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Reviews, Commentaries, Perspectives

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From Subjects to Partners: Rethinking Research Methodologies through Citizen Science[1]

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Keywords: Citizen Science; Participation; Integration; Multi-disciplinarity; Inter-disciplinarity; Trans-Disciplinarity; Occupational Medicine; Biomonitoring; Human biomonitoring

Summary

The article will first introduce a general definition of Citizen Science (section 1), followed by an excursion of its foundations and of the different understandings and ways of applying it, with examples drawn from diverse research and policy areas (section 2). It will then focus more closely on the field of health and the environment (section 3), including occupational medicine (subsection 3.1), community response to environmental risks (section 3.2), biomonitoring (sub-section 3.3), and human biomonitoring (subsection 3.4). Section 4 will address some of the advantages (section 4.1) and challenges (section 4.2) of adopting CS in research and policy. Finally, section 5 will trace the legislative and normative background of participatory approaches and point to the challenges ahead.

1. Introduction

This article does not aim to provide a systematic review of Citizen Science (CS) practices and applications, nor is it primarily focused on biomonitoring. It describes the basics of CS, identifies its precursors, and provides several examples of its applications in various research areas, including biomonitoring. The primary objective of this work is to demonstrate the potential of working in a multi-, inter- and trans-disciplinary mode, highlighting both its advantages and challenges, while also considering socio-political contexts and the normative framework.

Overall, citizen science refers to the involvement of members of the general public, laypeople, volunteers, non-credential researchers, and non-professional scientists in scientific research activities through a range of participatory approaches. Such actors may be individual or collective, such as NGOs, activist groups, pressure groups, private businesses, and public administrators. Experiences generally grouped under the umbrella term of Citizen Science (CS) have been growing exponentially over the last few decades, covering a wide range of diverse topics and research areas. Though the term is relatively recent [1, 2], the same cannot be said for the ideas at its roots. Indeed, some similar practices date back decades and even centuries, being considered innovative and even daring for the times they were introduced.

As a side note, it is worth recalling that, as Kaiser [3] pointed out, the term "scientist" with its current meaning was introduced less than two centuries ago.

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This marked the shift from the (amateur) natural philosopher of the Scientific Revolution to a professional scientist with recognized status, defined roles, and specific tasks. Additionally, disciplines as we know them today were established only in the 19th and 20th centuries and have rapidly expanded since then, including the creation of subdisciplines that led to increasing specialization, university departments, faculties, sectors, and units [3].

The term Citizen Science was independently introduced in the mid-1990s by two scholars from different backgrounds: Alan Irwin, a sociologist, [1] and Rick Bonney, a wildlife expert. Their focus differed: Irwin emphasized the level and quality of engagement and the ownership of knowledge, while Bonney concentrated on the volume and speed of data collection. Although the label CS is quite new, the activities it includes are not; some examples date back decades and even centuries. These activities include fossil or plant gatherers who donated their finds, collections, drawings, and catalogs to museums or scientific societies. Additionally, in a somewhat different category, are craftsmen who solved technical and scientific problems that had stumped renowned scientists, or natural philosophers, of their time. For instance, John Harrison, with his precise clocks, developed a reliable method for measuring longitude—a complex problem that haunted the best minds of the 18th century and caused significant loss of life and economic damage [4].

Among collective experiences, a notable one is the Nature's Calendar, a British phenology project that started in 1736 when Robert Marsham began recording in his diary "indications of spring" on his family estate. The project now involves about 40,000 people observing 67 spring events and 24 autumn events related to nature across the UK [5]. Similar initiatives are countless, from volunteers tagging monarch butterflies to track migrations, to sailors contributing to oceanographic research, and fishermen providing input to establish fishing quotas.

2. Foundations and Typologies of Citizen Science

The ideas associated with the term CS have been accumulated over time under various labels, such as action research, participatory action research, community-engaged research, and community-based participatory research (CBPR). They also align with the concept of "extended peer community" introduced within the framework of Post-Normal Science (PNS) [6], which I will revisit.

In any case, the term CS quickly became popular and was soon accepted by many groups, even though its understanding and ways of application often vary significantly. Additionally, a terminological debate soon arose, giving rise to a vast and growing body of literature. The term "citizen," for example, may sound exclusive or non-inclusive, as it omits those who do not hold official citizen status. And is there such a thing as a "general public"? "Lay people" is a too broad and reductive term, as is "volunteers," among others. Expressions like "community science" and "civic science" are gaining prominence, along with related terms such as "community scientists" and "civic scientists," which are sometimes intended to include both professionals and non-professionals—focusing on interest and commitment rather than on roles or credentials. Similar dilemmas exist around defining knowledge that cannot be fully expressed in scientific terms but is still relevant and valid for understanding and addressing certain issues: lay knowledge, local knowledge, situated knowledge, lived knowledge, experiential knowledge, lived experience, and so on. Nonetheless, the terms citizen science/scientists remain the most widely used in the literature, sometimes accompanied by an explanatory note.

Yet, far from pointing to a very specific, unambiguously defined type of activity, CS is an umbrella term that encompasses a wide range of understandings. Especially since the 2010s, proposals for classifications, typologies, frameworks, and mapping have multiplied in an effort to provide clear yet nuanced distinctions. However, this has also inevitably led to some disagreement and confusion. For example, in 2015, ECSA (European Citizen Science Association) developed and shared its Ten Principles of Citizen Science [7], translating them into all official EU languages, as well as other languages spoken across the 27 EU countries and many languages worldwide. Yet, many believed these principles were insufficient for distinguishing what qualifies as citizen science and what does not. Around ten years later, a group of 19 researchers aimed to address some of these gaps and ambiguities in defining citizen science practices [8].

A recent study identified 13 types addressing various aspects of citizen science [9]. Some of these types are more popular and widely adopted than others [10]. Here is a simplified version based on the previously mentioned types, with the level of engagement of non-professionals as its main criterion: a) crowdsourcing (or contributive) involves laypeople acting as data collectors, an unpaid workforce performing tasks designed by professionals; b) co-created design signifies full collaboration between lay and professional scientists; c) extreme (or autonomous) citizen science includes initiatives led by lay participants, with scientists possibly serving as advisors or consultants. The third type is somewhat the reverse of the first, with professional scientists being hired as service providers, likely for payment. This is a simplified typology, and many intermediate forms could exist. Crowdfunding is related, although not exclusive to citizen science projects. It involves collecting money to fund projects that are not, or not sufficiently, sponsored by traditional sources. Participation, engagement, and involvement are terms often used in the literature, sometimes interchangeably or arranged on a scale from lower to higher levels of involvement [11].

Evidently, different modes involve significant differences in power dynamics and how leadership is attributed, especially regarding framing the research question, choosing the research design and methods for data collection and analysis, and ownership and dissemination of results, including their use in policy processes. The recognition of power as a crucial issue in participatory experiences was highlighted by Sherry Arnstein, somewhat ahead of her time, in the context of urban planning. In her widely cited 1969 paper, she proposed a ladder with eight rungs, grouped under the three categories of "non participation, tokenism and citizen power" [12].

Not surprisingly, most experiences so far fall into the first category, crowdsourcing, regardless of the research area. Their rapid growth is mainly due to the spread of digital media. Smartphones, tablets, inexpensive sensors, open-source software and platforms, high-speed internet, and powerful computers have all expanded possibilities for data collection, access, management, storage, and sharing. A well-known example is the crowdsourced astronomy project Galaxy Zoo, which focuses on classifying the shapes of large numbers of galaxies [13]. It gained major visibility early on, starting in 2007, thanks in part to extensive coverage by the mainstream press. Overall, projects related to ecology and the environment are most common. Still, more examples are emerging across diverse research fields: archaeological exploration, anthropology, disaster studies, history, sociolinguistics, space and astronomy, technological innovation, and increasingly, health, epidemiology, and biomonitoring—areas I will now explore in more detail.

3. Citizen Science in the Environment and Health

This section will focus on Citizen Science initiatives which relate to the fields of health and the environment including some innovative experiences which preceded the emergence of the CS vocabulary.

3.1. Occupational Medicine

Aspirations for the "democratization of medicine"—including a renewed doctor-patient relationship and increased attention to environmental stressors—have existed for decades, coming from both civil society and the medical community itself. In Italy during the late 1960s and 1970s, these ideas led to several noteworthy innovative practices, especially in occupational medicine. During a time of student protests and class struggles, numerous initiatives emerged that could be called, in today's terms, citizen science. "Citizens" in this context were mainly workers employed in large factories in the metallurgical and chemical sectors. Alongside medical and other healthcare professionals from various backgrounds, they promoted new ways of understanding and addressing the impact of the work environment on people's health, rejecting monetary compensation for exposure to toxic and other risky agents and instead emphasizing safety, prevention, anticipation, and care.

The experiences of the "homogeneous groups" – groups of employees sharing the same working environment and consequently being exposed to similar risks - were genuinely participatory and trans-disciplinary, integrating the contributions of experts from different disciplines (through measurements, tests, etc.) with knowledge ensuing from the lived experience of the workers. In the typology presented above, such experiences would fit into the category "co-created", or even "extreme" Citizen Science. This innovative form of full collaboration between workers and technicians was possible thanks to the individual commitment of many (mostly young) medical professionals, as well as the support of some established academics and prestigious institutions such as the Clinica del Lavoro Luigi Devoto in Milan, in a new season of legislative reforms promoting and expanding civil rights [14-21].

3.2. Communities at Risk and Patient Activist

Ideas and initiatives related to the safety of the working environment gradually expanded to encompass the broader environment. This shift moved the research focus from specific workplace settings to entire communities, where residents often organized or led their own investigations to detect toxic elements after experiencing unexplained symptoms. The Love Canal case, a residential area near Niagara Falls in New York state, is perhaps the most well-known example of what the main (female) protagonist called "housewives epidemiology" [22] (see also [23]). Popular epidemiology is also a commonly used term for these kinds of experiences, [24].

Similarly, it was due to the persistence of advocates for patients who had been undiagnosed and untreated for decades that the cause of what is now called Lyme disease was finally discovered, and treatment became available in the early 1980s [25]. Another well-known case from before the CS nomenclature was established is summarized by Epstein in the abstract of his 1995 article with these words: "In an unusual instance of lay participation in biomedical research, U.S. AIDS treatment activists have established themselves as credible contributors to the knowledge-building process, leading to changes in the epistemic practices of biomedical research" [26] (p. 408). The author further adds: "This surprising result is, of course, at odds with the popular idea of science as a fairly autonomous field with high barriers to entry" [26] (p. 409).

Over the years, associations of patients or undiagnosed, untreated individuals have proliferated, building their agendas on different philosophies and strategies, but all sharing the goal of giving people with similar conditions the opportunity to share information and experiences and provide mutual support. One notable example is PatientsLikeMe [27], created in 2005 by the two men who became citizen scientists after their brother had been diagnosed with ALS (amyotrophic lateral sclerosis) in 1998. In 2011, the digital health platform began to include communities of patients with other conditions, and as of 2025, it has more than 850,000 members across over 2,800 conditions. PatientsLikeMe works in partnership with various public and private institutions and commercial businesses, including pharmaceutical companies.

However, in many circles, there is a widespread skepticism and even mistrust toward the research establishment. Suspicion has been fueled by cases such as that of Henrietta Lacks', which was brought to public attention by Rebecca Skloot. From her highly publicized 2010 book [28], large audiences learned that significant benefits—economic and otherwise—had been gained from the continuous use of the "immortalized cell line" of a poor African-American woman who died of cervical cancer in 1951 in Baltimore, at the only hospital that would admit her during racial segregation. Neither she nor her family were informed, and it was only in the mid-1970s that her relatives discovered what had happened and began to claim their rights to information, privacy, and economic profits, sparking a broad debate and several posthumous recognitions of Henrietta's unknowing contribution to scientific research.

3.3. Biomonitoring

In biomonitoring research, CS practices appear to be gaining rapid popularity and broader acceptance as they are no longer solely used by pioneers but also by mainstream researchers. Crowdsourcing is the most common approach, with non-professionals guided by scientists to use various methods for detecting and measuring pollution and ecotoxicity from many agents, both natural and artificial, such as chemicals, glass fibers, metals and metalloids, microplastics, oil, pesticides, PFAS, plasticizers, and substitutes. Nearly any type of element or environment has been investigated when the proper tools are available and conditions permit: air, fresh water, lagoons, seas, oceans, coastal zones, soil, sediments, food, plants, animals (vertebrates and invertebrates), biodiversity, and the human body— the last, which I will discuss separately below. So far, no geographic area has remained unexplored, including the most remote or hard-to-reach places, like the Russian Arctic [29] or the Canadian permafrost zone [30]. In the latter case, a community-based participatory research (CBPR) approach for health impact assessment related to development plans was chosen, involving indigenous communities more than in crowdsourcing. However, as explained further in section 4.1, many barriers still exist in these efforts.

A quite different and somewhat paradoxical example – given the high environmental impact of the transport means – consists of observations provided by cruise ship passengers, including those in the Arctic and Antarctica. These passengers collect observations (pictures, videos, notes) on animals, plants, and natural phenomena such as aurora borealis and australis using mobile applications supported by artificial intelligence that helps with recognition and classification. These contributive practices, along with others involving birdwatchers, hikers, hunters, mushroom collectors, fishermen, and more, are often promoted by educational institutions or scientific societies.

3.4. Human Biomonitoring

Due to high expectations regarding the results and impact of HBM research, there is significant investment in securing broad participation of potential subjects in local, national, and international HBM projects and programs. People's knowledge, perceptions, and attitudes are examined through surveys or focus groups to help develop strategies for facilitating recruitment [32, 34, 35, 37].

The importance of informing research subjects is universally recognized, but a one-way communication approach still prevails in practice despite acknowledgment of the greater effectiveness of a two-way method [31-35]. Building multidisciplinary networks is recommended, including a wide range of expertise related to health—such as physicians, chemists, biochemists, biologists, toxicologists—and from social sciences and humanities, like social psychology, sociology, history, ethics, and media studies [32, 33, 35]. Even so, the preference for top-down strategies appears to dominate, viewing potential study participants as subjects to be informed and educated not only about the technical aspects of HBM research but also about the value of bio-surveillance HBM programs for individual and societal well-being [33]. When suggesting strategies, recommendations, roadmaps, and toolkits, authors do acknowledge some lessons from risk communication literature but rarely report firsthand initiatives [34, 36]. Currently, in HBM research and practice, the situation differs significantly from that of occupational medicine practices in the late 1960s and 1970s, described in section 3.1 [14-21].

Genuinely participatory research entailing equal partnership between scientists and non-professionals as in co-created projects is still in its infancy. It has to be acknowledged, as it will be detailed later, that the challenges are significant and require considerate and careful planning. Big projects such as the recently completed HBM4EU [38] or the ongoing PARC [39] are already so challenging in coordination tasks [40] to appear an unlikely place for large scale citizen science experimentation, even if it is acknowledged as worth pursuing [36, 41].

Smaller projects appear more suitable for testing and evaluating the feasibility of full partnerships between professional and non-professional scientists in co-created research initiatives. For example, the CitieS-Health project [42-45] also offered a toolkit to facilitate similar practices [46]. The newly initiated project, One Health Citizen Science [47], is applying a similar model across various Italian sites, including Valle del Serchio, which was already part of the previous CitieS-Health project. The smaller scale of these projects also enables experimentation with inter- and trans-disciplinary collaborations aimed at genuinely integrating diverse perspectives (rather than merely combining them), whether disciplinary or not. This approach should ideally lead to framing HBM and bio-surveillance broadly, with increased focus on sensitive socio-ethical issues, including "societal risk," which has received limited or insufficiently sophisticated attention so far. I will briefly mention some of the issues raised by scholars from the social studies of science tradition.

Extensive bio-surveillance can have negative effects on individual privacy and enable harmful uses of control and restrictions on personal freedoms. Additionally, when people are turned into chemical sensors for environmental issues, the line between body, self, and environment becomes blurred, making personal experience less unique. Both individual and collective identities may be redefined in techno-scientific terms, leading to new "bio" social phenomena such as biological citizenship, bio-sociality, bio-activism, and biomedicalization, possibly shifting the responsibility for risk exposure and preventive measures [48-51]. While not all these developments may be negative, they still require foresight from an "extended peer community," including not just scientific experts but also various social actors. In fact, when viewed in its full complexity, HBM is just one of many current problems with policy implications that can be described by the post-normal science (PNS) principle: "uncertain facts, values in dispute, high stakes, and urgent decisions" [6].

4. Advantages and Challenges of Citizen Science

CS projects and programs share some advantages and challenges with more traditional types, occasionally exaggerated, while some are unique to that specific approach. Nearly all papers on the topic include a list of benefits and drawbacks, either theoretically defined or practically observed. Some refer to the research team, others to the external environment, and some address both. Below, I will briefly list the most common ones, highlighting those specific to health research, many of which are summarized in [52-53].

4.1. Advantages

As already mentioned, the possibility of acquiring more data quickly often influences the decision to include non-professionals in research activities. While this is generally true for the contributory type of CS, it is not necessarily the case with other CS modes, where the process can actually be slowed down. The perspectives offered by "lay people" and their contributions, which provide valuable but not strictly scientific knowledge, are often more appreciated in more inclusive initiatives that are open to the possibility of even redefining research questions and procedures. In such cases, reciprocal learning is emphasized rather than one-way instruction. Other often-cited benefits include the lay participants' chance to learn more about the issues being studied, improve their scientific literacy by familiarizing themselves with research procedures, and even change their behaviour based on the new awareness and knowledge they gain.

People often assume there is increased trust in scientists and scientific research, but this trust is not guaranteed and depends on several factors. One of the most important factors is the relationship built between professionals and citizen scientists. For instance, lack of transparency or violations of agreements about sharing results or using data and findings (research versus commercial use) can weaken or even ruin trust—not only in a specific group of researchers but in the scientific community as a whole. This is especially true in environmental and health research, particularly concerning BM and HBM (whether CS or not), where there is a strong emphasis on using the knowledge gained to implement appropriate measures for regulation, prevention, remediation, management, and governance.

4.2. Challenges

The recruitment of research subjects involves many well-known challenges, not only technical (e.g., sample validity, data anonymization, etc.) but also other types, especially when it comes to HBM, which requires acquiring body fluids and tissues, inevitably raising sensitive socio-ethical issues [48], including privacy concerns, reporting individual and community exposure, and more. Regarding report-back in personal exposure studies, the debate remains open, and different approaches exist. According to a study based on in-depth interviews with various stakeholders and a review of relevant literature, new forms of community-based research ethics and participatory scientific practice are emerging [54].

In CS health projects, both technical and ethical issues can become more complex because non-professionals are not just research subjects; they often become partners to some extent and have their say. This includes decisions on platforms (opensource vs. proprietary), use and dissemination of results, which challenges the power balance within the research team. This is a key issue, as previously discussed in section 2. Delegating some of these concerns to ethical committees isn't easy, especially in international research projects, since rules and procedures vary greatly between countries and can often be confusing, conflicting, or even contradictory within the same country [43] (see also [40]). Reaching preliminary agreements takes time—a valuable resource in research—and some issues may remain unresolved if disagreements occur, causing internal conflicts and fatigue. Additional challenges come from the diversity of traditions, cultures, and jargon, not only across disciplines but also across different fields of study.

In some cases, differences may appear insurmountable, such as between Indigenous communities and research or government institutions, whose worldviews inevitably clash from the very beginning, starting with the way they conceptualize problems. For example, this is evident in the impact assessment of development plans, which the former views holistically, while the latter sees as separate components to be studied by different disciplines and managed with various governance strategies [30] (p. 449). Trust, which is essential for success, is not automatically given; it must be patiently built through openness, clarity, and fairness, as suspicion of sham participation [37] can arise both internally and externally. Additionally, and rarely mentioned in the literature, there may be cases where internal boycotts occur—where individuals or groups prefer the failure of the participatory project over its success due to personal or collective hidden agendas.

CS projects of all different types still face significant hesitation in the academic setting, especially if they are large, particularly innovative, or cause concern due to potential objections from important stakeholders, especially research sponsors. Doubts about the quality of data and the proper assessment of methods and results are often raised in many areas, and acceptance by regulatory agencies and decision makers is not always guaranteed [52].

5. Conclusion and Way Forwards

The origins of CS in health and environmental research trace back to times of political struggles for workers' and citizens' rights, when such issues were often not a priority on institutional agendas [14-22]. Emerging during periods of social mobilization and calls for justice, these early efforts anticipated the participatory shift that later transformed the relationship between science, policy, and society. Over the following decades, increased awareness of the crisis facing traditional institutions—and ultimately, democracy itself—prompted calls for reform across various areas, leading to a re-evaluation of science's role in society and the rights and duties of citizens.

Today, many conventions, declarations, and policy frameworks recognize citizens' rights not only to access information but also to actively participate in decisions and processes that affect their lives. Research and political institutions have gradually adjusted their goals and strategies to align with these principles. In the European Union, for example, the so-called Seveso Directive was the first to introduce the obligation to inform the public about risks, specifically major-accident hazards. Later revisions expanded this principle by including participatory mechanisms in risk governance [55]. Similar commitments appear in the REACH Regulation [56], which in point (117) of its preamble affirms citizens' rights to information, justice, and participation in decision-making.

Regarding research policies, a significant change for CS and similar activities happened with the Framework Programme Horizon 2020, which ran from 2014 to 2020, following the European Commission Green Paper on CS in 2013. Its goal was "to foster the interaction between the Citizen Science stakeholders and the EU policy officers" [57] (p. 8). The trend continues with the current Framework Programme Horizon Europe, covering 2021-2027, which promotes citizens' participation in various scientific fields. Additionally, the European Commission established the Competence Centre on Participatory and Deliberative Democracy, [58] whose main goal is to support the development of socially robust policies through citizen engagement.

Yet, the future of these participatory goals remains uncertain. In a time marked by renewed attacks on both science and democracy, the institutionalization of CS cannot be assumed. Efforts to revive outdated models are unlikely to address the challenges we face today. Instead, as Donna Haraway [59] suggests, we may need to "stay with the trouble": to accept the messy, complex realities of coexistence. As she writes, "Staying with the trouble requires making odd kin; that is, we require each other in unexpected collaborations and combinations, in hot compost piles. We become with each other or not at all. … Learning to stay with the trouble of living and dying together on a damaged earth will prove more conducive to the kind of thinking that would provide the means to building more livable futures." [59] (pp. 3 and 4).

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Occupational-Related Exposure to Diesel Exhaust and Kidney Cancer: Systematic Review and Meta-Analysis of Cohort Studies

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Abstract

Background: *The association between diesel exhaust and cancer other than the lung is not well established. We aimed to conduct a systematic review and meta-analysis on the association between diesel exhaust exposure and kidney cancer in workers.* **Methods:** *Two trained researchers conducted a systematic review to identify cohort studies examining the relationship between occupational exposure to diesel exhaust and the risk of cancer other than lung cancer. Of the 43 retained studies, 15 reported information on kidney cancer. We performed random-effects meta-analyses for ever-exposure to diesel exhaust. Summary relative risks (RR) and 95% confidence intervals (CI) were calculated for the association between diesel exhaust exposure and kidney cancer.* **Results:** *Overall, the RR of kidney cancer was 1.08 (95% CI=1.01-1.15, heterogeneity p=0.1, I2=28.6%). The summary RR was 1.08 for incidence (95% CI=1.01-1.16; I2=36.7%) and 1.09 for mortality (95% CI=0.92-1.30, I2=14.5%), p of heterogeneity=0.914. The summary RR of European studies was 1.08 (95% CI=1.00-1.16, I2=37.8 %), that of USA/Canada studies was 1.10 (95% CI=0.94-1.29, I2=8.5%), p of heterogeneity=0.837. Publication bias was not detected.* **Conclusions:** *Workers exposed to diesel exhaust may experience an increased risk of developing kidney cancer, although the evidence is not entirely consistent, and residual confounding cannot be excluded.*

1. Introduction

Diesel exhaust has been investigated as a potential carcinogen for multiple organs [1]. Most of the available studies focus on lung cancer, for which an association has been reported [1]. A carcinogenic effect on the lung is justified by the fact that inhalation represents the main route of exposure. Exposure to diesel exhaust can be occupational as well as environmental, through traffic emissions and machine operation ([2]; Table S1). Workers who are most exposed to diesel exhaust include drivers, heavy equipment operators, and non-metal miners [3].

Among the organs besides the lung for which a carcinogenic effect of diesel exhaust has been reported are the urinary bladder [4-6] and the kidney [6, 7]. The high vascularization of the kidney and its filtering function, combined with the possible

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passage of diesel exhaust particles into the circulatory system, support the hypothesis that the urinary tract may be susceptible to the harmful effects of this agent [8]. The assessment of health effects from diesel exhaust exposure is complicated by various factors, including exposure misclassification and the variable composition of the agent itself. Evidence of an association between diesel exposure and urinary tract cancer remains limited. Cohort studies are the most appropriate research design to describe the effects of exposure to carcinogens [9]. We aimed to conduct a meta-analysis of cohort studies involving workers exposed to diesel exhaust and the risk of cancers other than the lungs. The present paper focuses on the association with kidney cancer.

2. Methods

2.1. The Preferred Reporting Items for Systematic reviews and Meta-Analyses

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement was followed to conduct this meta-analysis [10]; the checklist is available in Table S2. A study protocol was built and registered in the PROSPERO database (Registration No. 352729).

The systematic review was based on the Patients, Exposure, Comparator, Outcomes, Study design (PECOS) criteria [11], with the following structure:

- Population (P): workers in multiple industrial settings;
- Exposure (E): occupational diesel exhaust exposure;
- Comparator (C): individuals not exposed to diesel exhaust;
- Outcomes (O): incidence or mortality of cancer types other than lung cancer;
- Study design (S): industry-based or population-based studies reporting information on the exposure (including nested case-control studies).

We reviewed all publications included in the IARC Monograph on diesel exhaust [1] and conducted a PubMed search in May 2024 for studies reported after that publication. This search aimed to identify studies reporting results on occupational exposure to diesel exhaust and the risk of any cancer type except lung cancer. The search was performed independently by two authors (GC and FT) and focused on studies of cancer among workers exposed to diesel exhaust in industries such as railway, transportation, and mining. We created a search string using the terms (diesel OR miner OR garage OR railway OR ((truck OR bus) AND driver) OR (heavy equipment OR docker)) AND (cancer OR neoplasm). Additionally, we included reports from the personal archives of one of the authors (PB), adding nine non-overlapping studies. If multiple reports were published on the same population, we only included the most informative one, usually the one with the largest number of cases or deaths. Studies with minor overlap (less than 10%) were considered independent.

We abstracted data using a standardized form on (i) sociodemographic factors, (ii) occupation and industry type, (iii) person-years of observation, (iv) type of cancer and ICD code with version, (v) measure of association (odds ratio (OR), risk ratio, rate ratio, standardized mortality ratio [SMR], or standardized incidence ratio [SIR], henceforth referred to as relative risk [RR]) and 95% confidence intervals (CI), (vi) factors adjusted for in the analysis and (vii) characteristics of the study population (eg., number of subjects included, number of cancer cases). The dataset was organized by type of cohort study (historical vs prospective), design of the study (industry-based vs population-based), follow-up period, geographic area (USA/Canada vs Europe), and outcome (incidence vs mortality). Composition of the population by sex was reported when data were reported, as well as sex-specific results. When available, we abstracted results on dose-response analysis for different indicators of diesel exhaust exposure.

Next, we excluded studies with no reference to diesel exhaust, those with exposure other than occupational, those without data on cancer other than lung cancer, and those with a design other than cohort. We assessed the quality of the included studies based on the CASP scale [12]. We considered 11 questions for a total score of 14 points. We used the mean of the scores assessed separately by two authors (GC and FT). Studies which scored <8 were considered of low quality, 8-9.5 of medium-low quality, >9.5 & <11.25 of medium-high, and >=11.25 of high quality. Additional information is available on Supplementary Tables S3 and S4.

Data were collected for different types of cancers, excluding the lungs. We conducted analyses by cancer type. This paper focuses on the association between occupational diesel exhaust exposure and kidney cancer. We conducted a random-effects meta-analysis based on the Sidik-Jonkman method [13]. In the primary analysis, we included results on both kidney cancer incidence and mortality. Next, we stratified the meta-analyses by outcome (incidence and mortality), geographic area (USA/Canada and Europe), design of the study (industry-based and population-based), and quality score (low or low-medium and medium-high or high score). Data for women were too limited to allow a separate analysis.

We tested the heterogeneity among studies using the I-square test [14]. We assessed publication bias by the visual inspection of the funnel plot and the Egger test [15]. To address the plausibility of results on kidney cancer, we compared them to the corresponding results on lung cancer when reported. All the statistical analyses were performed on STATA, version 16.1 (Stata Corp., College Station, TX, US) [16].

3. Results

The flow chart showing the selection of studies is included in Supplementary Figure S1. Out of 2,867 potentially relevant publications, we retained a total of 3 publications reporting results on kidney cancer. An additional 19 publications were abstracted from the IARC Monograph [1], of which one study of U.S. non-metal miners was excluded because a more recent report from the same study was available, and 16 studies were retrieved from the reference lists of the studies identified earlier; among these, 9 were non-overlapping. Of the 30 non-overlapping studies meeting the inclusion criteria, 15 reported results on kidney cancer [3, 6, 7, 17-28].

The 15 studies retained in the review comprised 23 estimates of the association between diesel exhaust exposure and risk of kidney cancer, including eight studies (16 risk estimates) based on incidence and seven studies (seven risk estimates) based on mortality. They are illustrated in Table 1.

Figure 1 shows the main results of our meta-analysis. Overall, the RR of kidney cancer was 1.08 (95% CI=1.01-1.15, p-value of test for heterogeneity [p-het] =0.1, I2=28.6%). The p-value of the test for publication bias was 1.00.

Table 2 summarizes the results of the stratified analyses. When focusing on results on cancer incidence, the summary RR was 1.08 (95% CI=1.01-1.16, p-het=0.036, I2=36.7%), while the summary RR from mortality studies was 1.09 (95% CI=0.92-1.30, p-het=0.324, I2=14.5%). Results by outcome were not statistically heterogeneous (p=0.914). Publication bias was excluded for both study types (p=0.912 for incidence studies and p=0.884 for mortality studies). The summary RR of studies conducted in the USA/Canada was 1.10 (95% CI=0.94-1.29, p-het =0.248, I2=8.5%), whereas that of European studies was 1.08 (95% CI=1.00-1.16, p-het 0.042, I2=37.8%). These results were not heterogeneous (p-het=0.837). When considering study design, no significant difference was observed between industry-based (RR=1.07, 95% CI=0.93-1.24, p-het=0.284, I2=17.3%) and population-based studies (OR=1.08, 95% CI=1.01-1.17, p-het=0.07, I2=39.7%), with p for heterogeneity among the two categories equal to 0.910.

The summary RR for low- and medium-quality studies was 1.22 (95% CI=1.01-1.47, p-het=0.039, I2=41.4%), that for medium-high- and high-quality studies was 1.06 (95% CI=1.03-1.09, p-het<0.001, I2=0.0%); this difference was not statistically significant (p-het=0.147). Results on dose-response were too sparse to justify a meta-analysis, as well as those by sex.

Finally, we identified 16 cohorts with results reported for both lung and kidney cancers; the unweighted correlation coefficient was 0.23 (p=0.40). Supplementary Figure 2 shows the scatter plot of the results of the individual studies. Supplementary Table S4 provides information on the main characteristics of some common occupational exposures to diesel exhaust, based on IARC 2012 [1].

Table 1. Characteristics of the included studies.

Study	Country	Design (P, population-based; I, industry-based)	Years of FU	N participants	Persons years	Industry type	Exposure data	N cases kidney cancer	Adjustments	RR/SMR/SIR kidney cancer	RR/SMR/SIR lung cancer
Koutros et al., 2023 (17)	USA	I	1960-2015	12,315 people, both sexes	422,343 (miners) 282,840 (ever-underground miners)	Miners	Data collected from 8 non-metal miners US facilities. Historical measurements and surrogate exposure data were used to estimate exposure to diesel exhaust for each worker. Work history record were abstracted from employer personnel files. For six facilities, this information was available through end 1999; one facility only through 1997, and another facility through 1993.	34 (23 among ever underground miners)	Race and ethnicity	SMR=1.02, 0.71-1.43	SMR=1.24, 1.13, 1.37
Guo J et al., 2004 (7)	Finland	P	1971-94	Men and women	30 million person-years	Non-metal miners Truck drivers Forklift drivers Dockers	Occupations from the population census in 1970 were converted to exposures to diesel exhausts with a job-exposure matrix (FINJEM).	13 in men (non-metal miners) 131 in men, 2 in women (truck drivers) 15 in men (forklift drivers) 24 in men, 3 in women (dockers)	SES, smoking, BMI	Non-metal miners men: RR=0.88, 0.47-1.50 Truck drivers men: RR=1.00, 0.84-1.19; women: 2.50, 0.30-9.02) Forklift drivers men: RR=0.92, 0.0.53-1.58 Dockers men: RR=0.98, 0.63-1.45; women: RR=1.52, 0.31-4.43	no result reported for lung cancer

Jarvholm B and Silverman D, 2003 (18)	Sweden	I		1971-92	14364 men (heavy construction equipment operators) 6364 men (truck drivers)	217331 (heavy construction equipment operators) 97930 (truck drivers)	Heavy construction equipment operators Truck drivers	A computerised register of Swedish construction workers participating in health examinations between 1971 and 1992 was used. the referent group was carpenters/ electricians and general population for lung cancer, while for other cancers the referent group was only general population.	24 in heavy construction equipment operators 23 in truck drivers		SIR=0.74, 0.47-1.10 heavy construction equipment operators SIR=1.12, 0.71-1.68 in truck drivers	SMR=0.70 (95% CI=0.51-0.92) for heavy construction equipment operators SMR= 1.18 (95% CI=0.89-1.53) for truck drivers SIR= 1.14 (95% CI=0.87-1.46) for truck drivers and SIR= 0.76 (95% CI=0.58-0.97) for heavy construction equipment operators
Wong O et al., 1985 (19)	USA	I		1964-78	34156 men	372525.6	Construction equipment operators	Data derived from records maintained at Operating Engineers Local Union N3, San Francisco. No historical environmental measurements, but partial work histories were available for some cohort members through the union dispatch computer tapes. An attempt was made to relate mortality experience to the union members' dispatch histories.	17		SMR=0.74, 0.43-1.18	SMR= 0.99 (95% CI=0.88-1.10)
Van Den Eeden SK and Friedman GD, 1993 (20)	USA	P		1964-72	160230, both sexes (overall results reported)		Diesel exhaust exposure assessed across multiple jobs and industries	Diesel exhaust exposure reported in questionnaire interview during routine health examination, among members of the Northern California Kaiser Permanente Medical Care Program. Questions referred to exposure in the past year.	268	Race, education, smoking status (and smoking duration and smoking amount)	RR=1.38, 0.80-1.38, 0.80-2,41	RR=1.02 (95% CI=0.81-1.29)

Table 1 (*Continued*)

Study	Country	Design (P, population-based; I, industry-based)	Years of FU	N participants	Persons years	Industry type	Exposure data	N cases kidney cancer	Adjustments	RR/SMR/SIR kidney cancer	RR/SMR/SIR lung cancer
Boffetta P et al., 2001 (6)	Sweden	P	1971-89	All Swedish adult population	7 400 000 for men exposed and 240 000 for women exposed	Diesel exhaust exposure assessed across multiple jobs and industries	After excluding farmers, job and industry titles were classified according to estimated probability and intensity of exposure to diesel emissions (based on Swedish Cancer Environment Register III).	2243 in men 33 in women		SIR =1.06, 1.02-1.11 in men; SIR=0.82, 0.57-1.16 in women	SIR=1,09 (95% CI=1.06-1.12) in men, SIR=1.09 (95% CI=0.83-1.42) in women
Gustavsson P et al., 1990 (21)	Sweden	P	1952-86 for mortality 1958-84 for incidence	695 men	21317.5 16695	Bus garage workers	The intensity of the exposure to diesel exhaust was assessed by industrial hygienists and structured in a job-exposure matrix.	2 1		SMR=0.72, 0.09-2.59 SIR=0.70, 0.14-2.04	SMR= 1.15 (95% CI=0.67- 1.84) SIR=1.61 (95% CI=0.94- 2.57)
Soll-Johanning H et al., 1998 (22)	Denmark	P	1943-92	15249 men	386395 total person-years	Bus drivers and tramway employers	Computerised, highly-reliable individual data on employment.	83 in male workers employed at least 3 months		SIR=1.60, 1.30-2.00 (men employed for at least 3 months)	SIR= 1.6 (95% CI=1.5-1.8) for men SIR=2.6 (95% CI=1.5-4.3) for women
Rafnsson V and Gunnarsdottir h, 1991 (23)	Iceland	I	1951-88	28788 (truck drivers) 19284 (taxi drivers)	868 (truck drivers) 726 (taxi drivers)	Truck drivers Taxi drivers	Data obtained from the membership registers and files of truck and bus drivers (length of time, period of employment etc.)	6 8		SMR=1.77, 0.65-3.85 for truck drivers SMR=1.97, 0.54-5.05 for taxi drivers	SMR= 2.14 (95% CI=1.37-3.18) for truck drivers; SMR=1.39 (95% CI=0.72-2.43) for taxi drivers
Birdsay J et al., 2010 (24)	USA	I	1989-2004	156241 people, both sexes; 146,261 men		Truck drivers	Occupational data from electronic membership files of a trade association providing services to truck drivers.	55 (no sex distinction)	Smoking status	SMR=1.08, 0.82-1.41	SMR=1.00 (95% CI=0.92-1.09)

Schenker MB et al., 1984 (25)	USA	I		1967-79	2519 men	284000	Railway workers	Diesel exhaust exposure estimated for about 150 railway job classifications. Exposure determined based on previous reviews on railways and based on data from industrial hygiene measurements.	6		SMR=1.66, 0.61-3.62	SMR=0.82 (95% CI=0.59- 1.11)
Nokso-Koivisto P and Pukkala E, 1994 (26)	Finland	I		1953-90	8391 men	212 800	Locomotive drivers	Reconstruction of usual working conditions and standard hygienic operations, with the help of older workers; air sample collection; measurement of diesel exhaust exposure.	38		SIR=1.25, 0.88-1.70	SIR= 0.86 (95% CI=0.75-0.97)
Pukkala E et al., 2009 (3)	Denmark, Finland, Iceland, Norway, Sweden	P		1961-2006	15 million people, both sexes 385 000 000	385 000 000	Machine operators	Original national occupation codes converted to a common classification with 53 categories + one category of economically inactive persons.	1142 in men, 23 in women		SIR=1.08, 1.02-1.14 in men; SIR=0.93, 0.59-1.40 in women	SIR =1.20 (955 CI=1.17- 1.23) in men; SIR=2.61 (95% CI=2.19- 3.11) in women
Bender AP et al., 1989 (27)	USA	I		1945-84	4849 men	96 567	Highway workers	Employment data on highway maintenance workers.	6		SMR=0.63, 0.23-1.37	SMR=0.69
Howe GR et al., 1983 (28)	USA	I		1965-77	43 826 men, 17838 ascertained cause of death	290 186	Pensioners of the Canadian National Railway Company	Experts classified occupations based on specific exposures, including diesel exhaust	58		RR=1.26, 0.97-1.64	SMR=1.06

FU= follow-up.
N= number.
BMI= body max index.
SES= socioeconomic status.
SMR/SIR= standardized mortality ratio/standardized incidence ratio.
CI=confidence interval.

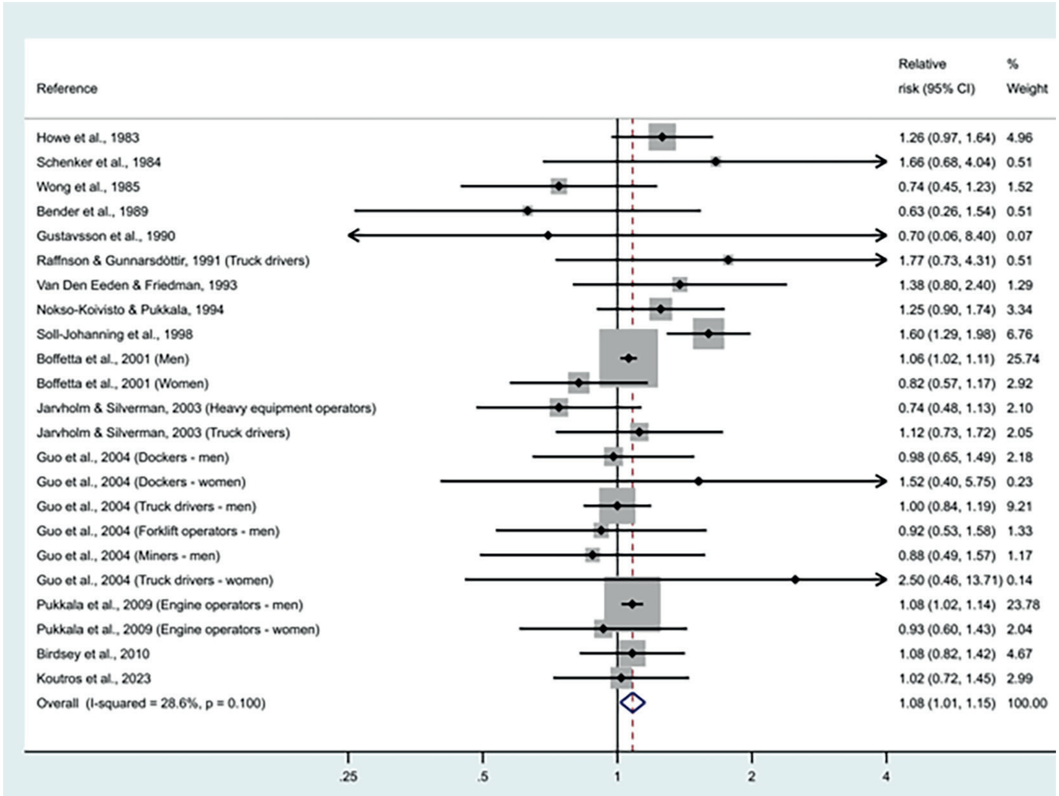

Figure 1. Results of the overall meta-analyses of studies on occupational exposure to diesel exhaust and risk of kidney cancer.

Note: confidence intervals do not match with those reported in Table 1 and in the original publications because of Stata approximations.

4. Discussion

We identified a weak association between occupational exposure to diesel exhaust and the risk of kidney cancer. The association did not vary according to outcome (incidence vs. mortality from kidney cancer) and geographic regions (Europe vs. North America).

We focused this meta-analysis on cohort studies because this design allows for a better definition of exposure. Industry-based and population-based studies, such as census-based ones, were included and analyzed separately, with no statistical difference observed. Census-based studies, like those by Boffetta et al. [6] and Pukkala et al. [3], as well as most cohort studies based on industry or occupation, essentially include all individuals employed in specific occupations but lack detailed data on diesel exhaust exposure. In fact, these studies estimate exposure based on occupation type rather than questionnaires or measurements. Additionally, census-based studies usually provide job title information at a single point in time. These factors make industry-based studies more appropriate for investigating occupational epidemiology. Conversely, the study by Koutros et al. [17], conducted among nonmetal miners in the US, provided detailed diesel exhaust exposure data based on historical measurements and surrogate indicators, including hygiene levels. Exposure estimates were made independently of outcomes, and cumulative and intensity exposures over time were calculated.

Additionally, exposure to other major occupational confounders was also estimated. These

Table 2. Results of the meta-analysis by main characteristics.

Characteristic	N risk estimates	RR, 95% CI; I2; p-het	Test heterogeneity between strata (p value)
Outcome			
Incidence	16	1.08, 1.01-1.16; 36.7%; 0.036	0.914
Mortality	7	1.09, 0.92-1.30; 14.5%; 0.324	
Country			
USA/Canada	7	1.10, 0.94-1.29, 8.5%; 0.248	0.837
Europe	16	1.08, 1.00-1.16, 37.8%; 0.042	
Design of the study			
Industry-based	10	1.07, 0.93-1.24, 17.3%; 0.284	0.910
Population-based	16	1.08, 1.01-1.17, 39.7%; 0.07	
Quality score			
Low or low-medium	9	1.22, 1.01-1.47, 41.4%; 0.039	0.147
Medium-high or high	14	1.06, 1.03-1.09, 0.0%; <0.001	

Notes: N, number; RR, relative risk; 95% CI= 95% confidence interval; p-het, p for heterogeneity within the studies.

strengths make the study by Koutros et al. [17] the most rigorous in quality. Notably, their analysis found no relationship between diesel exhaust and kidney cancer (SMR 1.02, 0.72-1.45) [17]. Given the significant effort to account for various confounders and the well-documented diesel exhaust exposure within the cohort, the absence of an association with kidney cancer questions the validity of findings from other studies. In particular, the increased risk reported elsewhere may be due to exposure misclassification and residual confounding. Further insight is gained by comparing these results with those for lung cancer, which showed a significant increase, supporting the hypothesis that diesel exhaust does not have an actual causal role in kidney cancer [17].

The study by Pukkala et al. [3] presents some potential overlap with other census-based studies. They analyzed 53 job categories based on 1961-1981 censuses from five Nordic countries, and we selected engine operator as the category with the highest probability of exposure to diesel exhaust [3]. For example, the study by Boffetta et al. [6] included different types of machine operators, including engine operators, based on the 1971 census from Sweden, with the possibility of overlap of some data reported by Pukkala et al. [3]. We combined results on incidence and mortality from kidney cancer under the assumption that exposure to diesel exhaust is not associated with kidney cancer survival, i.e., that the association, if any, would be comparable for the two outcomes. We tested this assumption in the meta-analysis stratified by outcome, which resulted in no heterogeneity between studies based on incidence and studies based on mortality. For this reason, we maintained that including both outcomes was our primary analysis.

There was no evidence of a different risk of kidney cancer in studies from Europe or USA/Canada, despite some difference including: (i) different diesel technologies reducing emission levels [29]; (ii) different working conditions [30]; (iii) differences in lifestyle habits [31, 32]; (iv) higher prevalence of other occupational risk factors in Europe, including asbestos [33-35]; (v) time of exposure, where European studies were based on older exposure.

The lack of sufficient data impaired the analyses by sex. In particular, most studies were conducted on men, and studies involving both sexes included a small proportion of women (eg, <10%) or did not report results separate by sex [20, 24]. As a consequence, our results refer to both sexes, but apply mainly to the male population, based on available data.

The identification of the role of diesel exhaust in cancer causation must take into account the latency between exposure and cancer occurrence. Our choice of focusing on cohort studies is based on the assumption that several decades are needed to observe the carcinogenic effect of diesel exhaust; in fact, a prospective design allows the detection of differences between exposed and non-exposed. According to the IARC [1], latent periods substantially shorter than 30 years cannot provide evidence for lack of carcinogenicity. While many included studies covered a period shorter than 20 years, others followed up the workers for several decades, including the extensive census-based study by Pukkala et al. [3], which covered between 1961 and 2006. Therefore, we cannot exclude that more extended observation of the study populations would have led to the identification of an increased risk of kidney cancer. Findings from long-follow-up studies should be considered more reliable and help in interpreting our results.

A few community-based studies reported results on occupational exposure to diesel exhaust and the risk of kidney cancer. Although they were not included in the meta-analysis, these studies can provide supporting evidence, since the results of some of these studies were adjusted for potential confounders such as tobacco smoking and overweight/obesity. In particular, Peters and coauthors reported an OR of 1.23 (95% CI = 0.99-1.53) for kidney cancer in Canadian men exposed to diesel exhaust at the workplace [36]. Also, the risk of kidney cancer in association with outdoor air pollution, including diesel exhaust, was investigated in a meta-analysis of 14 European cohort studies, where an increased likelihood of cancer occurrence was suggested (HR = 1.57, 95%CI: 0.81-3.01 per 5 $\mu g/m^3$ $PM_{2.5}$ and HR = 1.36, 95%CI: 0.84-2.19 per 10^{-5} m^{-1} $PM_{2.5}$ absorbance) [37].

Established risk factors for kidney cancer include cigarette smoking, obesity, and hypertension [38], as well as some medications (e.g., antihypertensive drugs) [39]. IARC lists trichloroethylene and X- and gamma-radiation among the carcinogens with sufficient evidence for kidney cancer in humans. In contrast, the kidney is not listed among known or suspected target organs for carcinogenicity of diesel exhaust [40].

The potential carcinogenic effects of diesel exhaust on the kidney include direct genotoxicity, oxidative stress, and inflammation. A hypothesis suggests an effect mediated by ultrafine particles that can be filtered by the kidney [8]. The role of diesel exhaust in the development of kidney disease is also supported by findings from studies conducted in rats [41, 42]. To our knowledge, this is the first meta-analysis on the association between occupational exposure to diesel exhaust and kidney cancer and provides new evidence on the carcinogenicity of diesel exhaust. The systematic review was conducted according to established guidelines. We focused on cohort studies, thus considering studies of the same design, and the most reliable in the literature in providing evidence on the presence or absence of an association, as information on the exposure is independent from the occurrence of the outcome. Restriction on studies reporting results on occupational exposure was imposed to focus on the population with the highest exposure to diesel exhaust. Also, a large number of publications could be included in this meta-analysis, allowing us to obtain precise results, even though kidney cancer is a relatively uncommon disease, which may be challenging to investigate in individual studies.

4.1. Limitations of the Study

This study suffers from some limitations, which suggest caution in the interpretation of our results. There was a high degree of heterogeneity between the results included in the meta-analysis. Exposure misclassification may have impaired the analysis because the subjects classified as unexposed may have been to some extent exposed to diesel exhaust in the general environment or in other occupations. Also, exposed workers could have been in contact with additional occupational carcinogens, which might be confounders that we could not account for because of missing information. This could lead to an underestimate of the investigated association; however, other sources of bias could have operated. To date, only the DEMS study [17] has adopted a detailed quantitative approach to the assessment of diesel exhaust exposure, using detailed exposure measurements. It should be noted that no excess of kidney cancer was reported in this study. Indeed, diesel exhaust exposure could vary between cohorts investigating the same job or industry, or within the single cohort, because of the different composition, intensity, frequency, and probability of exposure [43]. Moreover, only a few of the included studies accounted for confounders [7, 20, 24], like cigarette smoking and additional occupational factors.

We checked and compared the association observed with lung cancer in the same studies, to (i) understand if exposure misclassification might have impaired both kidney and lung cancer findings, and (ii) verify if a study which failed to assess an association with kidney cancer due to paucity of observed cases was able to identify an association for lung cancer. By doing this, we corroborated that some studies [19, 20, 24-26] could not find an increased risk of lung cancer in workers exposed to diesel exhaust, and that this unexpected finding was attributed to a lack of adjustment for important confounders, short monitoring period, or healthy worker effect. However, exposure misclassification, which receives considerable attention in occupational epidemiology, is an even more important limitation to consider. In addition, it is more challenging to evaluate the impact of exposure misclassification on relative risks in occupational studies than for confounding because of the absence of information on the level of misclassification present, and because exposure misclassification probably occurs in all studies.

An additional potential limitation is the fact that we focused on cohort studies. We made this choice since exposure assessment in case-control studies is less reliable, and selection bias is a potential limitation of this type of study. However, evidence from case-control studies is broadly consistent with our results [1, 36].

A few studies (e.g., [7]) reported results for multiple occupational groups exposed to diesel exhaust, using the same (or a largely overlapping) unexposed population. These risk estimates are therefore not independent, inflating the contribution of the overlapping populations to the results of the meta-analysis. Also, while the number of studies was relevant, it was insufficient to exclude publication bias with enough statistical power. We used the Sidik–Jonkman method for estimating the between-study variability (τ2) rather than the most popular DerSimonian–Laird method [44] due to the known tendency of the latter to underestimate τ^2 when the number of studies is small [45]. This offered a better picture of the inner uncertainties behind the results. We also wanted to relax the assumption that the distribution of random effects is normal. Using the Random-Effects Sidik–Jonkman model, the confidence interval has a higher coverage probability than the commonly used interval based on the DerSimonian-Laird method [46].

5. Conclusion

In conclusion, this meta-analysis suggests a weak positive association between occupational exposure to diesel exhaust and kidney cancer. This finds support in previous literature [36, 37]. Anyway, this positive evidence is not exempt from limitations and potential bias, and is balanced by several arguments, including (i) lack of association reported in the DEMS study [17], which had the highest quality; (ii) lack of adjustments for important potential confounders. Thus, the causal nature of the association cannot be conclusively determined. Additional high-quality prospective studies are needed to elucidate better the relationship between diesel exhaust exposure and kidney cancer. Cohort studies similar to the DEMS study [17], with information on the level of diesel exhaust exposure, and accounting for potential confounders, would provide high-quality data. New studies would gain additional value when conducted on selected industry types (e.g., mechanics, highway workers, engine operators, and handlers) and geographical areas (e.g., Latin America, Asia, and Australia) from which few data have been reported. Moreover, studies including a considerable proportion of women are needed to provide evidence on a possible modification of the association by sex.

Despite these limitations, the hypothesis of a carcinogenic effect of diesel exhaust exposure on the kidney remains. Workers should be aware of this potential hazard, which is mainly due to the risk of lung cancer but may also affect other sites, and should be provided with adequate personal protection equipment.

Supplementary Materials: The following are available online: Table S1. Characteristics of common occupational diesel exposures; Table S2. PRISMA checklist; Table S3. Modified version of the Critical Appraisal Skills Programme (CASP) checklist for cohort studies adopted for quality assessment; Table S4. Quality assessment of the included studies according to the Critical Appraisal Skills Programme (CASP) score; Figure S1. Flow diagram of the study selection process; Figure S2. Scatter plot of unweighted correlation coefficients between risk of lung and kidney cancers of the 16 studies reporting them.

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Author Contribution Statement: PB and GC conceived and designed the study; GC and FT performed the literature research; GC and PB performed the data analysis; GC wrote the manuscript; PB supervised the work; PB revised the manuscript; all authors approved the final version of this manuscript.

Declaration on the Use of AI: None.

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Occupational-Related Exposure to Diesel Exhaust and Kidney Cancer: Systematic Review and Meta-Analysis of Cohort Studies

SUPPLEMENTARY MATERIAL

Table S1. Characteristics of common occupational diesel exposure.

Occupational activities	Exposure scenarios	Particle characteristics	Composition
Maintenance shops for railroads and trucks	Briefly move vehicles in/out of shop; emissions into confined space; slow removal by ventilation	High agglomeration; considerably reduced nuclei and surface area; most in accumulation mode	Lower EC and very high OC from lubricating oils
Railroad operations and exposures of crews	Emissions into the environment by leading locomotive(s); exposure intensity defined by downwind proximity to source	Low agglomeration Idling: high nuclei level and PM Steady speed: low/no nuclei, reduced surface.	Higher EC and very high OC Moderate EC and lower OC from lubricating oils
Underground mining	Exposure intensity defined by proximity to vehicles – haulage trucks, loaders; and fixed engines – generators, large equipment; moderate to fast removal by ventilation	High agglomeration; no nuclei and lower surface area	Higher EC and lower OC from lubricating oils
Above-ground mining	Brief exposure to occasional exhaust from preceding trucks or nearby heavy equipment	Idle: high nuclei level and PM Steady speed: up-hill, low nuclei and low hydrocarbons Down-hill, high, nuclei and high hydrocarbons	High EC and OC High EC and low OC High EC and OC
City driving	Exposure from preceding vehicles depends on traffic density and proximity	Moderate agglomeration; Idle and high acceleration: high nuclei level and PM Steady speed: low nuclei and accumulation mode (depends on proximity).	High EC and OC Moderate EC and low OC
Highway driving	Exposure from preceding vehicles depends on traffic density and proximity	Low agglomeration; low nuclei and accumulation mode (depends on proximity)	High EC and low OC

Ref [1] IARC 2012, Table 1.13

Table S2. PRISMA checklist.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	2
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	2
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	3
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	3
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	3
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	3,4
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	3
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	3
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	3
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	3,4
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	3,4

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	11
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	11
Study characteristics	17	Cite each included study and present its characteristics.	6-10
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	NA
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	12
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	NA
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	11, 12
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	4
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	12-14
	23b	Discuss any limitations of the evidence included in the review.	14,15
	23c	Discuss any limitations of the review processes used.	14,15
	23d	Discuss implications of the results for practice, policy, and future research.	15
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	2
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	2
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	16
Competing interests	26	Declare any competing interests of review authors.	16
Availability of	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included	16

Section and Topic	Item #	Checklist item	Location where item is reported
data, code and other materials		studies; data used for all analyses; analytic code; any other materials used in the review.	

Table S3. Modified version of the Critical Appraisal Skills Program (CASP) checklist for cohort studies adopted for quality assessment.

Items	Possible scores
Section A: Are the results of the study valid?	
1. Did the study address a clearly focused issue?	- 1.5 - 1.0 - 0.0
2. Was the cohort recruited in an acceptable way?	- 1.5 - 1.0 - 0.0
3. Was the exposure accurately measured to minimize bias?	- 1.0 - 0.5 - 0.0
4. Was the outcome accurately measured to minimize bias?	- 1.0 - 0.5 - 0.0
5.(a) Have the authors identified all important confounding factors?	- 1.0 - 0.5 - 0.0
5.(b) Have they take account of the confounding factors in the design and/or analysis?	- 1.0 - 0.5 - 0.0
6.(a) Was the follow up of subjects complete enough?	- 1.0 - 0.5 - 0.0
6. (b) Was the follow up of subjects long enough?	- 1.0 - 0.5 - 0.0
Section B: What are the results?	
7. What are the results of this study?	Excluded
8. How precise are the results?	- 1.0 - 0.5 - 0.0
9. Do you believe the results?	- 1.0 - 0.5 - 0.0
Section C: Will the results help locally?	
10. Can the results be applied to the local population?	- 1.0 - 0.5 - 0.0
11. Do the results of this study fit with other available evidence?	- 1.0 - 0.5 - 0.0
12. What are the implications of this study for practice?	- 1.0 - 0.5 - 0.0

For each item, scores were assigned according to researchers' consideration of the quality of the content (higher score means higher quality).

Table S4. Quality assessment of the included studies according to the Critical Appraisal Skills Programme (CASP) score.

Reference	CASP score
Bender et al., 1989 [27]	L
Birdsey et al., 2010 [24]	L
Boffetta et al., 2001 [6]	H
Guo et al., 2004 [7]	H
Gustavsson et al., 1990 [21]	L
Howe et al., 1983 [28]	L
Jarvholm & Silverman, 2003 [18]	H
Koutros et al., 2020 (17)	H
Nokso-Koivisto & Pukkala, 1994 [26]	L
Pukkala et al., 2009 [3]	H
Raffnson & Gunnarsdòttir, 1991 [23]	L
Schenker et al., 1984 [25]	L
Soll-Johanning et al., 1998 [22]	L
Van Den Eeden & Friedman, 1993 [20]	H
Wong et al., 1985 [19]	L

Note: Low- and medium-low-quality studies are indicated as "L"; medium-high- and high-quality studies are indicated as "H".

Figure S1. Flow diagram of the study selection process.

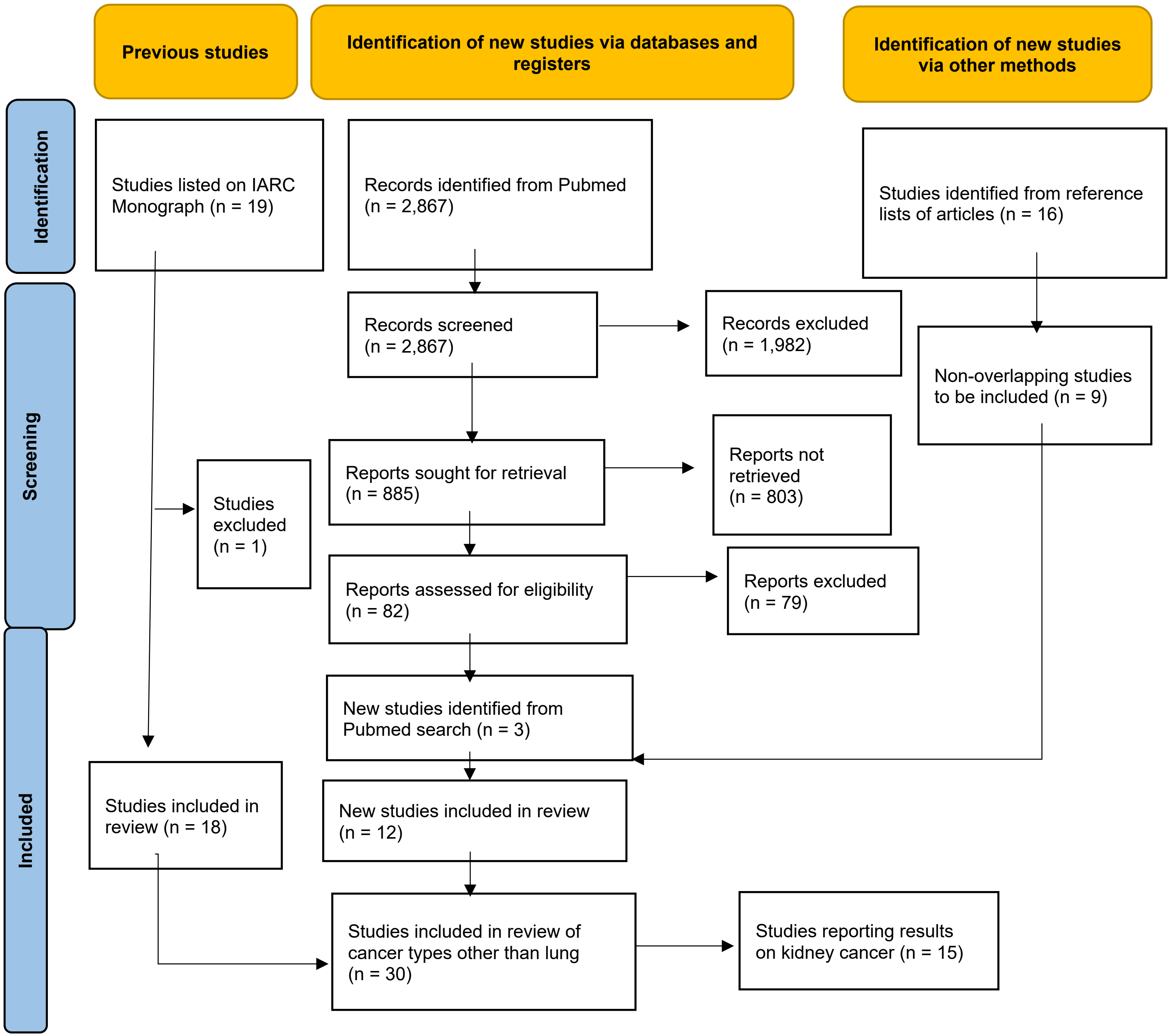
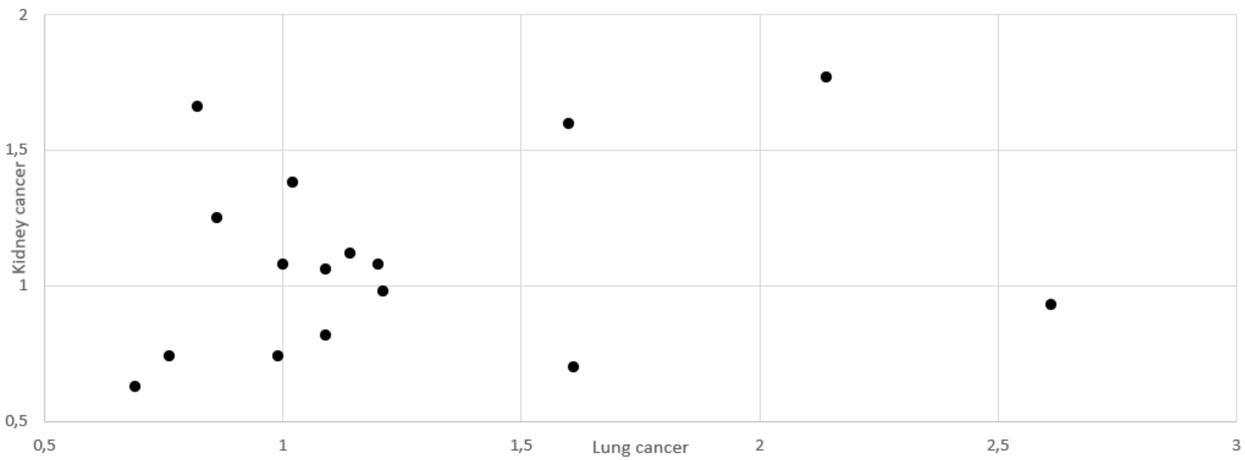


Figure S2. Scatter plot of unweighted correlation coefficients between risk of lung and kidney cancers of the 16 studies reporting them.



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Evaluation of the Workplace Accident Severity in an Underground Coal Mine By Logistic Regression Analysis

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Keywords: Accident Severity, Injury, Underground Coal Mining, Work Accident

Abstract

Background: *Accidents in underground coal mining can cause deaths, serious injuries, and material losses.* **Methods:** *This study examined 10,334 work accidents that occurred between 2011 and 2021, resulting in injuries, and evaluated the causes, severity, and types of injuries. The accidents were investigated under the following subheadings: location of accidents, causes of accidents, work shifts when the accidents occurred, accident time, accident days, distribution of accidents by months and years, age of workers, occupational groups, educational status of workers, working day losses, and body parts that were injured. The severity of accidents was categorized into three levels: mild, moderate, and severe, based on the workday losses incurred by the workers after the accident. The severity of accidents and factors affecting their severity were analyzed using multinomial logistic regression.* **Results:** *There is a significant statistical relationship between the severity of accidents and factors such as experience, workplace, accident cause, age, education status, occupational category, and the affected body part, work shift, according to the analysis. The findings indicate that accident severity is influenced not only by the immediate circumstances of the incident but also by broader individual and occupational factors, such as the employee's level of experience, the work environment, the occupational group, and the specific body part affected. The analysis revealed that the occupational group variable had statistically significant interaction effects with multiple other variables.* **Conclusions:** *The study presents all aspects of the hazards faced by the workers and suggests measures to reduce the number and severity of accidents that occur in underground coal mining.*

1. Introduction

Mining is one of the sectors that includes the most occupational health and safety risks. In particular, underground coal mining is a complex process. It requires numerous professional disciplines (mining, geological, geophysical, mechanical, and electrical and electronics engineering) to work in harmony under changing environmental conditions, where carelessness and small mistakes can result in significant injury [1]. A lack of qualified personnel in underground and surface mining operations, failures in periodic maintenance of heavy machinery, and faulty operating methods can lead to an increase in work-related accidents.

In the Occupational Health and Safety Law (OHSL), a work accident is defined as "an event that occurs in the workplace or due to the execution of work, causing death or causing mental or physical disability to the unity of the body" [2]. The International Labour Organization (ILO) defines a work accident as "an unexpected and unplanned event

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that occurs outside or in connection with work, including acts of violence, that causes injury, illness, or death of one or more workers". Work accidents are categorized into fatal and non-fatal, depending on the severity of their occurrence. Work accidents with injuries are grouped according to loss of working days and permanent disability [3]. In Turkey, the Social Security Institution (SSI) determines the severity of work accidents with injuries: Working on the same day, 1 day of work loss, 2 days of work loss, 3 days of work loss, 4 days of work loss, five or more days of work loss [4].

Work accidents can happen in underground mines due to cave-ins, gas and dust explosions, transportation of equipment, flooding, machinery use, electrical hazards, mine fires, falling material or slips, lack of breathable air, and exposure to toxic and suffocating gases, among other causes. These accidents often lead to fatalities, serious injuries, and material damage [5]. One effective way to prevent work accidents is to analyze past incidents and develop appropriate mitigation measures. There are numerous studies on work accidents available in the literature [6-11].

This study systematically examined work accidents that occurred between 2011 and 2021 in an underground coal mine in Turkey over a 10-year period. Unlike similar studies, it analyzed not only the types of accidents but also various personal and occupational variables—such as injured body parts, workers' educational levels, occupational groups, work duration, and age—to evaluate their combined impact on accident severity. As one of the few studies conducted in Turkey's underground coal mining sector using such a comprehensive dataset and multinomial logistic regression analysis methods, this research is considered to make a significant contribution to the literature.

2. Methods

Classifying accidents solely as injuries and fatal incidents is insufficient for a detailed analysis (Figure 1).

It is essential to classify injuries based on whether they lead to lost workdays or not (when a worker returns to work on the same day). The probability of an accident offers insights into the frequency of work-related incidents across various sectors; however, data on lost workdays also indicate the severity of accidents within these sectors. This study analyzed accident severity according to the number of lost workdays. Work accidents with no injury or with a loss of 2 or fewer workdays were categorized as "mild injury," a loss of 3-9 days as "moderate injury," and a loss of 10 or more days as "severe injury." According to the Regulation on Social Insurance Procedures, the workplace physician authorized by the company can prescribe rest for up to 2 days, while an institutional healthcare physician can prescribe up to 10 days of rest [12]. Therefore, the classification was based on the authority of both the workplace physician and the institutional healthcare physician. Factors affecting accident severity were

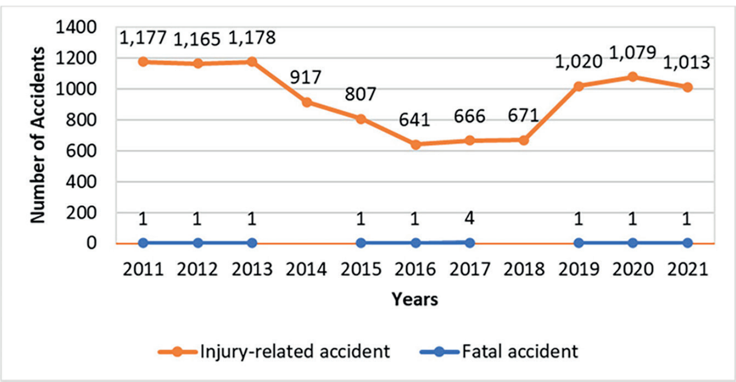

Figure 1. Injuries and fatal work accidents in an underground coal mine from 2011–2021.

Table 1. Dependent and independent variables.

Variables	**Categories**
Dependent variable	
Accident severity	1. Mild (working day loss < 3); 2. Moderate (working day loss 3-9)and 3. High severity (working day loss ≥ 10)
Independent variables	
The body part injured	1. Head, face, eyes; 2. Hand, finger; 3. Foot, toe; 4. Arm, shoulder; 5. Leg, calf; 6. Torso and other parts (reference category)
Workplace	1. Mine face; 2. Preparation; 3. Transportation(reference)
Occupational group	1. Preparation worker; 2. Production worker; 3. Transportation worker (reference)
Age (y)	1. 18–23; 2. 24–29; 3. 30–35; 4. 36–41; 5. 42 and over (reference category)
Duration of work (y)	1. 0–4; 2. 5–9; 3. 10–14; 4. 15–19; 5. 20 years or more (reference category)
Education status	1. Primary school; 2. Middle school; 3. Secondary school and above (reference)
Cause of the accident	1. Electricity and machinery; 2. Cave-in; 3. Transportation; 4. Firedamp and gases; 5. Material handling and use; 6. Miscellaneous/other (reference category)
Shift	1. 07:59–15:59; 2. 16:00–23:59; 3. 00:00–07:59 (reference category)

analyzed using multinomial logistic regression analysis. A multinomial logistic regression model was created to identify variables (such as workplace, occupational group, age, injured body part, experience, shift, etc.) that influence accident severity. Data were processed using IBM SPSS 22.0. In this study, accident severity (mild, moderate, and severe) was the dependent variable, while occupational group, workplace, cause, injured body parts, and age group served as independent variables. Table 1 lists the variables considered.

3. Results

Between 2011 and 2021, this enterprise experienced 10,334 injuries and 12 fatal accidents (Figure 1). The number of accidents decreased after 2013, then rose again after 2016. No fatal accidents occurred in 2014 and 2018.

Table 2 displays the distribution of accidents based on the demographic information of the study groups. The most common causes of accidents (43.1%) were related to material handling and use (Table 2). The least common causes involved firedamp and gases. Accidents mainly occurred in July (9.2%) and March (9%) (Supplementary Material, Figure S1). The majority of accidents happened on Monday (19.7%), Tuesday (19.4%), and Wednesday (19.5%) (Supplementary Material, Figure S2). After the first three workdays of the week, the accident rate gradually declined.

When accidents occurring during three different shifts are analyzed in 2-hour intervals, the most frequent accidents happen in the 2nd hour, followed by the 3rd and 1st hours, with the fewest accidents in the 4th hour of each shift (Supplementary Material, Figure S3). For the total number of accidents across different shifts (Table 2), the highest count occurs during the 1st shift, likely due to increased preparation, repair, and scanning activities during this time. Additionally, workers' difficulty in fully concentrating during the initial hours of their shifts and their struggle to adapt may also contribute to the occurrence of accidents (Table 2).

One factor contributing to accidents is employees' educational background. Notably, 49.7% of employees who experienced accidents in underground coal mining had only completed primary school (Table 2). When examining the experience of workers involved in accidents, it was found that the accident rate was 40.6% for those with 0–4 years of work experience and 32.7% for those with 5–9 years of experience. The rate declined as experience increased, although the highest number of accidents occurred

Table 2. Distribution of accidents based on demographic information of the study groups.

Demographic information		**N.**	**%**
Accident severity	Mild (working day loss < 3)	1,330	12.9
	Moderate (working day loss 3-9)	4,552	44.0
	High (working day loss ≥ 10)	4,452	43.1
Injured body parts	Head, face, eyes	1,017	9.8
	Hand, finger	3,124	30.2
	Foot, toe	2,010	19.5
	Arm, shoulder	1,254	12.2
	Leg, calf	1,054	10.2
	Torso and other parts	1,875	18.1
Workplace	Mine face	8,494	82.2
	Preparation	1,033	10
	Transportation	807	7.8
Occupational group	Preparation worker	1,269	12.3
	Production worker	7,987	77.3
	Transportation worker	1,078	10.4
Age (years)	18–23	407	3.9
	24–29	2,488	24.1
	30–35	4,362	42.2
	36–41	2,579	25.0
	42 and over	498	4.8
Experience (years)	0–4	4,196	40.6
	5–9	3,376	32.7
	10–14	2,184	21.1
	15–19	448	4.3
	20 years or more	130	1.3
Educational status	Primary school	5,132	49.7
	Middle school	1,669	16.2
	Secondary school and above	3,533	34.2
Accident cause	Electricity and machinery	103	1.0
	Cave-in	2,471	26.5
	Transportation	573	5.5
	Firedamp and gases	56	0.5
	Material handling and use	4,455	43.1
	Other	2,406	23.3
Shift	08:00–15:59	5,456	52.8
	16:00–23:59	2,734	26.5
	00:00–07:59	2,144	20.7

among workers in the production group. The body parts most frequently affected by accidents were hands and fingers (30.2%), feet and toes (19.5%), and the torso and other areas (18.1%) (Table 2).

Approximately 12.9% of injured employees returned to work within 0–2 days, 44% within 3–9 days, and 43.1% after 10 or more days. The number of accidents with moderate and high severity exceeded those with mild severity (Table 2).

The severity of accidents and the factors influencing their severity were analyzed using multinomial logistic regression. These results show that the impact of the occupational group on accident severity becomes clearer when considered alongside other variables.

The fact that the interactions between the occupational group and variables such as accident cause, workplace, educational status, and shift were found to be statistically significant suggests that the severity of work accidents should be assessed not only based on individual factors but also within the context of the occupational group (Supplementary Material, Table S1).

As shown in Table S1, the occupational group variable displays significant interaction effects with several other predictors. Therefore, the analyses were stratified by occupational group to allow for a more precise and context-sensitive interpretation of the results. The multinomial logistic regression analysis indicates that being a preparation worker is linked to a significantly lower likelihood of experiencing minor injuries (fewer than three lost workdays) compared to severe injuries (ten or more lost workdays) ($B = -0.609$; $p < 0.001$). This suggests that preparation workers may face a higher risk of more severe occupational injuries. Similarly, being a production worker is significantly associated with decreased odds of minor injuries versus severe injuries ($B = -1.486$; $p < 0.001$), implying that this group also encounters an increased risk of serious workplace accidents. For transportation workers, the model likewise shows a significantly reduced likelihood of minor injuries compared to severe injuries ($B = -0.467$; $p < 0.001$), indicating a greater vulnerability to severe injury outcomes within this occupational category (Supplementary Material, Table S2).

Based on the model fit information, including the Pearson and Deviance statistics, the established model is determined to be statistically significant (Supplementary Material, Table S3-S4).

The variables of age, injured part, and experience are significantly linked to accident severity, as removing them from the model causes a notable decline in model fit ($p < 0.05$). Furthermore, interaction terms between occupational group and other variables—such as accident cause, education level, workplace, and shift—significantly improve the model's ability to explain the variation in accident severity (Supplementary Material, Table S5).

The factors influencing accident severity were examined using a multinomial logistic regression model. The dependent variable was accident severity, classified into three categories based on lost workdays: 0–2 days, 3–9 days, and ≥10 days (reference category). Independent variables included experience, workplace, occupational group, cause of the accident, age, injured body part, education level, and work shift. Additionally, interaction terms between occupational branch and each of these variables were assessed to understand their combined effects on accident severity (Table 3).

Statistically significant interactions were identified between the occupational group variable and several other variables. The interaction between occupational group = 1.00 and accident cause = 5.00, as well as the interaction between occupational group = 1.00 and education = 1.00, are statistically significant in the mild severity (0–2 days) category; the interaction between occupational group = 1.00 and accident cause = 3.00 is statistically significant in the moderate severity (3–9 days) category.

4. Discussion

This study analyzed in detail the injuries caused by accidents in an underground coal mine from 2011 to 2021, focusing on various individual and occupational risk factors. It revealed that multiple factors influence the severity of accidents. Among the workers involved in an accident, 42.2% (n = 4,362) were aged 30–35, 25% (n = 2,579) were 36–41, 24.1% (n = 2,488) were 24–29, 3.9% (n = 407) were 18–23, and 4.8% (n = 498) were 42 and older. Most

Table 3. Parameter estimates

Accident Severity[a]		B	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower Bound	Upper Bound
1. Mild (Working Day Loss < 3)	Intercept	1.457	0.000			
	[Accident Cause =1.00]	-1.627	0.000	0.197	0.084	0.460
	[Accident Cause =3.00]	-1.040	0.000	0.353	0.215	0.581
	[Accident Cause =5.00]	-0.691	0.001	0.501	0.337	0.746
	[Educational Status=1.00]	-0.995	0.000	0.370	0.250	0.546
	[Workplace=1.00]	-0.939	0.000	0.391	0.258	0.592
	[Workplace=2.00]	0.733	0.004	2.081	1.266	3.421
	[Injured Body Part=1.00]	0.748	0.000	2.114	1.656	2.698
	[Injured Body Part=2.00]	-0.691	0.000	0.501	0.411	0.611
	[Injured Body Part=3.00]	-0.324	0.003	0.723	0.584	0.895
	[Injured Body Part=5.00]	0.619	0.000	1.857	1.454	2.373
	[Experience=1.00]	-0.858	0.007	0.424	0.227	0.790
	[Experience=2.00]	-0.933	0.003	0.393	0.214	0.722
	[Experience=3.00]	-0.617	0.035	0.540	0.304	0.958
	[Occupational Group =1.00] * [Accident Cause=5.00]	-0.575	0.047	0.563	0.319	0.992
	[Occupational Group =1.00] * [Educational Status=1.00]	0.649	0.017	1.915	1.122	3.267
	[Occupational Group =2.00] * [Educational Status=1.00]	0.949	0.000	2.584	1.689	3.955
	[Occupational Group =1.00] * [Workplace=2.00]	-1.232	0.000	0.292	0.149	0.572
2. Moderate (Working Day Loss 3-9)	Intercept	0.018	0.956			
	[Accident Cause=1.00]	-0.705	0.047	0.494	0.246	0.991
	[Age=1.00]	0.582	0.003	1.790	1.225	2.616
	[Injured Body Part=1.00]	0.579	0.000	1.784	1.493	2.133
	[Injured Body Part=2.00]	-0.582	0.000	0.559	0.494	0.633
	[Injured Body Part=3.00]	-0.212	0.002	0.809	0.706	0.927
	[Injured Body Part=5.00]	0.495	0.000	1.640	1.381	1.948
	[Experience=1.00]	-0.577	0.033	0.562	0.330	0.955
	[Experience=4.00]	-0.586	0.024	0.557	0.335	0.926
	[Shift=1.00]	0.430	0.031	1.538	1.041	2.273
	[Occupational Group =1.00] * [Accident Cause=3.00]	-1.257	0.048	0.285	0.082	0.990

a. *The reference category is High (Working Day Loss ≥ 10).*

accidents occurred at the mine face. Production in underground coal mines is carried out within the time specified in the deadline plan. Underground mining conditions are highly variable; therefore, the monthly production rate must be planned well. Otherwise, occupational accidents are inevitable. The increased rate of accidents in July and March may have been due to efforts to complete production within the specified deadline.

In all three work shifts, accident rates were especially high during the 2nd hour of work and gradually decreased in the subsequent working hours. This may be due to workers' inability to adapt and lack of attention, as a result of starting work in the evening hours in Shift 2 and at night in Shift 3. Working in shifts can cause sleep problems and various physical and mental health issues, which can affect the likelihood of work accidents [13]. When the distribution of accidents in Shift 1 was examined at 2-hour intervals, the highest number of accidents occurred between 10:00 and 11:59. This could be because employees are less able to focus on work before the meal break.

When the causes of accidents were examined, material handling and use were found to be the most common causes of accidents. In addition, the most commonly affected body parts were the hands, fingers, feet, and toes. There are sometimes disruptions in the production rate in underground coal mines, as workplace conditions are constantly changing. With excessive acceleration in the production process, incidents may occur, such as falling rocks, which cause numerous head injuries. Hand, arm, foot, and finger injuries may occur due to material handling and use during accelerated installations. The production group had the highest number of accidents, and 49.7% of the workers had only completed primary school. Karadeniz [14] identified low education status as the primary cause of work-related accidents and illnesses, which can be understood through two aspects. First, uneducated employees often take hazardous jobs to support their livelihoods. The second aspect is that a lack of education hinders employees from recognizing the occupational risks they face.

Accordingly, the reasons for the high number of accidents among production workers may be the dangerous nature of the work and the low level of education. The number of moderate-severity accidents (44%) was higher than that of high-severity (43.1%) and mild (12.9%) accidents. These assessments help determine what kind of accidents can be prevented and how. Furthermore, the accidents that cause the most frequent and highest number of working day losses should be urgently included in the accident prevention program. Based on this justification, accident severity was categorized according to working day losses.

There are many studies about work accidents. Laflamme and Blank [6] examined injuries in underground mines in Sweden from 1980 to 1993 and reported that the most common injuries were to the hands, fingers, and wrists (28%). One study reported that injuries during maintenance and repair at mining sites in the United States result in an average of 20 finger cuts, 180 hand and finger fractures, and 455 hand and finger cuts annually [7]. Similar to previous research findings, hand and finger injuries were the most common in this study. Stojadinovic et al. [8] analyzed accidents using data recorded in Serbian coal mines over 10 years, from 2000 to 2009, examining severity, injured body parts, accident location, shifts, occupational groups, and workers' ages. They found that most accidents were mild, that workers aged 31–40 experienced the highest number of accidents, that injuries mostly involved the upper limbs and occurred during Shift 1, and that injured workers had lower education levels. Tatar and Özfırat [9] investigated work accidents that occurred between 1992 and 2000 at the Eynez underground lignite mine of Aegean Lignite Enterprise in Turkey, which is operated by the Turkish Coal Enterprise (TCE). They assessed workers' ages, shifts, injured body parts, and the day, type, and location of accidents. They observed that accidents increased due to worker demoralization, high work intensity, the transition to mechanized production alongside traditional methods, adaptation issues, and working conditions such as narrow and hazardous environments. Önder and Önder [10] analyzed injuries in TCE-related enterprises in Turkey from 2001 to 2008 and found that cave-ins and material handling were the leading causes. They identified that surface diggers were the riskiest occupational group, that construction machinery was the primary cause of accidents, and that mechanics in the repair, maintenance, and manufacturing departments were at high risk. The most frequently injured body part across all enterprises was the hand. Önder [11] examined non-fatal work accidents with lost workdays occurring from 1996 to 2009 in ELE's open mines under TCE, using binary logistic regression analysis.

This study analyzed the severity of occupational accidents in an underground coal mine in Turkey over a 10-year period using a multinomial logistic regression model. The results showed that experience, age, and the injured part had statistically significant effects on accident severity ($p < 0.05$) (Supplementary Material, Table S5). The occupational group exhibited significant interactions with several predictors; therefore, analyses were stratified by this variable for more precise and context-specific interpretation. The stratified analysis results highlight notable differences in accident severity among preparation, production, and transportation workers, with each group facing a higher risk of severe injuries compared to minor ones.

Additionally, interaction effects between the occupational group and other variables—such as accident cause, education status, workplace, and work shift—also played a significant role in explaining the variation in accident severity. This indicates that accident severity should not be interpreted solely through individual variables but rather through their contextual interactions within specific occupational settings. For example, while material handling was the most common cause of accidents (43.1%, Table 2), its impact on accident severity varied depending on the context. This study examines factors influencing occupational accident severity in underground coal mining, highlighting the roles of occupational group, experience, injury site, cause, education, age, workplace, and shift. Injuries to hands and feet are most common, with severity influenced by occupational roles and shift patterns. Less experienced workers (0–4 years) are more vulnerable, accounting for 40.6% of accidents, emphasizing the importance of targeted training (Table 2).

Multinomial logistic regression revealed that variables such as accident cause, education, experience, age, injured body part, workplace, and shift significantly influence severity, with the majority of outcomes being more severe (≥10 days off). Lower education and experience increased risk, suggesting these may serve as protective factors through increased awareness and safety practices. Specific causes (categories 1, 3, and 5) are more likely to result in serious injuries, underscoring the need for targeted prevention.

The injured body part is crucial; head, chest, or multiple injuries tend to cause longer recovery and work absence, aligning with prior research on injury location and severity. Significant interaction effects indicate that the influence of education and cause varies by occupational group, with some categories at higher risk due to low education or specific accident types.

In summary, the findings reveal the multifaceted nature of accident severity, emphasizing the need for targeted safety training among less experienced and lower-educated workers, as well as enhanced safety measures in high-risk areas and industries.

4.1. Limitations

This study presents valuable insights by comprehensively analyzing occupational accident data from an underground coal mine. However, several limitations should be acknowledged. The most critical limitation is the unavailability of denominator data—specifically, the total number of workers stratified by relevant variables such as age, gender, or occupational group. As a result, it was not possible to calculate precise accident rates or to assess the proportion of accidents in relation to the population at risk. Consequently, definitive conclusions regarding relative risk levels across subgroups (e.g., occupational branches or age categories) could not be drawn. Future studies should aim to access more detailed workforce data, including the number of employees in each subgroup and their exposure times, to enable more precise calculation of accident incidence rates. Comparative studies across multiple mining sites may also enhance the external validity and generalizability of the findings.

5. Conclusion and Recommendations

Underground coal mining is a hazardous activity, with accidents often caused by factors such as excessive speed, fatigue, carelessness, lack of experience, inadequate safety measures, difficult working environments, non-compliance with safety rules, ineffective oversight, and insufficient control mechanisms. Retrospective accident analysis can help identify accident types and locations that cause significant workday loss or damage. Training programs and safety measures should be developed based on these findings, considering accident severity by analyzing the number of rest days lost.

This study examined the severity of occupational accidents in a Turkish underground coal mine from 2011 to 2021, using multinomial logistic regression. Accident severity was classified as less than 3 days, 3–9 days, or 10+ days of work lost, with factors like experience, age, workplace, occupational group, education, shift, cause, and injured body part analyzed for their impact. Significant relationships were found between severity and experience, workplace, cause, education, and injury site. Workers with lower education, less experience, and certain causes are more likely to suffer severe injuries. The injured body part also significantly influenced severity. Interactions between occupational groups and variables like education, shift, and cause suggest the need for tailored safety policies, as uniform approaches may be insufficient.

Findings indicate that accident severity depends on individual attributes and workplace conditions, especially experience, workplace, and occupational group. Interactions between occupational groups and variables such as age, cause, injury site, education, and shift type necessitate customized safety measures for each group. Recommendations include targeted training for less educated and inexperienced workers, specific precautions for high-risk sectors, and protective measures focused on common causes. These measures should help reduce accident frequency and severity.

The study emphasizes moving beyond generic risk assessments towards comprehensive, group-specific safety policies. Proposed actions include providing more training and supervision for new workers, conducting regular analyses of accident causes and injury patterns by sector, restructuring work schedules, and implementing fatigue management, particularly during shift start times. Future research could involve larger datasets or comparative studies across mining enterprises.

Injuries to hands, fingers, and wrists are most common, caused by careless practices, lack of precautions, and neglect of PPE. Safety training must emphasize the use of PPE, including gloves, footwear, and helmets, and ensure compliance. Limb injuries require stronger PPE enforcement and worker evaluation. Frequent warnings and post-accident health assessments are crucial, as accidents affect not only individual workers but also companies and the economy. Regular data analysis can inform prevention strategies.

Accident evaluation data should guide safety training, with the shared goal of zero incidents. Proper use of PPE, responsibility, vigilance, training, and discipline are essential. Regular statistical analysis can prevent similar accidents and mitigate risks, ultimately reducing costs for all parties involved.

Supplementary Material: The following are available online: Figure S1. Monthly distribution of the accidents"; Figure S2. Distribution of the accidents according to days; Figure S3. Distribution of the accidents according to working hours and shifts; Table S1. Step summary; Table S2. Intercept estimates of stratified multinomial logistic regression by occupational group; Table S3. Model fitting information; Table S4. Goodness-of-Fit; Table S5. Likelihood ratio tests.

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Appendix

Supplementary Material

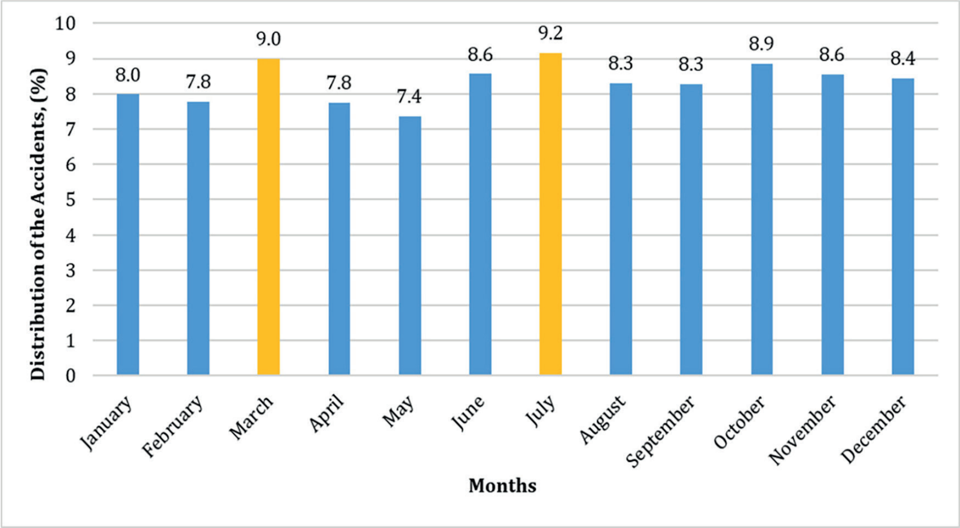

Figure S1. Monthly distribution of the accidents.

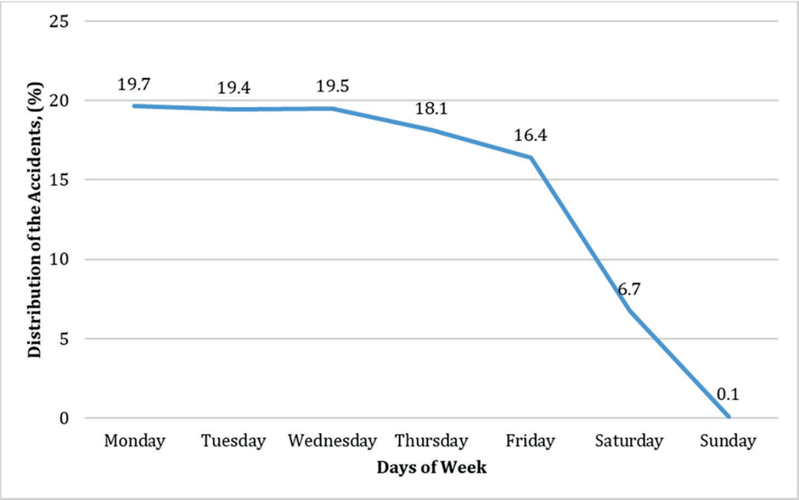

Figure S2. Distribution of the accidents according to days.

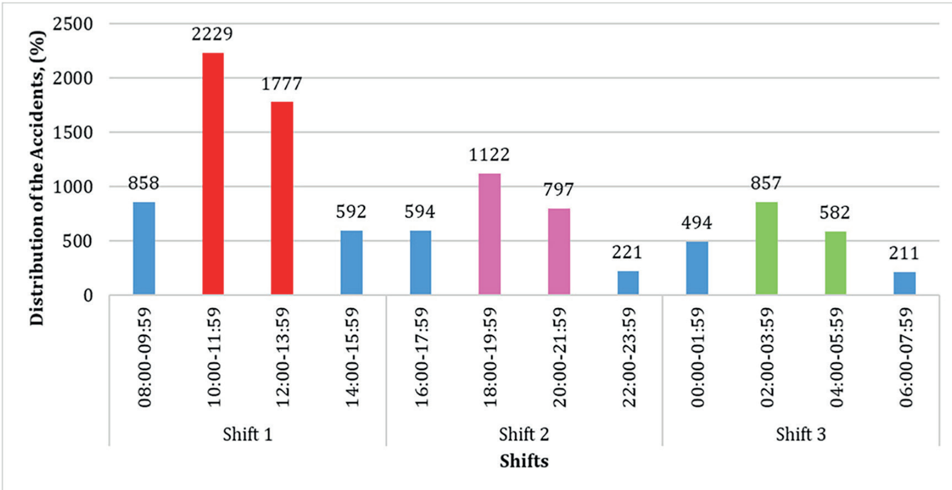

Figure S3. Distribution of the accidents according to working hours and shifts.

Table S1. Step summary.

			Model Fitting Criteria	Effect Selection Tests		
Model	**Action**	**Effect(s)**	**-2 Log Likelihood**	**Chi-Square[a]**	**df**	**Sig.**
0	Entered	Intercept, Accident Cause, Experience, Age, Workplace, Occupational Groups, Injured Body Part, Education, Shift	9756.091			
1	Entered	Occupational Group * Workplace	9719.057	37.035	8	0.000
2	Entered	Occupational Group * Shift	9691.042	28.015	8	0.000
3	Entered	Occupational Group * Education	9663.680	27.362	8	0.001
4	Entered	Occupational Group * Accident Cause	9626.170	37.510	20	0.010

Stepwise Method: Forward Entry
a. The chi-square for entry is based on the likelihood ratio test.

Table S2. Intercept estimates of stratified multinomial logistic regression by occupational group.

Occupational Group	Accident Severity Level	B (Intercept)	SE	Wald	Sig.
Preparation Worker (1)	Mild (Working Day Loss < 3)	-0.,609	0.077	62.442	0.000
	Moderate (Working Day Loss 3-9)	0.105	0.063	2.781	0.095
Production Worker (2)	Mild (Working Day Loss < 3)	-1.486	0.039	1445.512	0.000
	Moderate (Working Day Loss 3-9)	0.025	0.024	1.078	0.299
Transport Workers (3)	Mild (Working Day Loss < 3)	-0.467	0.078	35.824	0.000
	Moderate (Working Day Loss 3-9)	-0.101	0.070	2.071	0.150

Table S3. Model fitting information.

Model	Model Fitting Criteria	Likelihood Ratio Tests		
Intercept	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	10723.515			
Final	9626.170	1097.345	96	0.000

Table S4. Goodness-of-Fit.

	Chi-Square	df	Sig.
Pearson	6465.199	6200	0.009
Deviance	6662.190	6200	0.000

Table S5. Likelihood ratio tests.

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	9626.170[a]	0.000	0	.
Accident cause	9626.170[a]	0.000	0	.
Education	9626.170[a]	0.000	0	
Age	9656.013	29.843	8	0.000
Occupational Group	9626.170[a]	0.000	0	
Workplace	9626.170[a]	0.000	0	
Injured Part	10040.212	414.042	10	0.000
Experience	9655.513	29.343	8	0.000
Shift	9626.170[a]	0.000	0	.
Occupational Group * Accident Cause	9663.680	37.510	20	0.010
Occupational Group* Education	9651.742	25.572	8	0.001
Occupational Group* Workplace	9662.445	36.275	8	0.000
Occupational Group * Shift	9649.996	23.826	8	0.002

a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

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Original Article

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Epidemiological Study of Functional Dry Eye Disease in a Working-class Population in Shanghai, China

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Keywords: Functional Dry Eye Disease; Questionnaire; Risk Factor; Contact Lens; Deep Sleep

Abstract

Background: *To investigate the current status, morbidity, and risk factors of functional dry eye disease (DED) in Shanghai's working-class population and explore measures to prevent and manage functional DED.* **Methods:** *A questionnaire was used to record the data of positively diagnosed functional DED working-class subjects in Shanghai. Subjective symptoms and clinical results were also documented. The classification and corneal staining between subjects who wear contact lenses and those who do not were compared. Correlation of classification and corneal staining with their risk factors was analyzed.* **Results:** *Risk factors of functional DED showed much in common in subjects of this population, though their specific types of work differed. Evaporative dry eye (EDE) accounts for a large proportion of DED (45.35%) and many subjects with co-existing symptoms and signs (mixed DED, 32.64%). The age of 21-40 year old is most prominent, accounting for 70.4% of the subjects. Wearing contact lenses, working with computer monitors, working in air-conditioned offices, interior decoration, staying up later, sleep disorders, and smoking were risk factors in most functional DED subjects. Notably, wearing contact lens is the leading risk factor for causing functional DED and ocular surface complications (both were p<0.01), while deep sleep seems to be a protective factor (p<0.01%).* **Conclusion:** *The incidence of functional DED in Shanghai is high, and most risk factors are closely related to daily work and life conditions. Reducing and eliminating these daily risk factors are expected to be uesful in preventing and managing functional DED.*

1. Introduction

Dry eye disease (DED) is a multifactorial condition of the ocular surface characterized by a loss of homeostasis in the tear film, accompanied by ocular symptoms. In this condition, tear film instability and hyperosmolarity, ocular surface inflammation and damage, and neurosensory abnormalities play significant etiological roles [1]. According to a meta-analysis conducted in the United States, the estimated incidence rates of DED and meibomian gland dysfunction (MGD) are 8.1% and 21.2%, respectively. In comparison, the incidence rate of DED in China is reported to be 17.0% [2, 3]. A 10-year investigation found that DED symptoms have not been effectively treated; the discomfort and visual disturbances experienced by patients have continuously worsened, significantly impacting their daily work and lives [4].

Similarly, in Shanghai, a major metropolis in China, DED is becoming an increasingly prominent issue for the working class. The work pace in

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Shanghai is quickening, along with a fast-paced lifestyle, leading to heightened anxiety among the population. Mobile phones, computers, and other electronic devices have become essential in daily activities. Furthermore, factors such as a polluted environment, confined work and living spaces, frequent overtime, poor sleep habit, and insomnia likely contribute to an unhealthy state of the eye, resulting in insufficient tear film quality or quantity and a high incidence of DED. The pathogenetic classification divides DED into aqueous deficient dry eye (ADDE) and evaporative dry eye (EDE). ADDE describes conditions affecting lacrimal gland function, while EDE encompasses lid and ocular surface-related causes. Recently, Bron et al. published a series of reports on the clinical diagnosis and treatment of DED [5]. They proposed that the causes and classifications of DED are diverse, and thus, the corresponding treatment methods should also be personalized, reflecting the pathophysiological aspects of DED. Notably, in 2019, Liang et al. described the concept of functional DED, referring to patients with dry eye symptoms but without detectable signs [6]. In our clinical practice, we also found that most dry eye patients belong to this subtype, displaying a discrepancy between subjective ocular symptoms and objective signs, with unexplained severe symptoms absent visible indicators. Additionally, the triggering factors for most dry eye patients can be attributed to various unhealthy work and lifestyle habits, such as excessive use of computers and mobile phones, working overtime, staying up late, poor sleep quality, and continuous contact lens wear. It is feasible to prevent and treat DED by addressing these pathogenic factors. This aligns with a recent Chinese expert consensus on lifestyle-related dry eye and the Tear Film & Ocular Surface Society (TFOS) lifestyle epidemic report series on ocular surface diseases [7-11].

In light of this, we sought to explore the characteristics of functional DED within the working-class population in Shanghai, a typical metropolis in China. We enrolled 527 functional DED patients representing various industries in Shanghai. We administered a questionnaire to identify the risk factors associated with functional DED. An additional study combined the survey data with clinical examinations, revealing a high incidence of functional DED among the working class in Shanghai, with most cases linked to risk factors related to their daily work and life.

2. Methods

In this study, we only focused on the working class in Shanghai. They were all diagnosed in our hospital as functional DED patients.

The study protocol was approved by the Medical Ethics Committee of Huashan Hospital (No. 2021-880) and adhered to the tenets of the Helsinki Declaration in 2000. All participants gave informed consent. A power analysis was performed to determine the number of patients needed to be enrolled in the study.

2.1. Enrolled Patients

This study surveyed 527 patients diagnosed with functional DED. The enrolled subjects were office workers who lived and worked in the Shanghai metropolitan area. The scope of data collection included individuals working in various industries throughout Shanghai without any significant primary or organic diseases.

Patients with functional DED were enrolled based on the TFOS Dry Eye Workshop II (DEWS II) definition and classification and the Chinese expert consensus on dry eye [1, 7]. The criteria included the following items: (1) Dry eye symptoms - discomfort, photophobia, gritty sensation, etc. (2) Tear break-up time (TBUT) - less than 10 s. (3) Tear film curvature radius - less than 0.5 mm. (4) Positive corneal staining. (5) Abnormal morphology or opening of the meibomian gland. (6) Elevated tear film osmolality.

The inclusion standards required that the presence of symptoms and two or more positive examination indices mentioned above met the criteria for functional DED. The exclusion criteria included (1) Diabetes, (2) Sjogren's syndrome, (3) Ankylosing spondylitis, (4) Laser-assisted myopia correction or keratoplasty, (5) Active ocular surface inflammation, (6) Cataract surgery or similar procedures, and (7) Other known diseases or medications that could cause dry eye.

2.2. Characteristics of Subjects

In the study population, age of 21-40 years old was the prominent group with functional DED, accounting for 70.4% of the total enrolled subjects. There were more female than male patients (1.27:1), and subjects with college degrees and above accounted for 87.8%. The subjects' occupations cover various industries. IT practitioners, finance, teachers, science researchers, computer designers, marketing and consultants were the most common types of jobs with functional DED patients, accounting for 78.8% (Table 1).

Table 1. Basic Characteristics of Enrolled Patients

Characteristics	N (%)
Total	527 (100)
Age (years old)	
• ≤20	4 (0.8)
• 21-30	178 (33.8)
• 31-40	193 (36.6)
• 41-50	113 (21.4)
• ≥51	39 (7.4)
Gender	
• Male	232 (44.0)
• Female	295 (56.0)
Highest Education	
• Middle school or lower	3 (0.6)
• High school	61 (11.6)
• University or college	281 (53.3)
• Graduate school	182 (34.5)
Profession	
• IT pratitioner	92 (17.5)
• Office staff	42 (8.0)
• Financial staff	46 (8.7)
• Teacher/researcher	103 (19.5)
• Computer design	79 (15.0)
• Consultant	53 (10.1)
• Others	112 (21.2)
DED classification	
• ADDE	116 (22.0)
• EDE	239 (45.4)
• Mixed DED	172 (32.6)

2.3. Observation of Clinical Symptoms and Signs

In our clinical practice, when a subject reported dry eye symptoms such as dryness, a foreign body sensation, and burning discomfort without other abnormal signs like vision problems, intraocular pressure changes, or fundus abnormalities, we initially diagnosed the patient as functional DED suspect. We then utilized a corneal topography instrument (SW-6000D, Suoer Electronic Technology Co., Ltd., Tianjin, China) to conduct specific dry eye examinations. Additionally, we observed the meibomian glands and checked for positive staining of the cornea with fluorescein sodium using a slit lamp microscope (YZ5X1, 66 Vision Tech Co., Ltd., Suzhou, Jiangsu, China). When necessary, we employed an osmometer (Osmotic Molar Concentration Tester SMC 30C, Tianhe Analytical Instrument Co., Ltd., Tianjin, China) to assess the osmotic pressure of tear fluid. If two or more indices from these examinations aligned with DED, and other related diseases and surgeries were excluded, the patient was diagnosed as functional DED. We documented the subjective symptoms and their clinical observations, which primarily includes the state of the meibomian glands, TBUT, tear film curvature radius, and corneal fluorescein staining.

2.4. Questionnaire Survey

We maintained effective communication with patients diagnosed with functional DED, clarified relevant items, and encouraged them to join our functional DED volunteer program. After obtaining the patient's consent and signature confirmation, we provided a DED questionnaire survey form for them to complete on-site. The enrolled patients' age, gender, type of work, and education background were expected to reflect the general characteristics of this population in Shanghai. The questionnaire thoroughly documented their work nature and lifestyle habits, particularly focusing on underlying risk factors such as electronic screens (mobile phones, computers, TVs), daily life, working environment, contact lens use, and more. All survey forms were ultimately submitted to the researchers for evaluations and statistical analysis.

2.5. Statistical Analysis

Statistical analysis was carried out using IBM SPSS software version 22.0. Data were expressed as mean or mean ± standard errors. Using a chi-squared test, frequencies and DED classification percentages were compared between functional DED patients wearing contact lenses and other functional DED patient groups. DED classification and corneal staining associations with potential risk factors were estimated using multivariate logistic regression.

3. Results

3.1. Functional DED Classification

Among 527 functional DED patients, we found that most participants were classified as EDE (n = 239; 45.4%). A significant number exhibited symptoms and signs of two types of DED (n = 172; 32.6%). The remaining subjects were diagnosed as ADDE (n = 116; 22.0%). Additionally, DED classification correlates with the frequent use of electronic screens, air conditioning, contact lenses, smoking, and drinking alcohol (Table 1 and Figure 1). These data of the distribution of DED classes align with the conclusions of the TFOS DEWS II Definition and Classification Report [1].

3.2. Evaluation of Potential Risk Factors

We administered a questionnaire to the enrolled patients to understand the potential risk factors of functional DED in the working class. We included specific questions that the general population in China believes are potential causes of DED. The specific questions, responses, and response rates are shown in the supplementary table (Table S1).

Based on this questionnaire and the patients' responses, we used logistic regression analysis to evaluate the potential association of these factors with DED. The multivariate logistic regression analysis and calculated odds ratios of these factors are shown in Table 2.

This analysis demonstrates no statistically significant correlation among the study subjects between functional dry eye disease (DED) and the variables

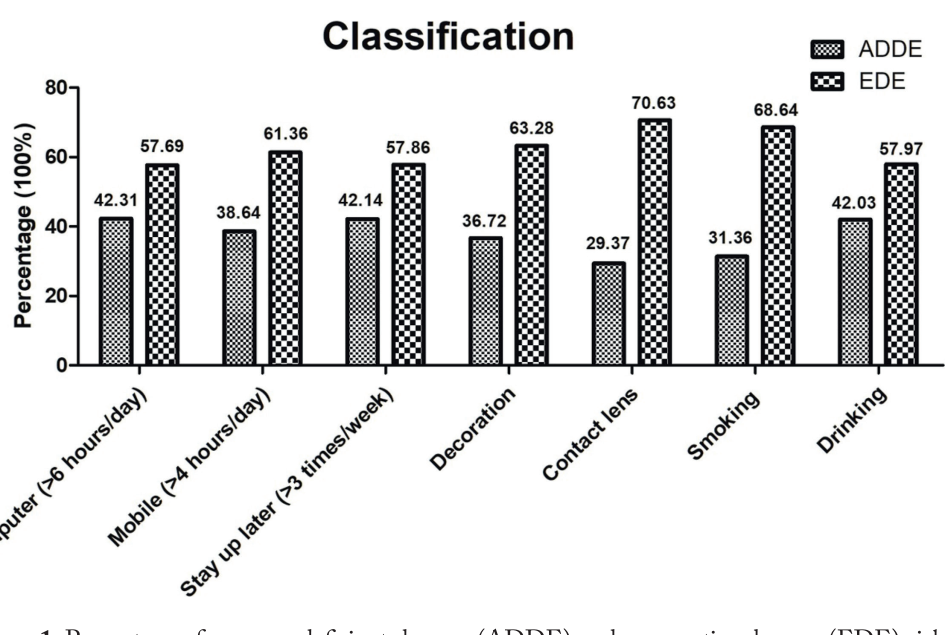

Figure 1. Percentage of aqueous deficient dry eye (ADDE) and evaporative dry eye (EDE) risk factors is classified based on primary manifestations.

Table 2. Multivariate logistic regression analysis of various factors vs. functional DED.

Factors	*p*	Odds ratio	95% CI	
			Lower	Upper
Gender	0.494	0.815	0.453	1.466
Age	0.061	1.516	0.980	2.345
Education	0.901	1.038	0.578	1.863
Computer use	0.007*	2.847	1.328	6.104
Mobile phone use	0.004*	2.349	1.317	4.188
Television time	0.199	0.716	0.431	1.192
Deep sleep length	0.014#	0.685	0.507	0.926
Staying up late	0.007*	1.781	1.171	2.710
Staying under air-conditioning	0.843	1.184	0.221	6.347
Recent home/office renovation	0.014*	2.817	1.234	6.430
Work pressure	0.152	0.676	0.396	1.155
Anxiety	0.871	0.975	0.721	1.319
Wearing Contact lens	0.003*	2.104	1.282	3.453
Frequent overtime work	0.216	0.597	0.263	1.352
Smoking	0.000*	4.630	2.394	8.953
Drinking alcohol	0.008*	1.786	1.162	2.746

*Note: *: $p<0.05$, increase risk of DED, #: $p<0.05$, decrease risk of DED.*

of gender, age, or education level. Nonetheless, a trend suggests increased odds in the older age group, with an odds ratio of 1.516 ($p = 0.061$). Furthermore, the survey indicates that daily average time spent watching television, residing in air-conditioned environments, or engaging in frequent overtime work is not associated with functional DED. Similarly, the psychological states of the patients, including work-related pressure and anxiety, do not significantly influence the odds ratio of DED. Conversely, average daily time spent using a computer or mobile phone, wearing contact lenses, and undergoing recent home or office renovations are all associated with an increased odds ratio of functional DED by more than twofold.

Additionally, frequent alcohol consumption is linked to a heightened risk of DED. Notably, smoking emerges as a lifestyle habit exerting the most substantial impact on DED, with the odds ratio for smokers being 4.63 times (95% CI = 2.394-8.953) that of non-smokers. Among all factors analysed, the average nightly duration of deep sleep correlates with a decreased risk of functional DED by more than 30% (odds ratio = 0.685).

To provide an objective and independent evaluation of the patients' DED conditions, we employed a corneal topography instrument to confirm signs of dry eye. We also assessed the meibomian glands and examined the cornea for positive staining using a slit lamp microscope after the topical ocular administration of fluorescein sodium (Figure 2).

Subsequently, we analysed the potential association of lifestyle factors with positive corneal staining through logistic regression analysis. The multivariate logistic regression analysis and calculated odds ratios for these factors in relation to corneal staining are presented in Table 3.

This analysis of corneal staining produces similar results to that of DED evaluation in some factors but different results in others. For example, there is no statistically significant correlation between functional DED or corneal staining and gender, age, or

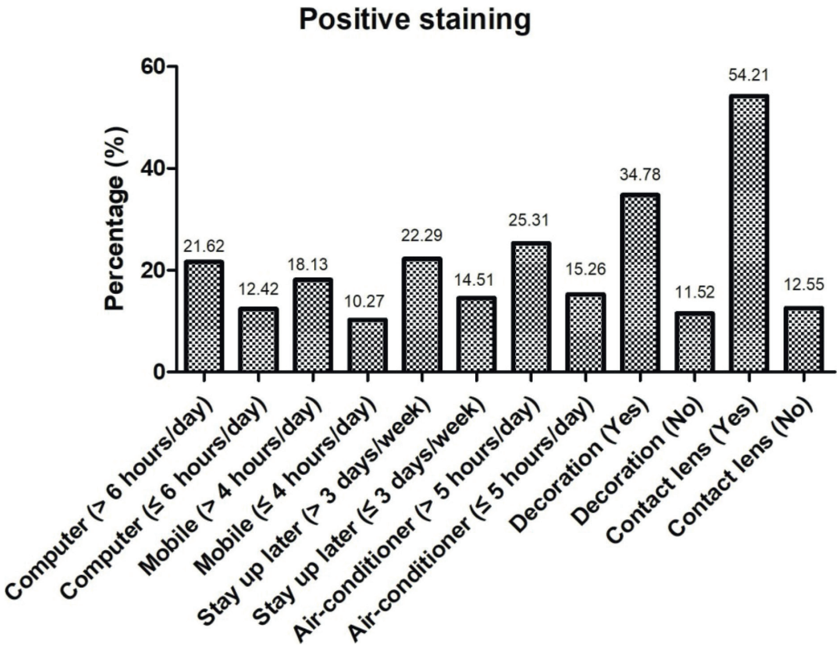

Figure 2. Percentage of positive corneal staining in risk factors.

Table 3. Multivariate logistic regression analysis of various factors vs. corneal staining results.

Factors	*p*	Odds ratio	95% CI Lower	95% CI Upper
Gender	0.055	1.818	0.987	3.347
Age	0.535	0.861	0.537	1.381
Education	0.426	1.286	0.692	2.388
Computer use	0.007*	1.626	1.142	2.315
Mobile phone use	0.003*	2.072	1.289	3.33
Television time	0.770	1.077	0.654	1.776
Deep sleep length	0.006#	0.458	0.263	0.795
Staying up late	0.000*	2.044	1.391	3.002
Staying under air-conditioning	0.006*	2.081	1.240	3.493
Recent home/office renovation	0.038*	1.989	1.039	3.81
Work pressure	0.112	0.604	0.324	1.125
Anxiety	0.158	1.757	0.803	3.844
Wearing Contact lens	0.025*	1.922	1.087	3.399
Frequent overtime work	0.232	1.300	0.846	1.998
Smoking	0.445	1.154	0.799	1.666
Drinking alcohol	0.500	1.311	0.596	2.884

*Note: *: $p<0.05$, increase risk of cornea staining, #: $p<0.05$, decrease risk of cornea staining.*

education level. Time spent watching television or frequent overtime work is not associated with functional DED or corneal staining.

Patient psychological states, like work-related pressure or anxiety, do not significantly influence the odds ratio of corneal staining. In contrast, daily time spent on computers, mobile devices, wearing contact lenses, and recent home or office renovations increases the chances of functional dry eye disease (DED) by over twofold. Nightly deep sleep duration correlates with a decreased risk of corneal staining. However, results for corneal staining differ from DED evaluations. Time spent in air-conditioned environments does not significantly impact functional DED risk but is a known risk factor for corneal staining. While smoking and alcohol consumption affect self-reported DED, they do not increase the risk of corneal staining. These differences between functional DED evaluations and corneal staining highlight a divergence between subjective experiences and objective symptoms.

3.3. Contact Lens

Both the results of the questionnaire and the clinical examination showed that contact lens was a leading risk factor for EDE (Table 2, p=0.003, 95% CI: 1.282-3.453) and ocular surface complications (Table 3, p=0.025, 95% CI: 1.087-3.399). By questionnaire data, we found that the proportion of DED patients who used contact lenses was not very high (22.39%), while the incidence of symptoms and signs were much higher than other DED patients. The symptoms, such as eye dryness, gritty sensation, photophobia, and ocular surface irritation were much higher than those induced by other risk factors. The incidence of EDE and ocular surface lesions such as corneal epithelial exfoliation were invariably detected in contact lens wearers (Figure 3, P <0.01).

3.4. Deep Sleep

Deep sleep acts as a protective factor in our study, contrasting with other risk factors. Our multivariate regression analysis indicates a protective effect in dry eye disease (DED) (Table 3, p=0.014, 95% CI: 0.507-0.926) and ocular surface lesions (Table 3, p=0.006, 95% CI: 0.263-0.795). Notably, increased deep sleep duration inversely correlates with DED incidence. Classification analysis reveals that as deep sleep duration rises, the incidence of evaporative dry eye (EDE) declines, along with its proportion in DED (Figure 4 (A), P < 0.01). Additionally, prolonged deep sleep appears to benefit ocular surface tissue function, as indicated by a gradual decrease in corneal staining incidence. Subjects with less than 6 hours of deep sleep exhibited significantly higher staining rates compared to those with over 7 hours (Figure 4 (B), P).

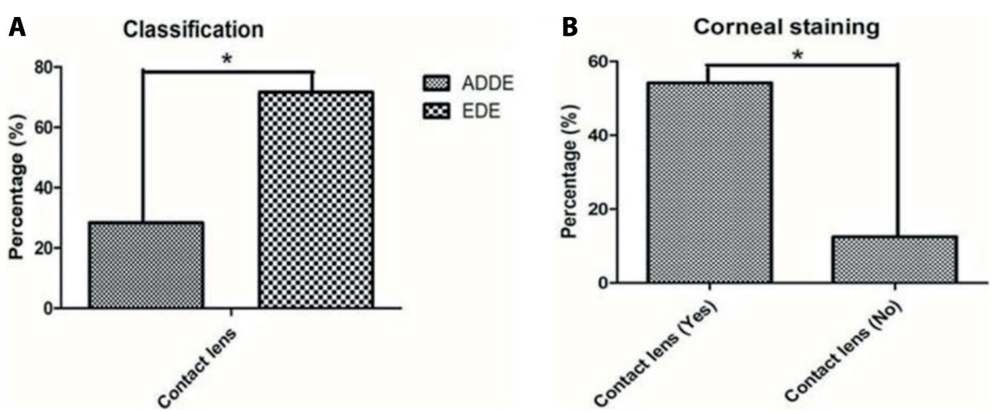

Figure 3. χ^2 test for DED and corneal staining. (A): *evaporative dry eye (EDE) prevalence *vs* that in the aqueous deficient dry eye (ADDE) in the contact lens group, P <0.01. (B): *positive corneal staining percentage in the contact lens group versus that in no contact lens groups, P <0.01.

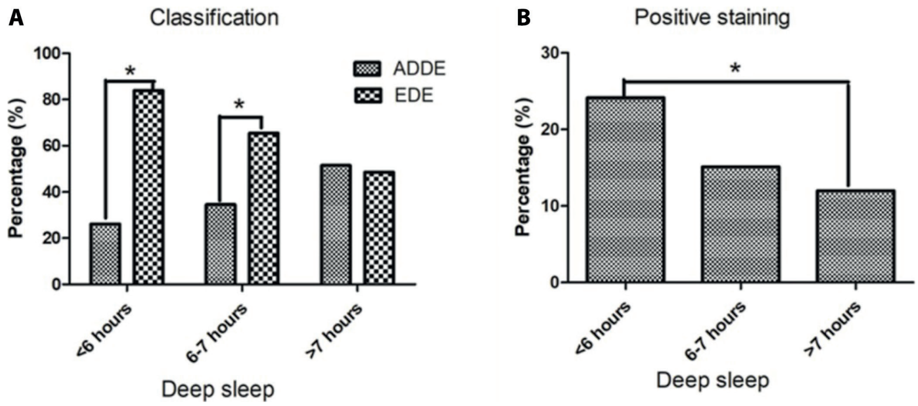

Figure 4. χ^2 test for deep sleep. (A): *prevalence of aqueous deficient dry eye (ADDE) *vs* evaporative dry eye (EDE), P <0.01. (B): * positive corneal staining incidence in <6 hours deep sleep *vs* >7 hours deep sleep, P <0.01.

4. DISCUSSION

Shanghai, as an international metropolis, showcases a fast-paced work and life rhythm for its working-class population. Clinical data indicates that functional dry eye disease (DED) has become a significant concern among workers. Daily, we encounter numerous DED patients, predominantly healthy individuals who often appear fatigued. Common traits among these patients include a rapid work pace, high stress levels, frequent overtime, irregular lifestyles, extensive use of electronic screens, and regular contact lens use. Recent research highlights occupational and lifestyle-related risk factors for DED, leading to important prevention and treatment guidelines [8-11]. Chinese researchers have introduced the concept of functional DED, associating it with unhealthy habits and proposing related expert consensus [7].

Our questionnaire reflects a high incidence of functional dry eye (DED) among Shanghai wage earners across various occupations, mainly due to the contemporary work environment and pace. Despite unique job characteristics, many share traits like high pressure, constant device use, and prolonged time in air-conditioned settings that impact their health. Most patients in our study sample are classified as having evaporative dry eye (EDE). However, some exhibit mixed DED, showing signs of aqueous deficient dry eye (ADDE) and EDE, aligning with TFOS DEWS II reports.

Prolonged high-frequency use of digital devices is a recognised risk factor for dry eye disease (DED) [12, 13]. Increased concentration reduces blink frequency, leading to partial or complete uncovering of the tear film on the cornea before the next blink. This intermittent exposure results in effects similar to those of the evaporative dry eye (ADDE), increasing tear osmotic pressure and causing inflammation on the ocular surface. Modern office environments also contribute to DED, primarily due to air conditioning and renovations [11, 14]. Air conditioning lowers humidity and increases tear film evaporation. Renovation materials can irritate the eyes, prompting reflex tear secretion and damaging the ocular surface.

Attention should also be paid to the damage caused by contact lenses. Their friction can harm conjunctival and corneal tissues, disrupting the epithelial cell barrier and causing inflammation [15, 16]. Additionally, contact lenses can damage meibomian glands and interfere with tear film dynamics, impeding tear production and leading to abnormalities in tear function [17-19].

Our questionnaire showed that functional DED subjects using contact lenses exhibited dry eye symptoms and ocular surface lesions from various risk factors. These patients often complained of dry eyes and foreign body sensation, with congestive and swollen meibomian glands. Chronic hyperemia of the conjunctiva was common, and some mucilaginous secretion was present in the conjunctival sac. The corneal epithelium frequently showed oedema, positive fluorescein staining was often present, and ocular surface inflammation, including keratitis, was commonly observed. Notably, functional DED subjects wearing contact lenses or experiencing sleep disorders often had positive fluorescein staining in the lower cornea, possibly due to Bell's phenomenon, causing incomplete eyelid closure and exposure of lower cornea or accumulation of inflammatory factors in the lower tear meniscus, resulting in corneal issues [20].

Additionally, our analysis highlighted deep sleep as a protective factor for DED. Poor sleep quality and insomnia, prevalent in modern society, are linked to DED, as sleep deprivation (SD) decreases tear secretion, reduces corneal sensitivity, and promotes epithelial defects and apoptosis [21-23]. Long-term SD can even lead to limbal stem cell deficiency [24]. Microvilli, crucial for ocular surface lubrication, are negatively affected by SD due to down-regulation of PPARα and other factors [25].

Increasing deep sleep duration appeared to reverse these issues, indicating its protective role in tear film maintenance and ocular surface function in functional DED patients. While various risk factors contribute to functional DED, most are retrospective and tissue damage is often reversible. Symptoms and signs in functional DED patients typically improve or resolve completely when they strictly follow health education and address specific risk factors in their lifestyle and work. Thus, we believe identifying and eliminating these risk factors is more effective for functional DED patients than solely relying on drug therapy. This approach targets the root cause, while drug therapy only alleviates symptoms. Therefore, functional DED patients must discuss their medical history, understand their condition, and eliminate harmful habits rather than focus solely on symptomatic treatment.

5. Conclusions

The data show that functional DED in Shanghai results from various risk factors, including contact lens use, sleep disorders, heavy screen time, air conditioning, and recently renovated spaces [1]. It's also associated with less obvious factors like work stress, lifestyle, and social environment [2]. The working class in Shanghai often lives a fast-paced, high-pressure life, leading to unhealthy coping mechanisms such as smoking, alcohol, and gaming [3]. Our dry eye survey illustrates these challenges in metropolitan life. By addressing unhealthy habits and lifestyles, we can potentially cure and prevent functional DED. Thus, adopting healthy work and life practices is essential, and society must recognize their importance [4].

Ethics and Consent to Participate: The study was approved by the Institutional Review Board (IRB) of Huashan Hospital, which is affiliated with Fudan University (No. 2021-880). All participants gave informed consent, and the study adhered to the tenets of the Declaration of Helsinki.

Competing Interests: None.

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Authors' Contribution: Nianhong Wang conceived the research idea and designed the questionnaire. Yan Liu and Huan Weng performed the questionnaire and collected data, Huiying Wang designed clinical examinations and analysed the results and data, Weibao Xiao conceived the research idea, analysed data, and wrote and revised the manuscript. All authors read and approved the final version of the manuscript.

Supplementary Material: Table S1.

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Supplementary Material

Table S1. Questionaire for Enrolled Functional DED Patients

Questions and Responses	N (%)
What electronic screen/monitor do you usually use during your daily activities?	527 (100)
• Mobile phone	396 (75.1)
• Computer	426 (80.8)
• Television	104 (19.7)
• E-book	26 (4.9)
• Three devises or more	137 (26.0)
How many hours per day in average do you spend in front of a computer screen?	426
• <4	29 (6.8)
• 4-6	73 (17.1)
• 6-8	228 (53.5)
• >8	96 (22.5)
How many hours per day in average do you use your mobile phone?	396
• <4	163 (41.2)
• 4-6	149 (37.6)
• 6-8	60 (15.2)
• >8	24 (6.0)
How many hours per day in average do you watch television?	104
• <1	8 (7.7)
• 1-3	39 (37.5)
• 3-6	44 (42.3)
• >6	13 (12.5)
How many hours per day in average do you spend under air conditioning?	406
• <3	63 (15.5)
• 3-5	149 (36.7)
• 5-8	160 (39.4)
• >8	34 (8.8)
In the past year, did you renovate your home?	527
• Yes	69 (13.1)
• No	458 (86.9)
If you had home/office renovation, did you feel eye irritation related to that?	69
• Yes	47 (68.1)
• No	22 (31.9)
Do you wear contact lens?	527
• Yes	118 (22.4)
• No	409 (77.6)

(*continued*)

Questions and Responses	N (%)
If you wear contact lens, how many times do you wear them each week?	118
• 1-2	43 (36.4)
• 3-4	49 (41.5)
• ≥5	26 (22.0)
If you wear contact lens, do you remove them before sleeping?	118
• Yes	112 (94.9)
• No	6 (5.1)
If you wear contact lens, what is their water content classification?	118
• High	69 (58.5)
• Middle	41 (34.8)
• Low	8 (6.8)
If you wear contact lens, how often do you replace them?	118
• Daily	65 (55.1)
• Monthly	32 (27.1)
• Quarterly	10 (8.5)
• Half year	8 (6.8)
• Yearly	3 (2.5)
Do you often need to work overtime?	527
• Yes	249 (47.2)
• No	278 (52.8)
If you need to work overtime, how many overtime hours per day in average?	249
• <1	52 (20.9)
• 1-2	123 (49.4)
• 2-3	46 (18.5)
• >3	28 (11.2)
When do you get up in the morning?	527
• Before 6 AM	56 (10.6)
• 6-7 AM	149 (28.3)
• 7-8 AM	251 (47.6)
• After 8 AM	71 (13.5)
When do you sleep at night?	**527**
• Before 9 PM	18 (3.4)
• 9-11 PM	117 (22.2)
• 11-12 PM	299 (56.7)
• After midnight	93 (17.6)
In average, how many hours of deep sleep per night do you have?	527
• <5	89 (16.9)
• 5-6	118 (22.4)
• 6-7	217 (41.2)
• 7-8	93 (17.6)
• >8	10 (1.9)

Questions and Responses	N (%)
In average, how many nights per week do you sleep after midnight?	527
• <1	82 (15.6)
• 1-2	215 (40.8)
• 3-5	158 (30.0)
• ≥6	72 (13.7)
Do you feel excessive pressure at work?	527
• Yes	293 (55.6)
• No	234 (44.4)
Do you usually feel anxiety?	527
• Yes	205 (38.9)
• No	322 (61.1)
Do you exercise often?	527
• Yes	224 (42.5)
• No	303 (57.5)
If exercise often, how many times per week do you exercise?	224
• 1-2	141 (63.0)
• 3-4	56 (25.0)
• >5	27 (12.0)
If exercise often, how many hours each time do you exercise?	224
• <0.5	55 (24.6)
• 0.5-1	102 (45.5)
• 1-2	47 (21.0)
• 2-3	17 (7.6)
• >3	3 (1.3)
Do you smoke?	527
• Yes	19 (3.6)
• No	508 (96.4)
If you smoke, in average how many cigarettes do you smoke each day?	19
• <5	1 (5.3)
• 5-10	3 (15.8)
• 10-20	10 (52.6)
• >20	5 (26.3)
Do you drink alcohol?	527
• Yes	112 (21.2)
• No	415 (78.8)
If you drink alcohol, in average how many times per week?	112
• 1-2	75 (67.0)
• 3-4	23 (20.5)
• ≥5	14 (12.5)

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Workplace Violence and Patient Management Time in the Emergency Department: An Observational Study

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Keywords: Healthcare Workers; Physical Violence; Verbal Violence; Workplace Aggression; Emergency Care Unit

Abstract

Background: *Workplace violence is steadily rising, and the healthcare sector is one of the most impacted areas. Several studies have shown that patients' long management times are a key factor in workplace violence in this setting.* **Objective:** *This study aims to analyze the prevalence and characteristics of aggressions against healthcare workers (HCWs) that occurred in 2023 in the Emergency Rooms (ER) of a large university hospital and to evaluate the potential relationship between the management time of a patient in the ER and the risk of violence incidents.* **Methods:** *To evaluate the prevalence and characteristics of aggressive events against HCWs that occurred in 2023, data from the "incident reporting" form were analyzed. Then, using the 2023 report on daily ER accesses, the management time of a patient at the ER was calculated. Finally, the average management times of patients on days when there were no aggressions were compared with those on days when there was one or more assaults against HCWs to evaluate the potential relationship between the average length of stay of a patient at the ER and the risk of aggression.* **Results:** *In 2023, 271 violent incidents were reported. Verbal aggressiveness was the most common (82.7%), and working the night shift was riskier (42.8%). In 36.2% of cases, patient management time was identified as a potential predictor of aggression. Other identified potential predictors included the patient and/or caregiver relationship with HCW (30.6%), the refusal to accept diagnostic-therapeutic protocols (27.3%), and the cultural background and temperamental traits of the patient or caregiver (18.8% and 11.8%, respectively). According to the logistic regression analysis, the likelihood of a violent incident during a 150-minute stay was less than 10%; it increased to 53% after 650 minutes.* **Conclusion:** *Workplace violence in healthcare settings results from a complex interaction of internal and external factors. Understanding how these elements interact and contribute to the development of incidents is essential for identifying key actions to reduce and mitigate violence.*

1. Introduction

The phenomenon of workplace violence is constantly rising, and the healthcare sector is one of the most affected areas [1, 2]. Violence against healthcare workers (HCWs) is a global issue, requiring targeted legislative actions. NIOSH (National Institute for Occupational Safety and Health) defines workplace violence as "any physical assault, threatening behavior, or verbal abuse occurring in the workplace" [3]. Several factors contribute to the development of aggression against HCWs and can be grouped into three main

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categories: characteristics of the patient and their caregivers, characteristics of HCWs, and organizational or environmental factors [4]. Organizational factors include lack of resources, staff shortages, long waiting times, compliance with hospital restrictions (such as only one caregiver per patient and inflexible visiting hours), inadequate security measures, and insufficient support and commitment from top management and staff to protect themselves [5, 6, 7]. There is a widespread lack of communication among healthcare workers, often driven by excessive workloads and worsened by job dissatisfaction caused by daily acts of aggression [8, 9, 10]. Additionally, rising healthcare costs, the commercialization of services, media attention, the availability of online health information, conflicting medical opinions, and reports of medical errors have altered doctor-patient relationships. The most common patient-related factors include psychomotor agitation (due to intoxication from alcohol or drugs, or cognitive disorders) and patients' expectations regarding access, speed, and effectiveness of care [11]. Several studies [12, 13, 14] indicate that long waiting times can be a primary factor contributing to workplace violence in healthcare settings.

The Italian Minister of Health's 2007 recommendations [15] emphasize the importance of comfortable and appropriate waiting areas to minimize stress-inducing factors. They also suggest ensuring that patients receive adequate information about waiting times.

This study aims to analyze the prevalence and characteristics of aggressive incidents against healthcare workers (HCWs) that occurred in 2023 in the emergency rooms (ER) of a large university hospital in Milan. The study will also evaluate the potential relationship between the average management time of a patient at the ER and the risk of violent incidents. The goal is to identify the most effective preventive interventions to protect the physical and mental well-being of HCWs, thereby maintaining the quality of healthcare services and care.

2. Methods

2.1. Subjects and Methods

The present study analyzed data from the HCWs population working in the ERs of a large University Hospital in Milan. The Hospital under study is part of the Italian public healthcare system, comprising four Hospital Centers and several Territorial Outpatient Units. An ER unit is present in every hospital center. To evaluate the prevalence and the characteristics of aggressive events against HCWs that occurred in 2023, data from the "incident reporting" form [15] were analyzed. This instrument was a reporting system that originated in complex and high-risk organizations, such as aviation or nuclear settings, which allows for the detection of risk situations for the safety of operators and users. Subsequently, it was adapted to the healthcare context also to identify factors potentially related to episodes of violence against HCWs. The HCW who experiences verbal or physical violence at the workplace fills out the incident reporting form, making sure to fill out all the mandatory fields. The required information includes:

1. HCW's details (professional profile and contact information of the assaulted individual), however, anonymous reporting is permitted;
2. date and time of the event;
3. the event location;
4. type of event;
5. description of the event (this is a free text field where the dynamics of the episode should be detailed);
6. patient data (gender, year of birth, identification code of the healthcare service)
7. contributing factors to aggression. HCW could select more than one option from:
    - Staff-related factors (communication, behavior, performance, cognitive factors, psychophysical factors)
    - Patient-related factors (communication, behavior, performance, cognitive factors, psychophysical factors)
    - Environmental factors (structure, physical environment, and infrastructure, equipment)
    - Organizational factors (protocols and procedures, safety culture, organization of the work group, resources/workload)
8. attachments, if the assaulted individual wishes to report a record or other supplementary documentation.

The 2023 report on daily ER accesses was also analyzed. This report included, for every patient admitted to the ER in 2023, the subsequent data: the patient's personal data, the way of the patient's access to the ER, the diagnosis at entry and discharge, the entry and discharge times, the color code assigned at admission and discharge, and the mode of discharge. Using this report, the average management time of a patient at the ER was calculated according to the Agenas (National Agency for Regional Health Services) report, from the patient's entry into the emergency department to their discharge [16]. Then, to evaluate the potential relationship between the average length of stay of a patient at the ER and the risk of aggression, the average management times of patients on days when there were no violent events were compared with those on days when there was one or more violent accidents against HCWs.

All data were anonymously extracted from both the incident reporting form and the 2023 report on daily ER accesses, and then analyzed in compliance with the most recent privacy protection laws.

2.2. Statistical Analysis

All data presented in our study were expressed as absolute numbers, percentages, and/or means ± SD. Further analysis was conducted using logistic regression and Student's T-test. Logistic regression compared, for each day, the occurrence of at least one event with the average length of stay in the emergency room, with each average calculated as the ratio of the total time spent in the emergency room (from entry to discharge) across all episodes on that day to the number of distinct patient episodes managed that day. Confidence intervals were determined using the lower and upper 95% Wald confidence limits.

For the ROC curve, ideal cutoffs were identified using Youden's index and the closest top-left methods. Additionally, 95% confidence intervals were estimated with 2000 stratified bootstrap replicates. All analyses were performed using the R software version 4.2.3.

3. Results

The demographic and occupational information of the population under study was shown in Table 1.

As shown in Table 2, in 2023, 271 violent acts against HCWs working at ERs were reported.

Verbal aggressiveness was the most common kind of assault (82.7%), and working the night shift was riskier (42.8%). The majority of aggressive events

Table 1. Characteristics of the study population.

	Total		Males		Females	
	n	**%**	**n**	**%**	**n**	**%**
HCWs (tot)	294	100,0%	91	31,0%	203	69,0%
Age (mean ± ds)	40,5 ± 11,3		42,1 ± 10,9		39,8 ± 11,4	
Age group (years)	**n**	**%**	**n**	**%**	**n**	**%**
20–30	72	24,5%	17	18,7%	55	27,1%
31-40	81	27,6%	24	26,4%	57	28,1%
41-50	71	24,1%	24	26,4%	47	23,2%
51-60	63	21,4%	25	27,5%	38	18,7%
>60	7	2,4%	1	1,1%	6	3,0%
Job category	**n**	**%**	**n**	**%**	**n**	**%**
Physicians	74	25,2%	18	19,8%	56	27,6%
Nurses	160	54,4%	48	52,7%	112	55,2%
Nursing assistants	59	20,1%	25	27,5%	34	16,7%
Administrative staff	1	0,3%	0	0,0%	1	0,5%

Table 2. Data from "incident reporting" form: violent events reported in 2023.

	n	%
Total violent events	271	100.0%
Type of assault		
Verbal assault	224	82.7%
Physical assault	42	15.5%
Damage to objects	2	0.7%
Not declared	3	1.1%
Time of the event		
Morning	52	19.2%
Afternoon	103	38.0%
Night	116	42.8%
Location of the event		
Triage Room	132	48.7%
Internal common areas	39	14.4%
Waiting room	36	13.3%
Clinic/medical room	33	12.2%
Observation room	19	7.0%
Emergency Room	5	1.9%
Other	7	2.6%
Aggressor		
Relative/caregiver	143	52.8%
User/Patient	123	45.4%
Not declared	5	1.9%
Job category of the assaulted HCW		
Nurse/pediatric nurse	178	65.7%
Physician	25	9.2%
Nursing assistant	5	1.9%
Security guard	3	1.1%
Not defined (multiple figures involved)	29	10.7%
Other	27	9.9%
Gender of the assaulted HCWs		
Female	189	69.7%
Male	53	19.6%
Data not available (multiple figures involved)	29	10.7%

(48.7%) took place in the triage area, and the aggressor was a patient's family member or caregiver in 52.8% of the incidents. Nurses/pediatric nurses were the most commonly targeted professional group (65.7%), and women were the victims in 69.7% of cases. (Table 2). The analysis of the ratio between the number of aggressive events that were recorded and the size of the population under consideration supports this data. Specifically, women recorded a ratio of 0.93 (95% CI, 0.80-1.07) versus 0.58 (95% CI, 0.44-0.76) in men, and nurses recorded a ratio of 1.11 (95% CI, 0.96-1.29) versus a physician's ratio of 0.34 (95% CI, 0.22-0.50).

As shown in Table 3, the analysis of the "incident reporting" form indicated that in 36.2% of cases, patient management times could potentially predict aggressive incidents. Other factors identified by healthcare workers as possible triggers for violence include the patient and/or caregiver relationship (30.6% of cases), the patient's refusal to follow diagnostic-therapeutic protocols (27.3% of cases), and the cultural influences and temperamental traits of the patient or caregiver (18.8% and 11.8% of violent cases, respectively). Additionally, work environmental factors such as the physical surroundings, equipment, staff shortages, and workloads were reported by approximately 26.5% of healthcare workers as potential contributors to violent events, while organizational factors were cited in 20% of cases.

The analysis of the 2023 report on daily ER visits showed that the average patient management time was 223.7 minutes, with notable differences depending on the severity of the illness and the triage code (white code: 173.7 minutes, green code: 203.9 minutes, yellow code: 346.8 minutes, red code: 492.3 minutes).

The analysis showed a significantly longer average patient management time on days when one or more violent events occurred compared to days when no events occurred (278.6 minutes vs. 249 minutes, $p<0.001$) (Figure 1).

The predicted probability of a violent incident within a 150-minute stay was less than 10%, according to the logistic regression analysis, which calculated the risk of an aggressive occurrence in connection with the prolonged patient management time at the ER. At 300 minutes (5 hours), the likelihood of one or more violent incidents was about 20%; after 420 minutes (7 hours), it rose to roughly 30%; and after 650 minutes (10/11 hours), it reached 53%, as shown in Figure 2.

Table 3. Data from "incident reporting" form: factors reported by HCWs as possible causes of the aggressive event (more than one answer was possible).

Possible determinants of violent act	n	%
Work environment elements		
Timing	98	36.2%
Staff	36	13.3%
Structure and design	19	7.0%
Workload/working hours	7	2.6%
Environment	6	2.2%
Equipment/supplies	4	1.5%
Factors related to tasks and work processes		
Availability and use of protocols	74	27.3%
Availability and accuracy of test results	1	0.4%
Individual factors		
Skills and knowledge	1	0.4%
Organizational factors		
Organizational structure	30	11.1%
Safety culture	27	9.9%
Imported/exported risks	1	0.4%
Patient-related factors		
Relationship between staff and patient	83	30.6%
Personal characteristics	51	18.8%
Treatment	47	17.3%
Conditions	32	11.8%
Medical history	1	0.4%
Factors related to the relative/caregiver		
Patient - Characteristics of relatives/caregivers/acquaintances	32	11.8%
Factors related to the workgroup		
Verbal communication	9	3.3%
Written communication	4	1.5%
Leadership and responsibility	3	1.1%
Colleagues' reaction to incidents	1	0.4%

Furthermore, a statistical analysis was conducted on the collected data to identify both a "safety" value below which the risk of assault can be considered acceptable and an "action" value from which to consider mandatory improvement interventions. The statistical analysis showed that the temporal cut-off with the highest sensitivity was 144 minutes of average management time, while the best compromise between sensitivity and specificity was 246 minutes of average management time (Figure 3).

4. Discussion

As evidenced by the rise in scientific publications on the topic [17] and legislative actions [18] during the previous 20 years, violence by patients and their relatives against HCWs are becoming more commonplace worldwide, and Italy is no exception.

In this context, starting from the incident reporting form, we preliminarily outlined the characteristics of violent acts perpetrated against healthcare workers in 2023 in the ER. Subsequently, we conducted a specific analysis to investigate the relationship between average patients' management times in the ER and the risk of violent acts against HCWs.

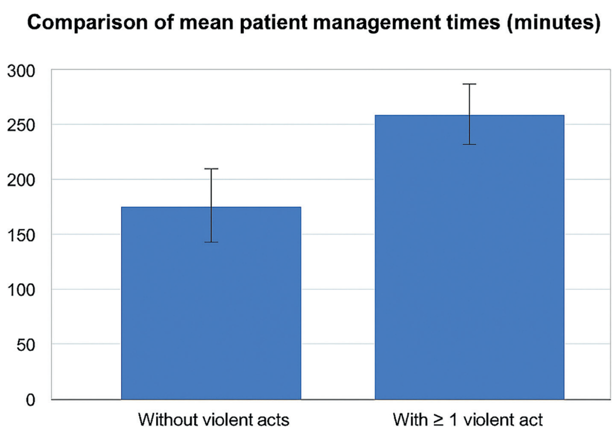

Figure 1: Comparison of average management times (minutes) of a patient in the ER on days without violent acts and on days with one or more violent acts.

Literature shows that over 80% of HCWs experienced physical or verbal assault during their careers, and verbal assaults/threats are more frequent than physical assaults [17]. Similarly, our study found that 82.7% of reported aggressive episodes in 2023 were referred to verbal assault, followed by physical assault (about 15%), while property damage was minimal (<1% of violent acts). The underreporting of verbal aggression incidents warrants consideration; healthcare professionals often perceive such episodes as inherent and unavoidable aspects of clinical practice, and otherwise elevated workload demands may contribute to the reluctance to formally report verbal assaults, in an effort to preserve time for direct patient care activities.

It is noted that in 42.8% of cases, the violence occurred at night, compared to 57.2% of events recorded during the daytime shift (19.2% of cases in

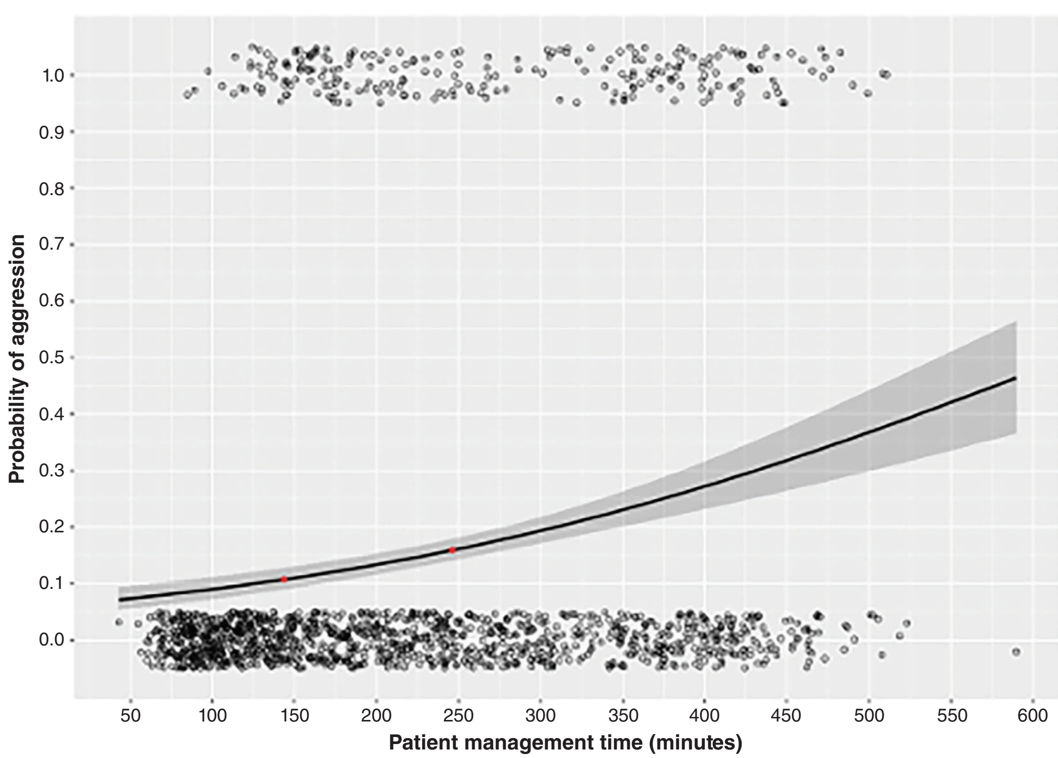

Figure 2. Scatter plot: probability of an aggressive event related to the patient's management time in the ER.

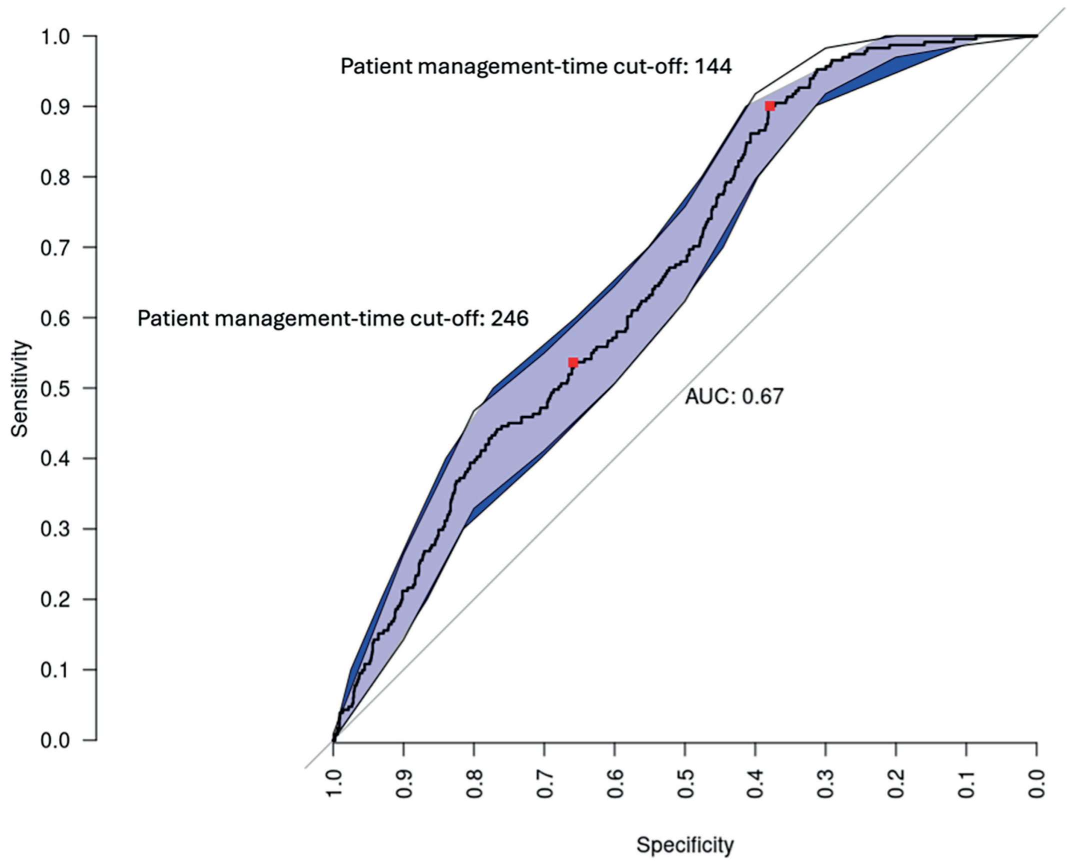

Figure 3. ROC curve: aggressive event related to the patient's management time in the ER.

the morning and 38.0% of events in the afternoon). These findings are supported by other research in the literature [19, 20]. Although the slightly longer night shift duration cannot be ruled out, several different factors, in our experience, may have contributed to the higher frequency of violent events at night. During nighttime hours, there is a noticeable increase in Emergency Department admissions involving patients experiencing acute intoxication from alcohol or illicit drugs. The resulting psychomotor agitation represents a risk factor for the onset of aggressive behavior, which is often unprovoked. Another contributing factor is the accumulation of patients whose care was not completed during the day, leading to a heavier workload for the night shift. This situation is exacerbated by reduced healthcare staffing levels, particularly in the radiology unit, resulting in delays in conducting diagnostic tests. Additionally, hospital volunteer support services, which are often involved in discharge planning and patient transfers during daytime hours, are typically unavailable at night, thereby removing a valuable resource for patient flow management. Together, these conditions contribute to increased tension and discomfort among patients, which, in our experience, may explain the higher risk of verbal and physical aggression during night shifts.

The violent episode occurred most frequently in the triage room (48.7%), and 65.7% of the assaults were perpetrated against nurses; this data is in accordance with the literature and plausible since nurses are the most represented professional figures and especially face high-tension situations in triage (demand for immediate assistance, caregiver's emotional vulnerability, patient's health concern) [21].

As expected and confirmed by literature [22], female staff were more frequently victims of violence (69.7%) compared to male colleagues; this data should be examined considering that in ERs of the hospital under study 69% of HCWs are women (203 women out of 294 workers).

Regarding the aggressor, our study highlighted that the relative/caregiver was the actor of the violence in 52.8% of cases and the patient themselves in 45.4% of events. The data is in line with the study conducted by Ferri et al. [23], in which verbal assault by relatives/ friends of patients was more frequent in emergency departments. In contrast, patients are the main culprits of physical attacks.

Starting from the evidence that the literature lists long management times as a risk factor for assaults on healthcare staff [12-14], we conducted an internal analysis to evaluate the possible relationship between average patients' management times in the ER and the risk of aggression. Indeed, although the literature agrees that the time factor is a target for improvement interventions [24], no study establishes a reference temporal cut-off for managing this risk.

Specifically, analysis of the 2023 report on daily ER accesses showed an average patient management time of 223.7 minutes, with wide variability depending on disease severity and subsequent triage code (white code: 173.7 minutes, green code: 203.9 minutes, yellow code: 346.8 minutes, red code: 492.3 minutes). These findings are consistent with nationwide data released by Agenas [16] in 2023, which indicated that the average patient management time in the emergency department was approximately 165 minutes for white codes, 230 minutes for green codes, and 416 minutes for yellow codes.

Regarding the possible relationship between patient management time in the ER and the risk of violent acts, our study showed a significantly longer average patient management time on days when one or more violent events occurred compared to days when no events occurred ($p<0.001$). In our study, the predicted probability of one or more violent acts was around 20% at 300 minutes (5 hours) of stay, increased to about 30% after 420 minutes (7 hours), and reached 53% after 650 minutes (10/11 hours), identifying a possible role of the "time" factor only for particularly prolonged management times and far exceeding the average waiting times of ER patient. Since there are currently no comparable works on this issue in the scientific literature, we are unable to compare this result. Our results indicate a possible co-causal but not an exclusive role of the "waiting time" factor in aggressive behaviour by patient/caregiver against HCWs, as confirmed by the event description on the "incident reporting" form. Among other co-causal factors are clinical and cultural reasons of the patient/caregiver (e.g., altered behavior due to drug use, alcohol abuse, or behavioral disorders, refusal to comply with procedures regarding the number of allowed companions and visiting hours, demand for immediate assistance even if not supported by an emergency-urgent clinical condition).

These results necessitate a reflection on the most appropriate measures to be implemented to reduce the risk of aggressive events in the healthcare setting and improve the safety of HCWs in carrying out their activities. Effective collaboration between the employer and the Occupational Physician is imperative. In the context of primary prevention, the occupational physician contributes to risk assessment by sharing insights with the employer. Health surveillance visits may be an opportunity to raise workers' awareness regarding the importance of incident reporting: workers' testimonies, collected in an anonymous and aggregated form, combined with the outcomes of workplace inspections, allow for a more accurate risk assessment and may contribute to the confirmation or revision of intervention priorities based on the epidemiological analysis of reported incidents and occupational injuries assault-related. Furthermore, during occupational health surveillance visits (periodic, on request, or at return to work), the Occupational Physician may detect early signs of psycho-physical distress related to previously experienced aggression. When appropriate, psychological support can be activated as part of a secondary prevention strategy. As outlined in Article 25 of Legislative Decree 81/2008 [25], the Occupational Physician also plays a key role in workers' education and training, providing information on procedures to follow in the event of aggression, and promoting participation in de-escalation, self-defense, and assertive communication courses. In our experience we think that, about the measures to reduce the risk of aggressive events in the healthcare setting, structural/environmental interventions (delimitation with airtight doors and safety glass of acceptance/triage area, limited access areas, security service, adequate spaces for de-escalation techniques, comfortable waiting rooms), and organizational interventions (clear policies, adequate number of operators to the workload) are crucial in all contest at risk. Furthermore, the HCWs' training program intervention would be appropriate to enhance their ability to manage these high-risk situations. Finally, the availability of a psychological support service appears to be effective in reducing post-traumatic stress symptoms through individual and group interventions (debriefing and defusing).

4.1. Study Limitations

It is necessary to mention some limitations of this study that could affect the accuracy of the results shown and the validity of the conclusions drawn. Firstly, we did not have data on patient waiting times from entry into the ER to being attended to by healthcare workers. Therefore, the investigation was conducted considering the patient's overall management time, from entry to discharge from the ER, in light of Agenas reports [18]. In addition, the unavailability of specific data on the ER stay of patients from whom the violent event originated meant that the survey was conducted by comparing, more generally, the average time of stay for ER patients managed during days with and without aggression. Furthermore, we do not have access to the actual number of hours worked by each category of HCWs; this data could help examine the increased occurrence of aggressive events in particular subgroups of the study population. Finally, an underestimation of the problem cannot be excluded due to a possible under-reporting by health professionals. Further studies are necessary on larger cases focused on the time of "patients taking charge", aggressors and not, for deepening and confirmation of the results obtained.

5. Conclusions

In conclusion, healthcare workplace violence is impacted by a complex interplay of external (political, sociocultural) and internal (individual and organizational) elements. Here, the "waiting time" element may contribute to, but not be the sole cause of, aggressive behavior by patients or caregivers against HCWs. Understanding how these elements interact and contribute to the genesis of events is crucial for maximizing the effectiveness of the interventions undertaken, as well as for defining priority actions to reduce and mitigate violent incidents.

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Author Contribution Statement: CDG, IC, MMa and MMe conceived and designed the analysis; CDG and ET collected the data; MMa performed data mining; MMe performed the analysis; CDG and MMe wrote the first version of the paper; MMa, CDG and IC revised the paper; MC, FT, PC contributed to paper revision; PC supervised all phases of research activity planning. All Authors reviewed the results and approved the final version of the manuscript.

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

Declaration on the use of AI: None.

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La Medicina del Lavoro

Case report

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Occupational Asthma Due to Subtilisin: The Power of Specific Inhalation Challenge*

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Keywords: Enzyme Allergy; FeNO Monitoring; Type-2 Inflammation; Workplace Sensitization; Respiratory Biomarkers; Endotyping; Healthcare Workers; Bronchial Provocation Test; Allergen Exposure; Negative Skin Tests

Summary
We report the first confirmed case in Italy of occupational asthma caused by subtilisin in a healthcare worker involved in cleaning surgical instruments. The diagnosis was confirmed through a specific inhalation challenge (SIC) performed one year after the last exposure and after stopping inhaled corticosteroid therapy. An immediate reaction was observed after three minutes of exposure to diluted Neogiozym ™, with a 30% decrease in FEV1. This case highlights the diagnostic importance of SIC even for high-molecular-weight (HMW) agents and emphasizes the need to reconsider occupational asthma as a complex, evolving disease influenced by both host and environmental factors. The patient exhibited a Type-2-high phenotype despite negative skin prick tests and normal IgE levels, reinforcing the value of dynamic, multi-marker assessment in occupational endotyping. This case supports the broader use of SIC in occupational settings where allergen-specific IgE testing is limited.

1. Introduction

The use of proteolytic enzymes in the detergent industry began in the 1960s. Subtilisins are serine proteases, widely used primarily because of their low substrate specificity and high stability. They are used in all types of laundry detergents, automatic dishwashing products, and disinfectants for cleaning medical-surgical instruments and devices. Their role is to break down protein-based stains [1], and since their introduction, subtilisins have been recognized as potent allergens linked to the development of occupational asthma [2]. The mechanism by which this high molecular weight (HMW) enzyme triggers allergic inflammation in the airways of susceptible individuals is not yet fully understood. Animal studies have shown that subtilisin is a strong inducer of type 2 immunity, activating both Th2-mediated responses and Innate Lymphoid Cells type 2 (ILC2), as well as promoting the production of specific IgE [3]. Asthmatic reactions described were immediate, with or without a delayed component [4]. We report a case of occupational asthma caused by subtilisin in a nurse.

2. Case Report

A 51-year-old woman, a former smoker since 2007 with a 1 pack-year history, had no family or personal history of respiratory or allergic diseases.

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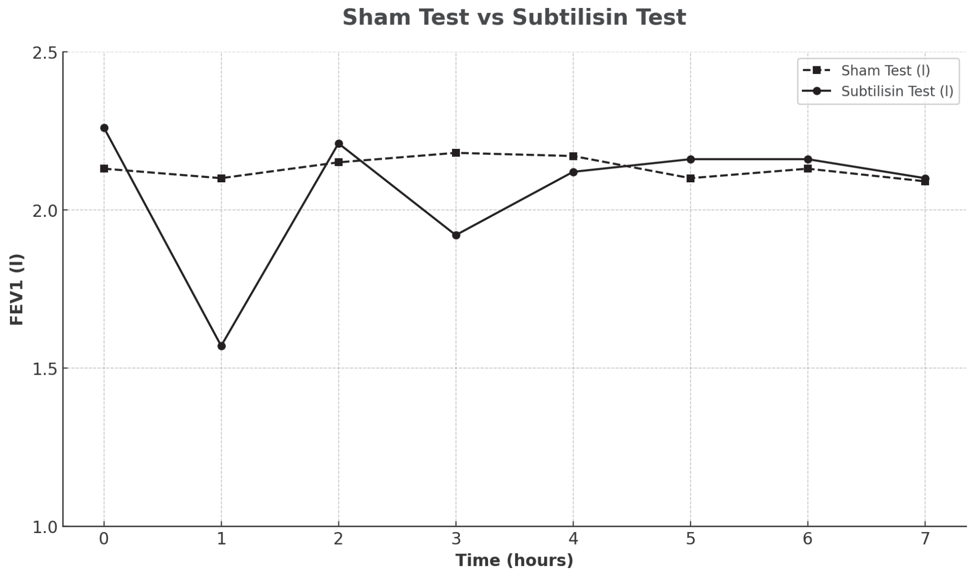

Figure 1. FEV1 trend during sham test and exposure to subtilisin.

She worked as a nurse in a hospital's medical department from 1998 to 2008, then in a surgical department from 2008 to 2023. Since June 2022, she was assigned to the digestive endoscopy department, where she was responsible for cleaning surgical instruments before sterilization using various detergents. The most used, Neogiozym ™, containing subtilisin, was prepared at a concentration of 0.2 mL diluted in 200 mL of water. Three months after starting this work, she developed dry cough and rhinitis, mainly with daytime rhinorrhea. No nocturnal awakenings or wheezing were reported. Her nasal symptoms worsened at work. In January 2023, she began experiencing nocturnal respiratory symptoms. She noticed slight symptom improvement during holidays. In May 2023, she underwent a non-specific inhalation challenge test with methacholine. The provocative dose causing a 20% fall in FEV1 (PD20 FEV1) was 91.99 µg, indicating severe bronchial hyperresponsiveness. Since then, she has been on inhaled therapy with budesonide/formoterol 320/9 mcg twice daily. Skin tests using the patch method with pure Neogiozym ™ (1 mL/1 mL) and diluted Neogiozym ™ (1 mL/10 mL), as well as prick tests for common inhalants and specific allergens to which cleaners are exposed, were negative; prick tests with pure and diluted Neogiozym ™ (1 mL/1 mL and 1 mL/10 mL) were also negative. A specific inhalation challenge (SIC) was performed in November 2024, when the nurse had not been exposed to subtilisin at work for a year, after discontinuing inhaled corticosteroids two weeks prior. Baseline FEV1 was 2.24 L (98% predicted), FVC was 2.85 L (106% predicted), and PD20 FEV1 was 732 µg; total IgE was 3.0 kUa/L. On the control day, with vapor exposure to water, FEV1 remained stable over 7 hours (see Figure 1). The following day, in a chamber maintained at 23–24°C, she inhaled vapor from diluted Neogiozym ™ (25 mL in 4 L of water). After three minutes, she started coughing, complained of chest tightness, and demonstrated a 30% decrease in FEV1 (1.57 L vs. a baseline of 2.26 L). She was monitored for seven hours post-exposure, and at the end of this period, her FEV1 measured 2.1 L (92.9% of baseline). At 24 hours post-SIC, PD20 was 838 µg. Additionally, fractional exhaled nitric oxide (FeNO) levels were monitored (see Figure 2): on the control day, before the sham test, the FeNO was 40 ppb; on the exposure day, before inhaling the specific vapor, it was 39 ppb. At the end of SIC, it rose to 45 ppb, and 24 hours later, it decreased to 33 ppb. The difference (between before and after- SIC levels), was not statistically significant.

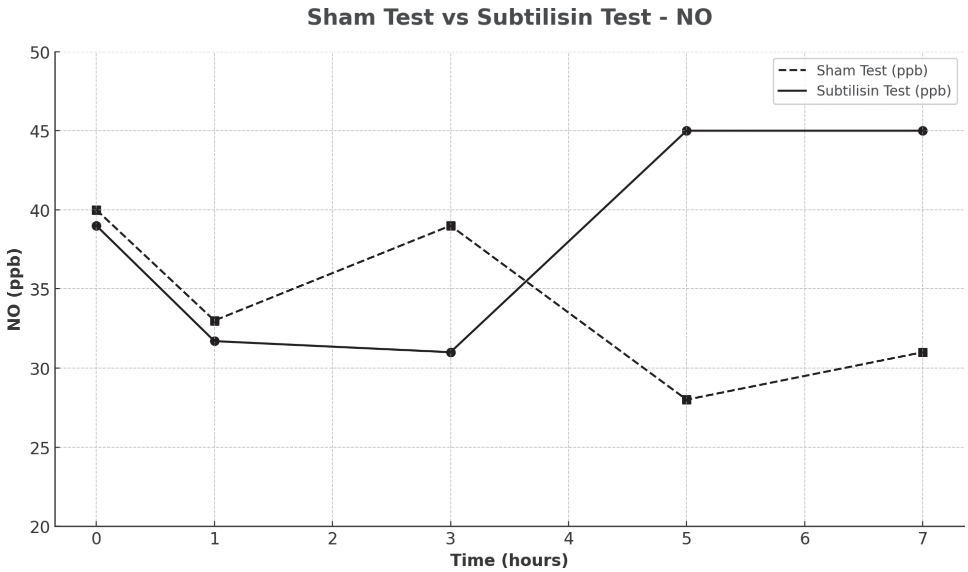

Figure 2. FeNO trend during sham test and subtilisin exposure.

3. Discussion

To our knowledge, this case report of occupational asthma caused by subtilisin is the first confirmed in Italy through SIC. It demonstrates the known potential of subtilisin to induce asthma. Further, it confirms that SIC remains the gold standard test for diagnosing occupational asthma, even in cases exposed to HMW agents. Whether occupational asthma is Type-2 high, Type-2 low, non-Type-2, or has a complex and mutant endotype remains a topic of debate. Historically and currently, the primary biomarkers analyzed to study the causal endotypes of occupational asthma include eosinophils and neutrophils in blood and/or induced sputum; total and/or specific IgE; FeNO; and cytokines and chemokines.

Asthma related to HMW agents is generally considered to be more Type-2 high, and this patient's initial phenotype supported this. She had work-related rhinitis before developing asthma symptoms, and her immediate response to SIC matched descriptions by Doyen et al. [5] as typical of asthma caused by HMW agents. Specifically, the decrease in FEV1 three minutes after exposure aligns with an IgE-mediated sensitization mechanism, confirming findings by Florsheim et al. [3]. The 24-hour pulmonary function monitoring showed no further decrease in FEV1, indicating no delayed-type reactions.

The rise in FeNO levels after exposure indicates eosinophilic inflammation, while the initial decrease in FeNO is linked to bronchoconstriction from subtilisin exposure, which reduced FeNO release, as described by Ferrazzoni et al. [6]. Notably, she had no blood eosinophilia or elevated total IgE. As Baur et al. [7] discussed in 2019, measuring specific IgE is often essential for pinpointing the exact cause of respiratory allergies, with testing for specific IgE to HMW allergens being a valuable diagnostic tool. Unfortunately, only a limited range of allergen-specific IgE tests are commercially available in the occupational field, and we could not develop an in-house test for this case. To address this, we performed a prick-by-prick skin test as described by Lemière et al. [4], which was negative. This result is hard to interpret—especially without specific IgE testing—but we speculate it's due to a mutant immune response. Like common asthma, occupational asthma should be considered a heterogeneous and complex condition, with the Th1/Th2 pattern shifting over time in response 1) to host–environment interactions and 2) stimuli encountered during various occupational exposures.

Our case demonstrates that a negative skin prick test does not exclude occupational asthma caused by HMW agents, as our patient showed an immediate response at three minutes during SIC and an increase in FeNO after bronchoprovocation. In healthcare settings, workers handling disinfectants for medical and surgical instruments are exposed to numerous products. If they develop allergic symptoms—either respiratory or cutaneous—they are usually tested for sensitivity to these substances using prick tests, including specific allergens.

The SICremains the gold standard for diagnosing occupational asthma. While HMW allergens like subtilisin are known as potential triggers, confirmed cases through SIC are rare, especially in healthcare environments. Literature suggests SIC primarily when the suspected cause is a low-molecular-weight agent; however, our study highlights its importance for exposure to HMW agents as well. In conclusion, there is a growing need to combine different endotyping methods—analyzing occupational exposures, biomarkers, and genetics simultaneously—and this case report supports that combined approach.

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Institutional Review Board Statement: Ethical review and approval were waived for this study, as it describes a single case managed during routine clinical practice and does not involve prospective research.

Informed Consent Statement: Written informed consent was obtained from the patient to publish this case report.

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

Author Contribution Statement: F.L. and P.M. contributed to the conception and clinical management of the case. M.B., L.F., and F.F. were responsible for the collection of functional and clinical-anamnestic data. F.L. and P.M. contributed to the analysis and interpretation of pulmonary function data and FeNO trends. They also drafted the manuscript and critically revised the discussion section. All authors approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Declaration on the use of AI: None.

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History

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Girls and Women in Mines: an Invisible Path of Forced Labour in Italy

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Gender and Work Committee, International Ergonomics Association

Keywords: Mine; Slate; Asbestos; Zinc-lead; Sulphur; Girls; Women; Italy

Summary

This study aims to shed light on the largely understudied history of girls and women working in Italian mines during the 19th and 20th centuries. Giovanni Loriga authored an outstanding paper on Pneumoconiosis in 1930 at the Johannesburg Conference. By examining his sources from earlier surveys, travel records, and congress proceedings, the research uncovers data on women and girls in slate (Liguria), asbestos (Piedmont), zinc-lead (Sardinia and Lombardy), and sulfur mines (Sicily), along with their working conditions. The research findings reveal that girls and women were integral to the mining industry throughout Italy, despite being underrepresented and relegated to specific tasks. Ultimately, the paper explores the development of protective Italian legislation, its inadequate enforcement, and suspension during World War I. The paper concludes by highlighting the ongoing global issue of girls' labour in mines, drawing a parallel between the historical situation in Italy and the contemporary reality denounced by organizations like the ILO and UNICEF.

1. Introduction

"*How can we know what happened in the past? We cannot travel back in time, ask the people who were alive long ago. Historians use evidence that survives from the past. Like detectives, they search for clues. They piece together what they think the past was like. Evidence can be of different kinds: archaeological evidence, oral history, visual evidence, written documents*" [1]. When searching for women's labor pathways in male-dominated fields, such as mining, historical evidence is complex. The purpose of this paper is to shed light on the evidence of the invisible path of girls and women forced into mine labour from the beginning of the nineteenth century to the twentieth century in Italy. Due to the pneumoconiosis being a central health theme in mining work, research began with the outstanding paper by Giovanni Loriga (1861-1950) at the Johannesburg Conference on Silicosis (13th-27th August 1930). Loriga, chief medical inspector of factories for Italy and member of the Committee on Industrial Hygiene of the International Labour Office (ILO), presented a fifty-page paper titled "*Pneumoconiosis in Italy*" with three pages dedicated to slate and one page to asbestos [2]. He reported on the work of women in slate quarries in Lavagna (Genoa, Liguria): "*About 1834 there existed in Monte San Giacomo (Cogorno) seventy slate quarries, now abandoned, and the whole population of the region (about 4,000 persons) was engaged in working the slate, the men as excavators and cutters and the women as transport workers*". Loriga references were two works by Giovanni Antonio Mongiardini (1809, 1812), the honor thesis by Giovanni

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Battista Ravenna (1812) "*De morbis quibus subiacent ardesianum effossores*" (Diseases of slate miners) and the monograph of Niccolò Della Torre "*Guide to the Quarries of Lavagna*" (1840).

2. Girls and Women in Slate Quarries

In 1809, the physician G.A. Mongiardini (1760-1841) published a "memoir" on the slate quarries of Lavagna [3][4]. He detailed the carrying of slate performed by girls and women: "*Every day, except holidays, you can see long lines of young and old women on the road that leads from Lavagna to Cogorno and S. Giulia, who, with the sole help of a rough diaper on the head, carry enormous weights. ....sometimes they are forced to march two, three, and four together in a row, and not in front, due to the narrowness of the path, to hold an extraordinarily heavy boulder*." Mongiardini, at the end of the memoir, cited the chapter on the health of miners from the De morbis artificum diatriba by Bernardino Ramazzini (1713). No women are mentioned as miners in Ramazzini's chapter, although, in the description of The Diseases of Porters, he describes women as porters, raising the question of why porters (men) carry heavy loads on their shoulders: *"...but women who carry great loads on their heads are obliged to walk erect, for any movement of the head to one side would move the heavy load that lies on it out of the perpendicular, and it would have to fall. It is wonderful to see how easily they carry huge baskets on their heads as they walk, erect and agile; this is because the weight is placed on a bone that is very strong and arched, the skull, and is directly above the vertebrae.*" [5].

Della Torre enriched Mongiardini's description of women's work in Lavagna (1840): "*Dangerous and extremely tiring work, done for a ridiculous fee of 30 cents a day... which would seem a small amount to a porter from Genoa for the journey of a quarter of an hour...Women, often still children or young girls, carried the slates from the mountain to the Lavagna beach, barefoot and with the load balanced on their heads*." [6]. Previously, in 1834, in the book "*Traveling through Liguria on the sea*", the words of the Italian writer Bertolotti: "... *we walked towards the mountains. Crowds of women descended from it, carrying slate slabs on their heads. On top of the slabs, they had the distaff and the spindle, because they spun when going to the quarries. They spin as soon as they put down their load: a single moment of idleness would seem like a crime to them. They carry out this transport from the quarries to the warehouses of the slabs in Lavagna in the morning and in the evening, attending to agricultural and domestic chores the rest of the day. The weight that they support on the spinal column is no less than 7 or 8 rubbi* (the Genoese unit of measurement with the metric-decimal equivalent*, 60 kilograms per trip). The bearers are fewer than the female bearers, but they also bear much heavier weights on their heads; and it seems that they seek balance with hurried steps, almost as if they were running*" [7].

Loriga, in the slate quarries pages, also reported that: "*Devoto himself records, moreover, that, during the Congress of Italian Scientists held in Genoa in 1846, there was discussed the pathology and hygiene of work in the slate quarries and that a priest, Giuseppe Ravenna, summarized all the medical and sociological studies on the subject in a publication dated 1879 and entitled "Memoirs of Lavagna*".

Giuseppe Ravenna, in "*Memories from Lavagna*" (1887), described the life of women in slate quarries as follows: "*Crowds of women and girls of all ages walked along the narrow pathways several times a day, in the summer, making up to four round trips a day to the coast. Images of the time portray crowds of barefoot women carrying slabs of slate on their heads arranged in a single file or paired two by two up to six couples ordered so that the weight is proportionate to the individual forces, who descended towards the sea using a cloth folded into a ring (sutéstu) that allowed the transport of dormer windows with two or sometimes four workers. The last stretch of slate transport from the Lavagna warehouses to the beaches was always carried out by around forty female porters who lived in the coastal town and also took care of the boarding. Arriving alongside on rickety gangways, the sailors directly took the plates to place them in the hold*"[8].

Carlo Picchio, Luigi Devoto's above-mentioned student, published in 1930 "*The Pathology of Slate Workers of Chiavari in the First Half of the Nineteenth Century*" in three parts of the journal "La Medicina del Lavoro". In the first part [9], he reported that women slate carriers could only perform the pathway from the quarries to Lavagna two or three times per day, earning only 80 centimes per day (a miner earned 4,000 centimes). In the second part [10], he described the technological change brought about by cableway transport, eliminating the need for women's work. In the third part [11], he argued that the high infant mortality in Lavagna in the nineteenth century was probably caused by women carrying slate stones, even during pregnancy. Women married at an early age (15 years old) and had a high fertility rate. Cases of childbirth during the pathway were reported in the register of the Cogorno parish. The lack of care for minors at home might also be the cause of high mortality among children. Tuberculosis was also a significant threat. Picchio also denounced the risk of work injuries due to quarry stone falls. It is conceivable that slate stones could also fall from women's heads, determining injuries not recorded in any of the cited works. The pathways of these women and girls from the quarries to the beach were pictured by unknown photographers in the late nineteenth century (Figure 1).

3. Girls and Women in Asbestos Quarries

Loriga, in the section dedicated to asbestos, also cited the work of Luigi Scarpa: "*From an interesting statistical study made by Scarpa (1908), it would appear that out of 30 workers (9 men and 21 women) who had been engaged in manipulating asbestos in the mines or factory laboratories for weaving this mineral, and who were being treated in the department of the Turin Polyclinic under the direction of the author from 1894 to 1906, only one showed simple catarrhal lesions of the respiratory apparatus. The other 29 suffered from tuberculosis. All died in less than a year after the first medical examination, since the disease, in a short time, brought about destructive and ulcerative lesions of the lung. The author claims, therefore, that the asbestos industry is one of the most dangerous of those industries involving predisposition to pulmonary tuberculosis*" [2]. The women with lung lesions treated at the Turin Polyclinic had likely worked in the asbestos quarries at Val di Lanzo and in the asbestos-processing factories in Nole Canavese, such as the Capamianto factory in Turin. In the mid-nineteenth century, asbestos production was also improved by Perotti and Brauns, who exhibited in a booth at the Turin International Exposition in 1898, and by Bender & Martiny (1899). In 1906, the Criminal and Civil Court of Turin issued a sentence on the asbestos victims both women and men, referring to testimonies, references and epidemiological issues, in favor of the local newspaper that stated "*The asbestos industry is more dangerous to the health of the workers than the other factories in Nole Canavese, because it yearly causes an incredible number of victims due to tuberculosis, bronchitis and gastroenteritis, as marked with sad frequency in the obituaries of men and women working with asbestos in that Municipality*" [12]. In the Piedmont region, long and short-fibre asbestos was

Figure 1. Women and girls carrying the slates at Lavagna, unknown photographer.

Figure 2. Women working in asbestos quarries in Valmalenco, photographer Secondo Incisa [13].

found in Val di Susa and Val di Lanzo, while in the Lombardy region, in Valtellina and Val Malenco in the province of Sondrio. Mining operations began in the early nineteenth century and progressively decreased until they ceased in the early 1930s, giving way to the talc mining industry. In Val Malenco, women and girls were employed in the Campo Franscia quarries to extract and process rocks containing asbestos in Tornadri. Images of women working in Campo Franscia quarries were published in *Italian Asbestos: Events and Prospects* by Secondo Incisa in 1933 (Figure 2) [13]. Small stones were removed from the asbestos and packed into bags weighing approximately 40 kilograms. Early in the morning, women and girls aged ten to fourteen carried the bags to the valley using a pannier. They transported asbestos to Tornadri, where machinery was ready to process it into engine gaskets, roof coverings, chimney flues, and coverings for school walls or train carriages. Here is a testimony from Speranza Bergomi, a girl who worked in the mines during the twentieth century: "*I started transporting asbestos when I was a child in primary school and stopped at nineteen years old. Before school, I went to Campo Franscia every day to get asbestos, which I then carried to Tornadri, where there was a large warehouse near the fountain. I started working at 5:00 a.m. and finished at 8:00 a.m., while still attending school. Then, as a girl, I would work until noon. I reached my workplace on foot because cars were costly, and few people could afford them. I made two trips a day, but some women made more. The transport was tiring, and you had to be very careful not to slip and fall; with that load, you could seriously injure yourself. In case of illness, we were allowed to stay home for only 10 days. I transported asbestos year-round, even in winter during deep snow; in this season, I used crampons ('crapelle') fixed to my boots. I received fifteen lire for each transport. I had no insurance, as it was not mandatory to insure workers daily*." [14].

In 1898, Lucy Deane and Adelaide Anderson, both British inspectors, highlighting the importance of having female inspectors, found the adverse effects of asbestos among girls, as dangerous material rather than "magic mineral": "*The incessant sore throat, the irritation of the bronchial passages, the frequent colds on the chest, and hoarse voice, along with morning cough from which girls employed in dusty processes suffer, are symptoms that to casual observers could be easily attributed to other causes*" [15]. The first case of lung fibrosis resulting from the inhalation of asbestos dust was diagnosed only in 1924. The case was Nelly Kershaw (1891-1924), a girl-woman who, from the age of thirteen, had worked in an asbestos factory in Rochdale (England) as a rover, spinning raw asbestos fiber into yarn, and died at the age of 33 [16]. In 1941, Bolognini, an occupational physician, confirmed, with his own words: "*The work is mostly done by men, with women's help limited to the transport of the mineral*", here the historical underestimation of the work of women in Valmalenco quarries [17].

4. Girls and Women in Sardinia Mines

The role of women and girls in Sardinia mines is well documented by Quintino Sella, Italian Deputy Chamber, in the *Report Mine Industry conditions in the Sardinia Island* (1871) [18]. Since 1859, before the unification of Italy, the Kingdom of Sardinia prohibited child labour under the age of 10 (art. 88, Law n. 3755, 1859). Sella compiled numerous tables of the Sardinian mines, providing an extraordinary picture of the many women and girls employed since 1860 (Table 1).

On average, 642 women (11% of all employees, years 1860-1869) were employed in Sardinia mines, of whom an average of 322 girls (50%) per year were under fourteen years old. Women were also employed in ore-processing foundries, with an average of 561 (16% of all employees) from 1859 to 1869, of whom 393 were girls (70%). Adult women (over 21 years old) received lower wages than men (1.55 lire), with wages related to age: 0.85 cents for those under fifteen years old and 1.15 cents for those between fifteen and twenty-one years old. In the Montevecchio mine (Medio Campidano), which closed in 1991 after 143 years of operation, more than 100 women were employed in selecting and sieving lead and zinc minerals. In 1871, on Thursday, the 4th of May, eight girls (Elena Aru, 10; Caterina Pusceddu, 10; Anna Melis, 11; Anna Azeni, 12; Anna Pusceddu, 14; Anna Peddis, 14; Rosa Gentila, 15; Luigia Vacca, 15) and three women (Antioca Armas, 32; Luigia Murtas, 27; Rosa Vacca, 50) died due to the fall of a poorly built dormitory wall caused by the overweight of the water container for mineral washing [19]. Montevecchio's working women were forced to sleep in the mine's dormitory because the village was more than a six-kilometer walk from Arbus and even farther from Guspini. The owner bore no responsibility, and only two women with children received some compensation. In the same neighborhood, the Ingortosu mine (established in 1869) extracted lead and employed a total of 440 workers, including 129 women. In Villasalto, women and girls were employed in sorting materials at the Su Suergiu antimony mine. In 1903, the Regulation (Law n. 41, art. 5) was enacted to enforce the law on women and child labor (1902), requiring employers to register boys and girls under 15 years old working in the mines. The town of Buggerru (Carbonia-Iglesias) (Figure 3) can be considered the cradle of zinc extractive industries, where a mining village near the Malfidano mine was built, reaching a population of 8,000 inhabitants, including many young

Table 1. Sella Q. Mine industry conditions in the Sardinia Island (1871) (modified) [18].

	Men				Women				
Year	Adult	<14 y.o.	%	Total	Adult	<14 y.o.	%	Total	Total
1860	2,536	217	7.9	2753	251	234	48.2	485	3238
1861	3,131	362	10.4	3493	448	109	19.6	557	4050
1862	2,993	157	5.0	3150	299	177	37.1	476	3616
1863	3,408	447	11.6	3855	303	224	42.5	527	4382
1864-65	5,003	683	12.0	5686	309	477	60.6	786	6272
1865-66	5,493	636	10.4	6129	339	591	63.5	930	7059
1866-67	5,302	623	10.5	5925	224	451	66.8	675	6600
1867-68	7,118	493	6.5	7611	325	328	50.2	653	8264
1868-69	7,885	590	7.0	8475	386	310	44.5	696	9171

Figure 3: Girls in Buggerru-Planu Sartu mine (1896) [Costante Sanna collection) [19].

people, women, and child laborers [20]. In Buggerru (Planu Sartu), where calamine (zinc) was extracted, 660 people were employed, though only 420 during the summer. Malaria was prevalent, affecting around half of those workers who had come from the mainland. On 18th March 1913, in the Genna Arenas mine (Buggerru), four women sorters (Anna Rosa Murgia, 15; Anna Pinna, 24; Maria Saiu, 36; and Laura Lussana, 20) were killed when raw ore fell from a hopper that could not support the heavy load [21]. In 1905, at the Nebida mines (Iglesias), Dr. Giovanni Leone, director of the Nebida hospital, reported that twenty girls working in mineral washing at the Nebida mines suffered from chlorosis, amenorrhea, and miscarriages (Association of Miners in Nebida).

5. Women and Girls in Sicilian Mines

Pasquale Villari, an Italian historian and politician, revealed in the Lettere Meridionali the real conditions of southern Italy. Many of his works were translated into English by his wife, Linda White Mazini Villari (1836-1915). Villari wrote on Sicilian sulfur mines: "*Now it is known that Sicily... is the centre of the sulphur mines, which, after agriculture, are the largest and richest industry on that island, an industry that employs many tens of thousands of workers of all sexes and ages*" and "*…hundreds and hundreds of boys and girls descend steep slopes or uncomfortable stairs, dug into crumbling and often wet ground. Having reached the bottom of the mine, they are loaded with ore, which they must carry on their backs, risking slipping on the steep and unreliable terrain and falling to their deaths. Those of greater age come up, uttering heart-rending cries; the children arrive crying. Everyone knows, it has been repeated a thousand times, that this work causes indescribable slaughter among those people. Many die, many remain crippled, deformed, or sick for their entire lives... Weak organisms remain destroyed, the strong survive to command, tyrannize, oppress children and girls piled up in those dark hallways, where anything can happen. Man becomes brutalized, demoralized, and easily becomes an enemy of the society that treats him so ruthlessly*" [22].

The first Italian law on Child Labour (Law Berti n. 3657) was promulgated in Italy only in 1886, following years of unsuccessful proposals. The first article cited: "*The work of children of one or the other sex is forbidden in industries, quarries and mines at the age of 9 years old or the age of 10 years old if the work is underground*". It is the first and unique occasion in which sex is taken into account by Italian legislation before the twentieth century. This child protection law, along with others, reveals how girls and boys were both employed in quarries and underground mines with no limitations.

Jessie White Mario (1832-1906) was inspired by Villari and devoted herself to philanthropic work among the poor of southern Italy in the early 1870s. She worked particularly on a research project aimed at raising governmental awareness and travelled to Sicily in 1890-91. Her report, "*The Sulphur Mines in Sicily,*" on the working conditions in the Sicilian mines, was published later in 1894. White Mario made extensive personal tours and investigations of the mines, both above and below ground. She first travelled to Palermo and started her visit to the sulphur mines in Lercara (Agrigento). "*Children of both sexes aged four and over, pregnant women, lying on their backs, walked on all fours inside the mine, working for twelve and fourteen hours, sometimes during the night*" [23]. There was a concern about child labor and the general health of the miners, many of whom were physically unfit for military service. She reported a total of 480 sulphur mines, 5,233 pickmen, 9,227 "adult carusi" of whom 4,681 (51%)

were under fifteen years old in forty-eight Sicilian villages in the provinces of Catania, Caltanissetta, Agrigento (Girgenti), and Palermo. "Caruso" was a "mine-minor prevalent a boy" who worked next to a "picuneri" or "pick-man", and carried raw mineral from deep in the mine to the surface. In the Girgenti mine, with a total of 1,586 workers, fifty-five girls under fifteen years old were working underground (3.5%). In the open quarries, 20 adult women (4,211 total, 0.5%) and 53 girls under fifteen years old (1,991 total, 2.7%) were found. In 1892, a total of 33,587 workers, comprising 25,825 adult men and 7,762 under fifteen years old, were recorded. Additionally, three adult women and 57 girls were also under fifteen years old. These numbers, produced by the White Mario script, showed an increase in workers since 1890, with 5,800 miners, including 1,030 boys under fifteen, while the number of girls decreased from 108 to 57.

In Lercara (Palermo), White Mario met Alfonso Giordano (1843-1915), a medical doctor engaged in the improvement of working conditions in sulphur mines with particular attention towards girls who used to go down the mine, although he referred to "*now they do not*". Mine work was among the first industries employing girls (11% of girls under 15 years old), after textiles (28%), metal manufacturing (14%), and hay and wood (13%). He underlined, however, "…. *the notable difference existing in the number of women employed in 1889 and that of 1903. In 1899, out of a total of 97,505 workers, 4,541 were women (4.6%), in 1903, out of 121,791 workers, 2,888 (2.30%), which proves that, in spite of the increase in workforce, even though women were less paid than men, there is still great common sense in the population to remove the weaker sex from that type of work, harmful to their health, especially in sulphur mines*" [24]. Giordano, using concepts such as "weaker sex" or "common sense", confirms the common stereotyped language when the work of women was discussed. In 1903, Salvatore Talamo, editor of the Journal Research in Social Sciences inspired by Christian values, wrote: "*The number of women working in the sulfur mines, always very small compared to the total number of workers, has significantly decreased in recent years. They are usually employed in the sorting of sulfur ore, or in the loading and unloading of*

Figure 4. Carusi "Coming up in sad procession"(1910). Photographer Louise Hamilton Caico [27].

limestone; so that the performance of their work is neither stable nor very painful, and can be compared to that which women elsewhere carry out in agricultural work, in civil constructions, and similar. Only in Cianciana, in the Bivona district, in the province of Girgenti, several girls transport ore underground, to their fathers or brothers, but usually leave the mine when puberty begins" [25]. Women mine work was again described as not "very painful "! In Cianciana mine only <15 y.o. girls were working transporting minerals from deep to the surface. In 1881 ninety girls were working as "caruse" although less paid than boys. In 1898, an inspector met a little and fragile 10-year-old. A girl is transporting the sulfur mineral on her shoulder from the underground. His inspection report, found in the State Archive, recalled her name, Ignazia Greco; she was born in Cianciana on January 16, 1888. [26] (Figure 4-5).

6. The Labour Legislation on Women, Girls and Boys in Mine Work

In 1899, Maria Montessori (1870-1952), one of the first Italian women to graduate in medicine, attended the Second International Women's Congress (ICW) hosted in London. She called for the prohibition of women and children under the age of 14 from working in sulphur and other mines, inspired

Figure 5 – Women in Cianciana mine. Photographer unknown [26].

by the Factory Acts. However, the Sicilian mines, under English proprietors, were no better than the others. She described the conditions under which young children worked, including the long hours, cramped positions, continual climbing up and down steps, the heavy weights they had to carry, and the need for proper lighting and ventilation. Martina G. Kramers (1863-1934), a delegate from the National Council of the Netherlands and a leader in the International Council of Women, spoke on the special legislation for children in mines under the factory laws. "*The age of going down in mines is generally fixed a little higher than that of entrance into the factory. In Germany and France, children are permitted to work when they have their school certificate, or when they are 13 years old. In Switzerland, New York, and some German States, they must have attained the age of 14; in Austria, Belgium, Holland, Luxemburg, Norway, Sweden, Portugal, Rumania, and Pennsylvania, that of 12; in England, Denmark, Hungary, and Spain, that of 10, and in Italy, 9… For working in the mine, the age required is 10 in Italy, 14 for boys and 18 for girls in Norway, 14 for both in Portugal*" [28]. It was only in 1902 that Italy finally had its first law on women and child labour (Legge Carcano N. 242), mainly due to the efforts of the physician Anna Kuliscioff (1855-1925), the self-educated Ersilia Majno Bronzini (1859-1933), and many others as part of the Italian women's movement. Women were prohibited from working in underground mines, while for boys, the limit was under the age of 13. Girls and boys under 12 years old were banned from working in open quarries and hazardous trades. The law limited the working day to 12 hours for women, 11 hours for children aged 12 and 8 hours for children aged <10 years [29].

The First Italian National Congress on work-related diseases was held in Palermo (Sicily) from 19th-21st October 1907, with many contributions concerning the unhealthy conditions of sulfur miners (pneumoconiosis, inguinal hernia, malnutrition, ancylostomiasis, etc.). No words on women working in sulfur mines, although women's and girls' conditions in zinc/lead mines in Gorno (Bergamo) were portrayed by Cesare Biondi (1867-1936), a socialist physician, in the paper "*Occupational diseases among the workers of the mine in Bergamo*". Those women were named "Taissine" from the local dialect, meaning to fragment and separate the mineral. Biondi's description was clear: "*The outside workers can be divided into various groups: the first group …separates the mineral from the sterile material and, in the*

Crown Spelter mines, also from the galena. This work is done mostly by women… Ordinary sorting work is not done in front of benches, but on the ground, so that the women are seated or, more often, half-kneeling; the sifting is done while standing up. A second group of outdoor workers consists of washery workers, including men, women, and children. There are only two washeries in the mines of Bergamo, the one in Campello of the Crown Spelter and the one in Oltre il Colle of the Vieille Montagne. …I have been able to observe how various underground workers, …also among women selecting materials, present a thin reddish halo on the gum edge.…and is indicative of the absorption of lead" [30]. Palermo Congress participants were invited to visit the Trabonella sulfur mine (Caltanissetta), where, just four years later, on 20th October 1911, a gas explosion caused 40 deaths and 16 injuries; the number of children is unknown.

7. Child Labour and Sex Differences in Body Growth

In 1908, Loriga wrote a book on "*Child labour and sex differences in body growing*" to set health standards for girls' and boys' growth, such as weight, height, chest circumference, lung vital capacity and muscular strength. Child labor was also a scientific question on sex differences in body growth! Loriga cited Alfonso Giordano's figures when comparing students of the municipal school of Lercara with the "carusi" of the sulfur mines in the same locality. The cause of the growth differences, found by Giordano between the two groups, was the unhealthy working conditions. Loriga also reported having asked the medical doctor of Arbus (Cagliari), Gildo Frongia, to improve his data records, including the pregnancy outcomes of women working in the galena washery (no data reported) and the heights of 389 children in the Sardinia mines of Montevecchio and Gennamari-Ingortosu. Frongia found that the undergrowth of miners differed from that of peasants in terms of sex differences. "These figures clearly demonstrate the harmful influence exerted on the *physical development of children by mining work, which is surely more tiring and unhealthy than that of the peasants, although relatively better paid.*" Taking these results into account, Loriga pleaded with the Italian State to increase the age limit to work, the work inspection on child labor, the medical surveillance on working children "to avoid the serious consequences of work". [31].

Two years later, in the spring of 1910, Sir Thomas Olivier, a Scottish industrial hygiene physician, travelled to Sicily. In his report, *The sulphur mines of Sicily: their work, diseases and accident insurance*, he mentioned women only briefly: "*No females are employed to look after the rooms or bedding; men and boys feed together in a canteen, their food being bread, oil, and macaroni, with vegetables, dried beans, and lentils.*" [32]. In the same year, African American community leader Booker Washington Talliaferro, along with sociologist Robert E. Park, traveled to visit Europe. They traveled to Italy and Sicily, visiting Palermo, the sulfur-rich region, and Catania. In his book *The Man Farthest Down,* he described: "*It is said that the employment of boys in the sulphur mines is decreasing. According to the law, the employment of children under fifteen years of age has been forbidden since 1905. As is well known, however, in Italy as in America, it is much easier to make laws than to enforce them. This is especially true in Sicily. The only figures which I have been able to obtain upon the subject show that from 1880 to 1898 there was an enormous increase in the number of children employed in and about the mines. In 1880, there were 2,419 children under fifteen years working there, among whom were eight girls. Of this number, 88 were seven years of age, and 163 were eight years of age, while 12 percent of the whole number were under nine years of age. In 1898, however, the number of children under fifteen was 7,032, of whom 5,232 were working inside the mines. At this time, the Government had already attempted to restrict the employment of children in the mines, but the age limit had not been fixed as high as fifteen years*" [33].

Subsequently, Italian women and children were mobilized in 1915 for industrial production during World War I, as the only available low-cost labour [34]. In 1918, Luigi Carozzi (1875-1963) reported in the annual inspection records that he was only able to assess the working conditions of fifteen miners; no women were included in the inspection. Currently, we do not know how many women returned to underground mining or worked in open quarries following the suspension of laws on women and child labor during the war. We do know, however, that the explosion at the munition factory in Castellazzo di Bollate (Milan) in June 1918, only recently brought to light, resulted in the deaths of fifty-two women and girls, with many other injured. This episode highlights, once again, the role of women and girls in hazardous occupations. Later on, in 1924, Livia Lollini (1889-?), who graduated in medicine in Rome in 1913, wrote the paper "*The Protection of Women and Children at work*", recently republished by this journal [35] together with an interesting updated commentary on the relevance of her gender-sensitive approach in occupational health [36]. Lollini, in fact, acknowledged Loriga's works, probably due to their similar sensitive approach and the women's movement's request for maternity protection. She renewed her call for more female labour inspectors and the enforcement of legislation in Italy, particularly in the South, where disparities had not been eradicated. Unfortunately, the fascist dictatorship halted and reversed all the praiseworthy efforts.

8. Conclusion

The purpose of this paper was to collect historical references, statistics, and pictures related to the invisible work of girls and women in Italian mines, despite the prevailing stereotype of women employed in "light jobs" or as the "weaker sex".

The results obtained show that little girls, girls, and women in Italy were often employed in mining work, particularly in open quarries, as well as underground work, especially during the nineteenth century. Data on mines in Liguria, Piedmont, Lombardy, Sardinia, and Sicily were found and recorded. Work exposure was mainly to slate, asbestos, zinc-lead, and sulphur ore, causing pneumoconiosis, tuberculosis, lead poisoning, chlorosis, etc. Carrying heavy weights, slips and falls, sexual abuse, and other acute injuries, such as the Montevecchio (1871) and the Buggerru (1913) mine disasters, were also reported. Adverse reproductive outcomes such as miscarriage, infant mortality, and other risks were only occasionally mentioned.

The lack of knowledge regarding mining work should be addressed with further investigation and research. The nearly century-long history of women and girls in mines in Italy, illustrated in this study, starting with Loriga's paper in 1930, underscores the need to gather data from diverse sources for ongoing research. The usefulness of women's studies and their "forward-thinking" is also essential to understanding the present. Around the world, girls and women are still working in mines, with 10% of children aged 5-17 (girls 8.4%; boys 10.7%). This percentage doubles in Africa (19.6%), as indicated in the "Child Labour" report [37].

ILO report on "Girls in mining" cited "*The studies demonstrated that girls are working longer hours, carrying out more activities and in some cases entering into even riskier underground work than in the past… Girls are stretched between growing labour activities and burdensome chores at home, which constitute excessive hours of often dangerous work, a lack of time for rest and recuperation, and an impossible schedule to fit around school attendance, or at least optimum school performanc*e" [38]. More work needs to be done to eliminate this "slavery." However, it cannot be ignored that women and girls have been working, and continue to work, in mines. Their history, at present, still awaits full consideration [39].

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