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Two Decades of Fatal Workplace Accidents in Milan and Monza, Italy: Trends, Work Sectors, and Causes from Autoptic Data

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Abstract

Background: *Work-related fatalities represent an important global public health threat, accounting for over 300,000 deaths annually. Despite preventive strategies, fatalities persist, necessitating extensive investigations. Autoptic investigations, when ordered, offer comprehensive data on fatal accidents, in particular with detailed information about the type of accident, lesions, and type of work, enabling a thorough analysis of various factors contributing to workplace deaths. This study investigates work-related fatalities in Milan and Monza Brianza, Lombardy, analyzing patterns, industries, and factors leading to death among workers.* **Methods:** *This retrospective study analyzed all fatal work accident data from the Autopsy Database of the Legal Medicine Institute of Milan from January 2000 to December 2022. We also estimated the risk of fatal accidents per 1.00.000 workers using ISTAT data for the different work sectors.* **Results:** *Of the 17,841 violent deaths in Milan and Monza Brianza, 308 resulted from work-related accidents. The majority were male (95.1%). The secondary sector showed the higher estimated risk (27 /10^6 vs. 19/10^6 in primary and 2.3/10^6 in tertiary sector) accounted for 78.5% of fatalities, with specialized workers (35.1%) and construction workers (25%) being the most affected. Falls from above were the leading cause of death (36.7%). A decreasing trend in fatal accidents over the study period was observed, with July having the greatest frequency. The most common causes of death were polytrauma (36.4%) and head injuries (19.2%). Non-Italian workers constitute a noteworthy percentage of fatal cases (24%).* **Conclusions:** *The secondary sector has the most fatal accidents at work despite a decrease in accidents over the observed time period. There is a need for rigorous analysis and interventions, using forensic autopsy case data to help understand causes, and collaboration between institutions is encouraged to develop effective preventive policies.*

1. Introduction

Work-related fatalities represent a critical public health and safety concern since they are accidents that could have been avoided with proper measures. Whether due to occupational hazards, safety breaches, or communication breakdowns, occupational injuries account for more than 300,000 of the 2.3 million work-related deaths globally each year [1, 2]. These numbers show that work-related

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fatalities are a serious issue that affects many countries and industries around the world. For example, over 6,200 people in the US die from work-related injuries each year [3]. Meanwhile, in Italy, the Italian Compensatory Authority (INAIL) estimates that roughly 1,300 fatal accidents occur each year during working hours [4].

Despite the development of newer and improved preventive strategies and tools, the issue of work-related fatalities is still very topical [5, 6]. The volume of work-related fatalities and occupational diseases varies significantly between occupational sectors. The primary and secondary sectors, defined by intrinsic dangers, usually have a greater incidence of deaths and occupational diseases than sectors with largely office-based work [7–12]. This persistence of fatalities at work has many probable causes, such as the diversity of work environments, the role of human error, economic pressures, globalization, technological changes, inconsistent enforcement of safety regulations, emerging risks, and evolving workforce demographics [11, 13–15].

In the Italian legal system, the communication of an accident at work that led to absence from work of at least one day, excluding one of the events, is an obligation for all employers. If the accident at work involves an absence from work for more than three days, an injury notification report is mandatory [16]. The Legislative Decree 9 April 2008 n.81 (D. Lgs. 81/08) is an Italian law that sets the rules relating to health and safety at work. According to the decree, the employer is responsible for the safety of their employees and must take all the necessary measures to guarantee it. Article 589 of the Italian penal code establishes that the punishment for whoever causes the death of a person through negligence is imprisonment from six months to five years. If there is suspicion of a death caused by a crime, the public prosecutor can order a judicial autopsy to establish the cause of death. Therefore, in the presence of a work-related fatal accident, the public prosecutor's office usually requests the execution of a judicial autopsy to ascertain the causes of death, together with an investigation aimed at understanding whether the death was caused by the employer's negligence or not. The judicial autopsy is then carried out by the Legal Medicine Institute of the province in which the fatal accident occurred.

Lombardy is Italy's most populous region, with approximately ten million residents, and it is home to almost one million production activities, both small and large enterprises. The provinces of Milan and Monza Brianza alone have more than 364,000 active businesses, and they are two of the wealthiest provinces in Italy. With more than 4 million workers, the region has the greatest labor force in Italy [17]. Therefore, there is a high risk of injuries at work; in fact, in recent years, the region has recorded a great number of fatal accidents [18].

INAIL publishes a national and regional report of all the notified accidents at work every six months. These are well-collected and processed data, but they are presented according primarily to its insurance agenda and not a prevention logic. The public data on fatal accidents is mainly aggregated and doesn't report details about what led to the death of the person and the type of job that the victim performed [4]. This lack of information makes it difficult to analyze the causes and patterns of work-related fatalities and design and implement effective prevention strategies. The autopsy act is necessary to identify the type of lesion that caused the worker's death. The added value of the autopsy data is highlighted by the need to differentiate the information sources to increase the data flow. Autopsies provide comprehensive data on the circumstances and events leading to fatal accidents, and crucial insights into the individuals involved, allowing for a thorough investigation of the numerous elements that contribute to workplace deaths.

This study aims to examine work-related fatalities in two of the biggest and wealthiest provinces of Lombardy, Milan and Monza Brianza, over 23 years, from January 2000 to December 2022. The study also intends to identify the industries and occupations that have the highest occurrence of fatal accidents and to evaluate the major factors that lead to death among workers.

2. Methods

The data for this retrospective study was obtained in March 2023 from the Autopsy Database of the Legal Medicine Institute of Milan. The Autopsy Database systematically collects the relevant information

available on all the violent deaths that occurred in the provinces of Milan and Monza Brianza since 1986, for a total of 36,618 autopsies. The Autopsy Database contains personal data (gender, weight, height, Body Mass Index (BMI), ethnicity, date and place of birth, city of residence, current job, smoking and drinking habits, history of drug abuse), medical history (pathological history, medications, previous surgical interventions, disabilities), and autopsy details (date and place of death, age at the time of death, details from the site inspection, long and accurate description of the circumstances of the fatality, cause of death, toxicology, site of lesions) of the deceased. All the autopsies are recorded using an anonymous ID, such as the report number. The inclusion criteria were: i) autopsies performed from 2000 to 2022, ii) all the fatalities labeled as work-related accidents, including commuting injuries. The exclusion criteria were: i) missing or questionable data about the type of fatal accident and occupation, ii) natural deaths or suicides that occurred during working hours.

We transferred the selected cases in a new database for further analysis. The long and accurate descriptions of the circumstances of the fatality and cause of death were then read and coded in six entries named type of fatal accident: fall from above, falling objects, stuck in machinery, commuting accident, electrocution, other (drowning, explosion, burned, chemical toxicity, animal attack, combination of two types of injury). The same was performed with the job of the deceased, classifying them according to the ATECO job sector categorization: primary sector (A-B such as farmers and breeders), secondary sector (C-F such as construction workers, maintenance/technicians such as electricians and plumbers, specialized workers such as carpenters and foremen, metalworkers, unskilled workers), tertiary sector (G-U such as couriers, white-collars, law enforcement, healthcare workers).

The statistical analysis was performed using the program SPSS PC version 29. Statistical significance was set for a P-value ≤ 0.05. We used the chi-square and ANOVA tests to compare categorical and quantitative variables between the different types of fatal accidents, respectively.

3. Results

From January 2000 to December 2022, there were 17,841 violent deaths in the province of Milan and Monza Brianza, with 308 (0.017%) caused by workplace accidents. Out of our sample of 308 casualties, 293 (95.1%) were men, and 15 (4.9%) were women, with an average age of 44.2 years at the time of death (±13.7 sd) ranging from 17 to 77 years. The mean BMI of the sample was 27.9 (±5.2 sd), with a minimum of 15.2 and a maximum of 45.5, with overweight being the most represented BMI class (26.6%). Two hundred thirty-three (75.6%) of the deceased were Italian, while 36 (11.7%) were European, 20 (6.5%) African, 12 (3.9%) Asian, and 7 (2.3%) South American. The pathological history of 258 (83.8%) of the sample was known, and it was positive for 81 (26.3%) of them. Out of the 81 deceased with a positive pathological history, 27 (33.3%) had hypertension, 11 (13.6%) from metabolic diseases, 6 (7.4%) were suffering from cardiovascular diseases, 5 (6.2%) from pluri-pathological diseases, 3 (3.7%) from neurological diseases, 2 (2.5%) from psychiatric diseases, and 27 (33.3%) from other diseases. Nonsmokers accounted for 33.8% of the sample, 40.6% weren't consuming alcoholic beverages regularly, 15.3% consumed coffee daily and 29.9% never consumed drugs. The demographic characteristics of the sample are described in detail in Table 1.

In the 23 years studied, there were an average of 13.3 fatal accidents each year, with a high of 27 in 2007 and a low of four in 2020. Figure 1 depicts a decreasing trend in the number of fatal accidents over time. Overall, the month with the most fatal accidents was July, with 34 (11%) fatal workplace accidents, followed by June with 32 (10.4%) fatal accidents.

The secondary sector was the one with the most fatal accidents at work with 242 (78.5%) events, 108 (35.1%) involved specialized workers, 77 (25%) involved construction workers, 35 (11.4%) involved maintenance/technician workers, 12 (3.9%) involved metalworkers, and 10 (3.2%) involved unskilled workers. The tertiary sector registered 59 (19.2%) fatal workplace accidents, 30 (9.7%) involved white-collar workers, 23 (7.5%) involved couriers, 3 (1%)

Table 1. Demographic characteristics of the sample (BMI, nationality, pathological history, smoking habit, alcohol consumption, coffee consumption, drug abuse).

Tot = 308	N (%)
BMI	
Unknown	90 (29.2%)
Underweight	4 (1.3%)
Normal weight	62 (20.1%)
Overweight	82 (26.6%)
Obese class 1	47 (15.3%)
Obese class 2	20 (6.5%)
Obese class 3	3 (1%)
Nationality	
Italian	233 (75.6%)
European	36 (11.7%)
African	20 (6.5%)
Asian	12 (3.9%)
South American	7 (2.3%)
Pathological history	
Unknown	50 (16.2%)
Negative	177 (57.5%)
Positive	81 (26.3%)
Cardiovascular	33 (10.7%)
Metabolic	11 (3.6%)
Pluripathological	5 (1.6%)
Neurological	3 (1%)
Psychiatric	2 (0.6%)
Other	27 (8.8%)
Smoking habit	
Unknown	83 (26.9%)
Nonsmoker	104 (33.8%)
Smoker	101 (32.8%)
<20 cig/die	62 (61%)
>20 cig/die	40 (39%)
Ex-smoker	20 (6.5%)
Alcohol consumption	
Unknown	88 (28.6%)
No	125 (40.6%)
Yes	95 (30.8)
Coffee consumption	
Unknown	228 (74%)
Yes	47 (15.3%)
No	33 (10.7%)
Drug abuse	
Unknown	211 (68.5%)
No	92 (29.9%)
Yes	3 (1%)
Past use	2 (0.6%)

involved law enforcement workers, and 3 (1%) involved healthcare workers. The primary sector had 7 (2.3%) fatal accidents at work involving farmers and breeders. In the primary sector, the most common accident at work was represented by other causes such as attacks from animals or drowning with 4 (57.1%) events, while a fall from above was the most common in the secondary sector with 99 (32.3%) events, in the tertiary sector the most common accident was represented by commuting accidents with 23 (7.4%) events. With 113 (36.7%) events, the most common type of fatal workplace accident was a fall from above. Commuting accidents accounted for 40 (13%) events, falling objects for 38 (12.3%), stuck in machinery accounted for 30 (9.7%), and electrocution for 5 (1.6%) events. Other fatal accidents were responsible for 82 (26.6%) events. Among genders, the predominant occupation for men was a specialized worker (36.2%), while women were mostly white-collar (53.3%). The most common fatal workplace accident for men was a fall from above, accounting for 110 (37.5%) fatalities, while for women it was commuting accidents with 6 (40%) events (Table 2).

With 112 (36.4%) occurrences, the most common injury was polytrauma, followed by 59 (19.2%) injuries on the head, 15 (4.9%) injuries on the thorax, 3 (1%) injuries on the abdomen, and 119 (38.6%) in other areas of the body.

No statistically significant differences were observed among accident types concerning age, nationality, history of drug abuse, BMI, alcohol consumption, or pathological history (Supplementary materials 1).

4. Discussion

A novelty of this study is the use of autopsy data to describe workplace fatal accidents, allowing for

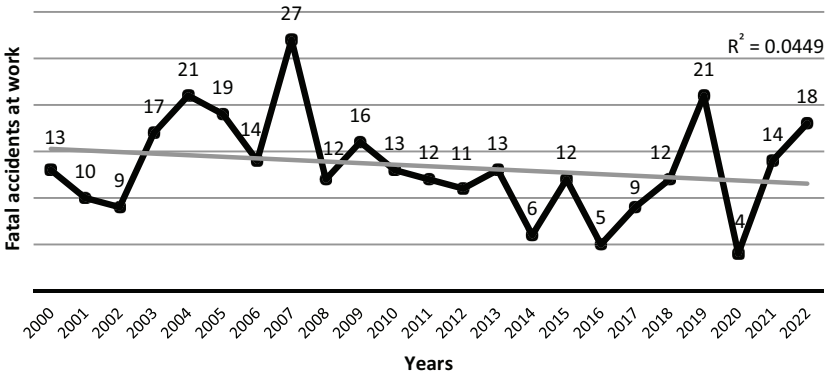

Figure 1. Fatal accidents at work from Jan 2000 to Dec 2022 in the provinces of Milan and Monza Brianza.

some comparability with traditional databases. This approach also helps to enrich our epidemiological understanding and provides insights into the affected individuals, fostering a holistic exploration of the multifaceted dynamics behind fatal accidents. Three hundred and eight fatal accidents at work were reported to the Forensic Institute of Milan in the study period. In the same years, INAIL's reports in the Lombardy region registered 4,408 fatal accidents at work for the whole region [18], with no province details for the whole period. Considering the proportion between the inhabitants of Lombardy and the inhabitants of the provinces of Milan and Monza Brianza, we estimated the number of expected fatal accidents in the provinces of Milan and Monza Brianza in the same period as 1,928. Thus, the data collected from the Forensic Institute of Milan would represent 16% of the expected fatal accidents in the Milan and Monza Brianza provinces.

The Lombardy's Regional Registry for Accidents at Work reports 17 and 24 accidents for 2021 and 2022 respectively, in the Health Protection Agencies' (ATS) territory of Milan and Monza Brianza [19]. The territory of Monza Brianza's ATS also comprehends the province of Lecco. The autoptic data reports 14 fatal accidents in 2021 and 18 in 2022. Based on the ATS's reports, the Forensic Institute of Milan data accounts for 82.3% and 75% of fatal work accidents in 2021 and 2022 respectively.

This partial coverage of the fatal accidents was expected and is part of the study's limitations. The Milan Forensic Institute's database underestimates the number of deaths caused by accidents at work because a judicial autopsy may not be ordered for all fatal occupational accidents, and their reporting can vary between institutions and their agendas. Divergent definitions of what constitutes a fatal accident at work, reporting timelines, and data collection methodologies may also lead to these differences. For example, in the INAIL's reports, all the deaths caused by work-related COVID-19 are considered fatal accidents at work [20]. At the same time, no judicial autopsies were ordered for this kind of death, and they aren't taken into consideration in Lombardy's Regional Registry for Accidents at Work. INAIL and ATS's databases have various recording techniques and timings that are not always easy to access and do not allow extensive or comparative examination. However, the incomplete coverage of fatal cases by the Forensic Institute of Milan may reduce the generalizability of our results. Another limitation is determined by a possible misclassification in the Institute's database. Anamnestic data are reported by third parties. Therefore, some are missing, and some may be unreliable. To explore potential preventive measures, it's vital to update and improve accessibility to the data collected.

Despite the above-mentioned limitations, the data obtained is valuable in bringing substantial insights to the larger context of our research. In our sample, most recorded accidents involved male workers, accounting for 95.1% of the cases. This gender imbalance reflects a prevailing trend observed in the literature on

Table 2. Analysis of fatal workplace accidents by ATECO job sector categorization (primary (A-B), secondary (C-F), and tertiary (G-U)), occupation (farmers and breeders, couriers, construction workers, maintenance/technicians, metalworkers, unskilled workers, white collars, law enforcement, healthcare workers), accident type (fall from above, falling objects, stuck in machinery, commuting accident, electrocution, other), and gender.

	Fall from above	Falling objects	Stuck in machinery	Commuting accident	Electrocution	Other	Total
Primary sector (A-B)	**0**	**0**	**1 (0.3%)**	**1 (0.3%)**	**1 (0.3%)**	**4 (1.4%)**	**7 (2.3%)**
Farmers and breeders	0	0	1 (0.3%)	1 (0.3%)	1 (0.3%)	4 (1.4%)	7 (2.3%)
Men	*0*	*0*	*1 (0.3%)*	*1 (0.3%)*	*1 (0.3%)*	*4 (1.4%)*	*7 (2.3%)*
Women	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Secondary sector (C-F)	**99 (32.3%)**	**32 (10.3%)**	**24 (7.9%)**	**16 (5.1%)**	**4 (1.4%)**	**67 (21.6%)**	**242 (78.5%)**
Construction workers	44 (14.4%)	9 (2.9%)	1 (0.3%)	5 (1.6%)	2 (0.6%)	16 (5.2%)	77 (25%)
Men	*44 (14.4%)*	*8 (2.6%)*	*1 (0.3%)*	*4 (1.4%)*	*2 (0.6%)*	*16 (5.2%)*	*75 (24.4%)*
Women	*0*	*1 (0.3%)*	*0*	*1 (0.3%)*	*0*	*0*	*2 (0.6%)*
Maintenance/ technicians	10 (3.3%)	1 (0.3%)	4 (1.4%)	3 (1%)	2 (0.6%)	15 (4.8%)	35 (11.4%)
Men	*10 (3.3%)*	*1 (0.3%)*	*4 (1.4%)*	*2 (0.6%)*	*2 (0.6%)*	*15 (4.8%)*	*34 (11.1%)*
Women	*0*	*0*	*0*	*1 (0.3%)*	*0*	*0*	*1 (0.3%)*
Specialized workers	41 (13.4%)	18 (5.8%)	15 (4.8%)	5 (1.6%)	0	29 (9.5%)	108 (35.1%)
Men	*41 (13.4%)*	*18 (5.8%)*	*13 (4.4%)*	*5 (1.6%)*	*0*	*29 (9.5%)*	*106 (34.5%)*
Women	*0*	*0*	*2 (0.6%)*	*0*	*0*	*0*	*2 (0.6%)*
Metalworkers	2 (0.6%)	2 (0.6%)	1 (0.3%)	2 (0.6%)	0	5 (1.6%)	12 (3.9%)
Men	*2 (0.6%)*	*2 (0.6%)*	*1 (0.3%)*	*2 (0.6%)*	*0*	*5 (1.6%)*	*12 (3.9%)*
Women	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Unskilled workers	2 (0.6%)	2 (0.6%)	3 (1%)	1 (0.3%)	0	2 (0.6%)	10 (3.2%)
Men	*2 (0.6%)*	*1 (0.3%)*	*2 (0.6%)*	*1 (0.3%)*	*0*	*2 (0.6%)*	*8 (2.6%)*
Women	*0*	*1 (0.3%)*	*1 (0.3%)*	*0*	*0*	*0*	*2 (0.6%)*
Tertiary sector (G-U)	**14 (4.6%)**	**6 (1.9%)**	**5 (1.6%)**	**23 (7.4%)**	**0 (0%)**	**11 (3.6%)**	**59 (19.2%)**
White collars	10 (3.3%)	1 (0.3%)	0	14 (4.5%)	0	5 (1.6%)	30 (9.7%)
Men	*7 (2.4%)*	*1 (0.3%)*	*0*	*10 (3.4%)*	*0*	*4 (1.4%)*	*22 (7.5%)*
Women	*3 (1%)*	*0*	*0*	*4 (1.4%)*	*0*	*1 (0.3%)*	*8 (2.2%)*
Couriers	3 (1%)	3 (1%)	4 (1.4%)	8 (2.6%)	0	5 (1.6%)	23 (7.5%)
Men	*3 (1%)*	*3 (1%)*	*4 (1.4%)*	*8 (2.6%)*	*0*	*5 (1.6%)*	*23 (7.5%)*
Women	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Law enforcement	0	2 (0.6%)	0 (0%)	0 (0%)	0 (0%)	1 (0.3%)	3 (1%)
Men	*0*	*2 (0.6%)*	*0*	*0*	*0*	*1 (0.3%)*	*3 (1%)*
Women	*0*	*0*	*0*	*0*	*0*	*0*	*0*

	Fall from above	Falling objects	Stuck in machinery	Commuting accident	Electrocution	Other	Total
Healthcare workers	1 (0.3%)	0	1 (0.3%)	1 (0.3%)	0	0	3 (1%)
Men	*1 (0.3%)*	*0*	*1 (0.3%)*	*1 (0.3%)*	*0*	*0*	*3 (1%)*
Women	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total	**113 (36.9%)**	**38 (12.2%)**	**30 (9.8%)**	**40 (12.8%)**	**5 (1.7%)**	**82 (26.6%)**	**308 (100%)**
Men	*110 (35.9%)*	*36 (11.6%)*	*27 (8.8%)*	*34 (11%)*	*5 (1.7%)*	*81 (26.3%)*	*293 (95.1%)*
Women	*3 (1%)*	*2 (0.6%)*	*3 (1%)*	*6 (1.8%)*	*0*	*1 (0.3%)*	*15 (4.9%)*

Occupational Health, where different studies highlight a disproportionate representation of men in work-related accidents. In a 2012 study on occupational accidents in Mexico, Gonzalez-Delgado et al. reported a frequency of 96.23% of male workers [11], while Perotti and Russo, in a 30-year study on fatal injuries in the Brescia province of Italy, reported a 99% majority of male workers [21]. Similar numbers can be found in many other studies with similar percentages such as 98% found by Errico et al. [22] and 98.95% by Yamaguchi et al. [23]. This phenomenon can be explained by the fact that men are still employed at a somewhat larger rate than women (80% males and 69.3% women in the EU in 2022) [24]. Our data isn't equally distributed between genders, and this can be also attributed to occupational segregation, with men traditionally being overrepresented in high-risk and physically demanding professions, except for healthcare occupations [25–27]. This is consistent with our study analysis, in which the predominant occupation for men was specialized worker (36.2%), while for women was white-collar (53.3%). The most common fatal workplace accident for men was a fall from above (37.5%) while commuting accidents accounted for 40% of the events for women. The percentage of commuting accidents for women is similar to the 56% found by Gilberti and Salerno in a 5-year analysis based on INAIL's data [26]. More studies, that possibly include more women, are needed in order to understand the reason behind this difference in terms of the type of fatal accidents.

With an average age of 44.2 years at the time of death, our sample is similar to the mean age of 44.5 found by Perotti and Russo [21] and by Errico et al. [22] in other provinces of Italy. As the working population ages, it's important to consider this factor for future studies.

A large percentage of accidents at work in foreign workers is expected and confirmed by both our data (24.5%) and in literature (13% in the province of Brescia [21], 11% in the province of Genoa [22], and 10% in the prefectures of Tokyo and Chiba [23]), as foreign workers are often employed in particularly demanding activities, which expose them to greater health and safety risks [28]. INAIL, in its reports, distinguishes between Italians and non-Italians for the last years only, and for the whole Region. Therefore, it isn't easy to make this comparison for the entire period (2000-2022) and Milan and Monza provinces. However, we compared our 2022 results (27% of fatal cases occurring in non-Italian workers – i.e. 5 on a total of 18) and the whole period (24% - i.e. 75 over a total of 308 of cases among non-Italians workers) obtaining comparable results with INAIL data for non-Italian workers from 2022: 11% of total workers, 22% of total injuries, 29% of fatal cases. This observation highlights the high risk of injuries and severe injuries in non-Italian workers. In interpreting our relatively low proportion is important to consider that our data covers a longer period, reflecting the increased share of foreign workers over time. In the contemporary world marked by increased migration, it becomes

imperative to acknowledge the differences in working cultures. One should not assume that all workers universally comprehend and share safety procedures, underscoring the importance of vigilant attention to these factors.

In the 23 years studied, we found a decreasing trend in fatal workplace accidents. This confirms what was shared by national and regional INAIL reports that states that the decline was probably caused by an efficient increase in risk control and that it was also partially caused by the reduction of COVID-19-related deaths [29]. Despite this decreasing trend in Italy, China, and Taiwan [21, 30, 31], overall occupational deadly accidents are on the rise worldwide [27]. According to our data, July and June had the highest percentage of fatal accidents (11% and 10.4% respectively), supporting the notion that workplace deaths typically occur during the summer [14, 21, 22] even though there isn't a consensus on the specific month [23]. More studies are needed to better understand the reasons behind this occurrence, but these findings underline the need for increased vigilance during the summer months. In the autopsy database, some data were not available, such as information on the employment relationship, shift duration and place of residence. We believe that this information, if added to the autoptic records could be very useful in terms of preventive medicine.

In our study, the sector with the most fatal work accidents was the secondary one with 78.5% of events, followed by the tertiary sector (19.2%) and the primary sector (2.3%). According to the Italian National Institute of Statistics (ISTAT), the approximate number of employees in the primary sector in the provinces of Milano and Monza Brianza is 18,359, while in the secondary sector is 444,111 and in the tertiary sector is 1,258,222. Therefore, we could approximate an estimated average risk (as the number of fatal cases per year in each sector) of 19/1,000,000 fatal accidents in the primary sector, $27/10^6$ fatal accidents in the secondary sector, and $2.3/10^6$ fatal accidents in the tertiary sector. The increased incidence of fatal accidents occurring in the secondary sector is a common finding in literature in Italy [21, 22], and worldwide [11, 14, 23, 27]. This, once again, underscores the inherent dangers associated with industrial and construction activities. We observed a noteworthy incidence of fatal accidents in the primary sector, but given the low percentage of workers in the agricultural sector in our mostly urbanized area, we observed a lower percentage of total cases if compared to INAIL national data (2.3% versus 10.7%), and in a previous epidemiological study conducted in Lombardy [21, 32]. Regional and province variations, the types of industries, and risk profiles included in our sample may differ from those studied in the existing literature, leading to a lower proportion of fatal accidents in the primary sector than anticipated. Understanding these sector-specific patterns is critical for formulating targeted Occupational Health and safety strategies.

Our research provided unique insights and information not included in public reports from other organizations that could considerably improve our understanding of the subject. The occupations with the most fatalities were specialized workers (35.1%), followed by construction workers (25%) and maintenance/technician workers (11.4%). These results differ from the ones by Errico et al. [22], Perotti and Russo [21], Al-Abdallat et al. [14], and Yamaguchi et al. [23] that found construction workers to be the most impacted by fatal work accidents (40.5%, 36.6%, 44% and 39% respectively). This difference may be due to regional differences in industries and different categorizations of workers' jobs in literature, which may include specialized workers in the large category of "construction workers". Therefore, a limitation of our study was the difficulty in attributing a clear ATECO code to the specific occupation, which would have improved the aggregation and comparability of our results to other databases. Understanding occupation-specific patterns is crucial for developing effective Occupational Health and safety strategies.

The most common type of fatal workplace accident was a fall from above (36.7%). This is also the main type of fatal workplace accident in the studies by Al-Abdallat et al. (44%) [14], Errico et al. (42.5%) [22], and Yamaguchi et al. (25%) [23]. It is noteworthy that some studies, such as the one by Perotti and Russo, while not distinguishing between various types of mechanical trauma, still highlight

its importance as the leading cause of fatal accidents (77.69%) [21]. The consistency in reporting falls from above as a primary cause of fatal accidents across different studies underscores the pervasive nature of this occupational hazard. Taking occupational sectors into consideration, is important to underline that, in our study, fall from above is the main accident in the secondary sector, but not in the primary and the secondary. The predominance of falls from above in the secondary sector might be attributed to the nature of work, involving activities at heights, construction, and other tasks that inherently expose workers to elevated fall risks, deadly or not [33, 34]. These findings across multiple studies emphasize the importance of targeted preventive measures specific to the occupational contexts.

Commuting accidents were the second leading type of fatal injury (13%). This percentage is larger than the 6.4% found by Errico et al. [22], but smaller than the average of 26.5% from 2018 to 2022 reported by INAIL in Lombardy [18]. This may be because different institutions may have different procedures and standards for determining if there is an autopsy to order for a commuting accident. Commuting accidents are the most represented in the tertiary sector (41.7% of the events). Workers in the tertiary sector, often involved in administrative and service-oriented roles, may frequently commute for work-related purposes, exposing them to increased vulnerability on the roads especially if they work long hours [35]. More studies are needed to understand the specific reasons behind these accidents and formulate effective preventive measures.

The most common injury was polytrauma with 112 (36.4%) events, followed by 59 (19.2%) injuries on the head. Fatal head traumas are a common finding in work-related accidents literature, in a 10-year study in Genoa they accounted for 63.4% of the events [22], and 33.56% of the events in a study in the Brescia province [21]. An injury on the head, a site with the most vulnerability, can lead to death, especially in falls from above accidents [36]. More studies are needed to understand the efficacy of implementing targeted preventive measures to avoid head injuries.

Concerning alcohol consumption and history of drug abuse, we didn't find any differences among fatal accident types. There is some evidence that alcohol and drug consumption impact the occurrence of fatal accidents, especially commuting ones, but the literature is not unanimous on this matter [37]. A study by Blandino et al. reports that over 40% of workers who died due to commuting accidents were positive for ethanol [38]. In the study by Al-Abdallat, 9.1% of the workers who died on the job tested positive for alcohol [14]. A study on car accidents in West Virginia by Rudisill et al. found that the chance of dying with a positive alcohol test was 85% less likely in those who were commuting from and to work compared to individuals who were driving for other reasons [39]. This lack of difference among types of fatal accidents and alcohol consumption in our data can be because toxicology reports aren't ordered for all the fatal accidents during work. They must be done as soon as possible after the death of the worker, and in some cases, they cannot be performed (i.e. a death that occurred after days of hospitalization). A limitation of our study consists in the impossibility of going into detail on this kind of information as a family member of the deceased reports them during the interview before the autopsy act. Some organizations have already implemented preventive strategies, such as a ban on alcohol consumption at work or alcohol and drug testing [40]. More studies are needed to investigate the impact of alcohol and drug intake on the workplace in terms of types of fatal accidents to implement specific preventive strategies.

We didn't find any statistically significant difference between individual characteristics (age, nationality, BMI, pathological history) and the type of fatal accident. The impact of individual characteristics should be investigated further as age <30 years old and higher BMI were described as a risk factor for occupational accidents in research by Chau et al. and Darus et al. [34, 41].

5. Conclusion

In conclusion, our investigation into work-related fatal accidents in the provinces of Milan and Monza Brianza over 23 years sheds light on some critical aspects of Occupational Health and safety. This study underlines that, despite an overall decrease in

accidents, the secondary sector is the occupational area with the highest number of fatal accidents, especially for specialized construction workers. These preventable deaths underscore the need for rigorous analysis and interventions. Our understanding of what causes fatal occupational accidents can be improved using forensic autopsy case data, including epidemiological information on individual cases. Collaboration between different institutions should be encouraged to improve the knowledge of these topics. By understanding the patterns, trends, and causes of work-related fatalities, policymakers, employers, and safety professionals can establish targeted preventive policies and legislation to decrease risks and preserve workers' lives. Further research should aim to reduce the human toll, which has also significant economic implications, and improve collaboration between different institutions.

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