based on the average number of deaths registered in the 5-year before the pandemic (2015-2019) [19]. The number of deaths attributed to COVID-19 in that period was 14,000 (68% of the total excess) and in July 2022 only 3,000 (50% of the total excess).

Between February and June 2022, the average excess mortality was close to 5%. In January and July, the excess was over 10%, but was influenced by the residual of the Delta wave in January and by the high temperatures in July. Assuming a 5% COVID-19-related excess mortality for the remaining months, at the end of the year this may translate into 30 to 35,000 excess deaths.

Our estimates are based on provisional data which may be incomplete for some municipalities due to delay in death registration. This may have underestimated the true excess mortality, especially in the most recent months. Consequently, we need timely mortality data in order to implement an effective monitoring of the pandemic. Considering the high social and economic impact of a premature death at working age, estimates of excess death should be also provided for this population, despite the low risk and the comparatively small total number of deaths.

5. Conclusions

Our data indicate a persistent excess in total mortality during the circulation of different lineages and sub-lineages of the Omicron variant in Italy. With few exceptions (i.e. the serious flu epidemic in 2015) until 2019 total mortality had been decreasing and hence life expectancy had been increasing in Italy, with implications on social security and retirement schemes, i.e. planned periodic increases of age at retirement. After decades, of increased life expectancy, the trend has reversed in Italy as in other countries [20], indicating that COVID-19 pandemic continues to have implications on total mortality in high-income countries. The impact was concentrated in the elderly, but an excess mortality is evident at working age too, even if the absolute number of excess deaths is small below age 65.

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

References

1. Alicandro G, Remuzzi G, La Vecchia C. COVID-19 pandemic and total mortality in the first six months of 2020 in Italy. *Med Lav*. 2020;111(5):351-353. Doi:10.23749/MDL.V111I5.10786
2. Sorveglianza integrata COVID-19: i principali dati nazionali. Accessed October 11, 2022. https://www.epicentro.iss.it/coronavirus/sars-cov-2-sorveglianza-dati
3. Alicandro G, Remuzzi G, Centanni S, Gerli A, La Vecchia C. Excess total mortality during the Covid-19 pandemic in Italy: updated estimates indicate persistent excess in recent months. *Med Lav*. 2022;113(2):e2022021-e2022021. Doi:10.23749/MDL.V113I2.13108
4. Monitoraggio delle varianti del virus SARS-CoV-2 di interesse in sanità pubblica in Italia. Accessed October 10, 2022. https://www.epicentro.iss.it/coronavirus/sars-cov-2-monitoraggio-varianti-rapporti-periodici
5. Istituto Nazionale di Statistica. Decessi e cause di morte: cosa produce l'Istat. Published 2022. Accessed October 2, 2022. https://www.istat.it/it/archivio/240401
6. Istituto Nazionale di Statistica. Popolazione residente e ricostruzione intercensuaria della popolazione. Published 2022. Accessed June 2, 2022. https://demo.istat.it/
7. Alicandro G, Remuzzi G, Centanni S, Gerli A, La Vecchia C. No excess mortality among working-age Italians during the Omicron wave of Covid-19. *Med Lav*. 2022;113(3). Doi:10.23749/MDL.V113I3.13092
8. Sigal A, Milo R, Jassat W. Estimating disease severity of Omicron and Delta SARS-CoV-2 infections. *Nat Rev Immunol*. 2022;22(5):267-269. Doi:10.1038/s41577-022-00720-5
9. Trunfio M, Portesani F, Vicinanza S, et al. Real-life Evidence of Lower Lung Virulence in COVID-19 Inpatients Infected with SARS-CoV-2 Omicron Variant Compared to Wild-Type and Delta SARS-CoV-2 Pneumonia. *Lung*. 2022;200:573-577. Doi:10.1007/s00408-022-00566-7
10. Governo Italiano - Report Vaccini Anti Covid-19. Accessed October 11, 2022. https://www.governo.it/it/cscovid19/report-vaccini/
11. Mehandru S, Merad M. Pathological sequelae of long-haul COVID. *Nat Immunol*. 2022;23(2):194-202. Doi:10.1038/s41590-021-01104-y
12. Raman B, Bluemke DA, Lüscher TF, Neubauer S. Long COVID: post-acute sequelae of COVID-19 with a cardiovascular focus. *Eur Heart J*. 2022;43(11):1157-1172. Doi:10.1093/EURHEARTJ/EHAC031
13. Xie Y, Xu E, Bowe B, Al-Aly Z. Long-term cardiovascular outcomes of COVID-19. *Nat Med*. 2022;28(3):583-590. Doi:10.1038/S41591-022-01689-3
14. Katsoularis I, Fonseca-Rodríguez O, Farrington P, et al. Risks of deep vein thrombosis, pulmonary embolism, and bleeding after Covid-19: nationwide self-controlled cases series and matched cohort study. *BMJ*. 2022;377:e069590. Doi:10.1136/BMJ-2021-069590
15. Puntmann VO, Martin S, Shchendrygina A, et al. Long-term cardiac pathology in individuals with mild initial COVID-19 illness. *Nat Med*. Published online September 5, 2022:1-7. Doi:10.1038/s41591-022-02000-0
16. Spadea T, Di Girolamo C, Landriscina T, et al. Indirect impact of Covid-19 on hospital care pathways in Italy. *Sci Reports*. 2021;11(1):1-6. Doi:10.1038/s41598-021-00982-4
17. Woolf SH, Chapman DA, Sabo RT, Zimmerman EB. Excess Deaths from COVID-19 and Other Causes in the US, March 1, 2020, to January 2, 2021. *JAMA - J Am Med Assoc*. 2021;325(17):1786-1789. Doi:10.1001/jama.2021.5199
18. Excess deaths in England and Wales: March 2020 to June 2022 - Office for National Statistics. Accessed October 11, 2022. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/excessdeathsinenglandandwalesmarch2020tojune2022/2022-09-20
19. Office of National Statistics. Coronavirus (COVID-19) latest insights - Office for National Statistics. Office of National Statistics. Published 2022. Accessed October 13, 2022. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/coronaviruscovid19latestinsights/deaths
20. Aburto JM, Schöley J, Kashnitsky I, et al. Quantifying impacts of the COVID-19 pandemic through life-expectancy losses: a population-level study of 29 countries. *Int J Epidemiol*. 2022;51(1):63-74. Doi:10.1093/IJE/DYAB207

Letters to the Editor
Med Lav 2022; 113 (5): e2022041

Commentary to "Mortality from Bladder Cancer in Dyestuff Workers Exposed to Aromatic Amines: A 73-Year Follow-Up" by C. Ciocan et al.

Ciocan et al. [1] describe an outbreak of bladder cancer among workers exposed to high levels of carcinogenic aromatic amines in a dyestuff factory in the province of Turin (Northern Italy). Findings are striking: during a 70-year follow up, 60 deaths from bladder cancer occurred in the cohort vs. 4.0 expected.

Not unusually for papers published in *La Medicina del Lavoro*, the name of the factory is not mentioned, which precludes an overall contextualization of the shameful episode in its geographical, historical, and social circumstances. However, my guess is that it was the IPCA (Industria Piemontese Coloranti Anilina) factory in Cirié, a town on the outskirts of Turin. In 1978, IPCA made history, when its managers were sentenced to jail for manslaughter in the first criminal court trial for occupational cancer ever taking place in Italy.

The working environment and conditions could hardly have been worse at IPCA that was a major player in the economy of the area. As reported by Ciocan et al., between 1946 and 1970 almost 600 men worked for at least one year at IPCA, while Cirié then had a population slightly above 10,000 inhabitants. Events and the trial had a great emotional impact on the population. Nowadays, one of Cirié's squares is dedicated to the IPCA victims and a street is named after Gino Franza and Albino Stella, the two IPCA workers who brought the bladder cancer deaths to the attention of the workers' union and subsequently of the judicial authority. Documents regarding the factory and the trial have been collected in a huge repository located in what is left of IPCA premises. I recommend Ciocan et al. to forward a reprint of their paper to the Mayor of Cirié for inclusion in the IPCA archive.

Given the relevance of the episode in the history of the area, a more precise measure of the impact IPCA had on the workers' health would be desirable. In Ciocan et al.' study, causes of death were not validated and bladder cancer morbidity was ignored. According to local witnesses, the actual number of victims exceeded the figure reported by Ciocan et al. An *a priori* count of bladder cancer prevalence in those days would be unfeasible. Ciocan et al. do not clarify whether the figure of 60 victims includes those identified through (death) certificates attributing death to conditions other than bladder cancer and mentioning bladder cancer among "other significant conditions contributing to the death". The article appears not to consider those certificates: would it be possible for the authors to count them and add the number of IPCA workers dying <u>with</u> bladder cancer? This would be an improved approximation to the actual number of IPCA victims.

Benedetto Terracini,
University of Turin (retired)

Reference

1. Ciocan C, Godono A, Franco N, et al. Mortality from bladder cancer in dyestuff workers exposed to aromatic amines: A 73-year follow-up. *Med Lav*. 2022; 113(2): e2022017. Doi: 10.23749/mdl.v113i2.12893. PMCID: PMC9073764

Reply to The Commentary to "Mortality from Bladder Cancer in Dyestuff Workers Exposed to Aromatic Amines: A 73-Year Follow-Up" by C. Ciocan et al" by B. Terracini

The comments by B. Terracini to our paper "Mortality from bladder cancer in dyestuff workers exposed to aromatic amines: a 73-year follow-up" by Ciocan et al. [1] give us the opportunity to clarify some methodological aspects of our study.

We have not disclosed the identity of the industries that we have investigated in current or past cohort studies. The data, methodology, and findings from our investigations are being presented for the goal of demonstrating to the scientific community the impacts of one or more exposures on human health. We therefore took the same approach with this particular industry that had previously been the focus of multiple prior publications [2-4], all of which were follow-ups of the same cohort after various latencies and documented the effects of aromatic amine exposure on health.

We agree that the severe effects of that specific exposure provide proof of unacceptable working conditions. Our updated results add further scientific evidence to this conclusion. Finding additional bladder cancer deaths after 73 year of follow up confirms the results from previous analyses with excess risk of bladder cancer persisting several decades after stopping exposure, thus providing additional information on the carcinogenesis process following occupational exposure to aromatic amines.

The expected number of events, specifically deaths from bladder cancer, was calculated relying on death certificates. The observed number of deaths must result from the same source in order to be comparable and to estimate risk. The Italian death certification validity is recognized as robust even for a cause like COVID-19, for which death for and with the disease is a key issue [5]. Still, some mis-certification is possible in observed and expected figures, whose impact on risk estimates and their pattern over time is however likely to be limited.

Furthermore, the main goal of our research was not to determine the total number of incident cases within the cohort but rather to compare the new results to those of earlier analyses of the same cohort (also based only on mortality data) in order to understand the trend of the bladder cancer risk decades after the cessation of exposure.

About incident cases of bladder cancer, screening programs applied to workers that undergo health surveillance for preventive purposes do not apply to the general population. Initial cases that do not lead to overt disease or death from bladder cancer would be identified more frequently in the working population than in the general population. Members of this cohort did not have their urine cytology and health monitored while they were employed; rather, they entered our Institute's follow-up program after retirement.

We will be pleased to provide a copy of all of our publications on the matter to the mayor of the concerned municipality.

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References

1. Ciocan C, Godono A, Franco N, et al. Mortality from bladder cancer in dyestuff workers exposed to aromatic amines: A 73-year follow-up. *Med Lav*. 2022 Apr 26; 113(2):e2022017. Doi: 10.23749/mdl.v113i2.12893. PMID: 35481579; PMCID: PMC9073764
2. Pira E, Piolatto G, Negri E, et al. Bladder cancer mortality of workers exposed to aromatic amines: a 58-year follow-up. J Natl Cancer Inst. 2010 Jul 21;102(14):1096-9. Doi: 10.1093/jnci/djq214. Epub 2010 Jun 14. PMID: 20548022
3. Piolatto G, Negri E, La Vecchia C, Pira E, Decarli A, Peto J. Bladder cancer mortality of workers exposed to aromatic amines: an updated analysis. *Br J Cancer*. 1991 Mar;63(3):457-9. Doi: 10.1038/bjc.1991.106. PMID: 2003988 4
4. Rubino GF, Scansetti G, Piolatto G, Pira E. The carcinogenic effect of aromatic amines: an epidemiological study on the role of o-toluidine and 4,4'-methylene bis (2-methylaniline) in inducing bladder cancer in man. *Environ Res*. 1982 Apr;27(2):241-54. Doi: 10.1016/0013-9351(82)90079-2. PMID: 7084156
5. Jha P, Brown PE, Ansumana R. *Lancet*. 2022 May 21; 399(10339):1937-1938. Doi: 10.1016/S0140-6736(22)00845-5. Epub 2022 May 6.PMID: 35533709