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Descriptive analysis of occupational accidents in Spain and their relationship with heatwaves

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ABSTRACT

Objective: The purpose of this work is to carry out a descriptive analysis of occupational accidents and to evaluate the relationship between heatwaves and work accidents in Spain's three most populated provinces: Madrid, Barcelona and Valencia.

Methods: Daily data of work accidents (including for each case: gender, age, date, length of time in the position, type of work, place of accident and duration of medical leave) was collected. A heatwave was defined when daily mean temperatures above the threshold (95th percentile) of the climatological period (1990–2021) were recorded for at least three consecutive days. To estimate the association between daily workplace accidents and heatwave events, we applied a Generalized Additive Model combined with a Distributed Lag Non-linear Model with a quasi-Poisson distribution.

Results: The average annual accident rate was 33.2 work accidents/100,000 employees in Madrid, 35.8 work accidents/100,000 employees in Barcelona and 31.8 work accidents/100,000 employees in Valencia. The total accident rates followed a downward trend between 2005 and 2021. The difference in work accident rates between sex decreased over the studied period ($p < 0.005$). In the first month of work, the highest casualty rate occurs among construction workers in Madrid and Barcelona, and in primary sector workers in Valencia. Work accidents tend to increase during heatwaves. The highest risk was recorded when considering a cumulative lagged effect of 3 days in Madrid and Barcelona and 5 days in Valencia.

Conclusions: Since work accidents increase during heatwaves, risk prevention services and public administrations must take special measures to prevent them.

1. Introduction

In recent years, some analysis has been published on the impact of exposure to adverse weather phenomena and, specifically, the effects from the thermal environment on work-related health (Santurtún and Shaman, 2023).

Scientific evidence on the health impacts (both morbidity and mortality) with the exposure to extreme temperatures (Alahmad et al., 2023) has led to the recognition of heat stress as a work risk in all sectors, both for indoor as well as for outdoor work, by the European Union. In March 2023, the European Agency for Safety and Health at Work, 2023 published a series of action guidelines associated with exposure to heat in the workplace. The guidelines emphasize the importance of acclimatization, that is, the physiological adaptation of a person to their environment, and it is estimated that this can take from six to seven days, although it is conditioned by the characteristics of each person (age, sex, physical shape, medical history, toxic habits, among others).

However, it should be taken into account that, on the one hand, adaptability to the environment is finite (Sherwood and Huber, 2010; Pal and Eltahir, 2015) and, on the other, that, under current

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environmental circumstances and without changing their workplace or job, a worker may have to be confronted to changes in their physical work environment. Thus, a period and process of adaptation cannot be established (Baldwin et al., 2019).

Both the manifestations of climate change and the ability to adapt differs between countries (EEA, European Environment Agency, 2018). Also, the climatic characteristics to which the person is exposed can be key elements when addressing the impact of extreme temperatures on health (Ebi and Mills, 2013).

In Spain, few studies have been published on occupational health, and most focus on the analysis of individual risk factors, such as alcohol consumption (Gómez et al., 2002) or socio-economic aspects (Rubiales-Gutiérrez et al., 2010), but often workers spend the majority of their time in a variety of indoor and outdoor harmful thermal conditions as their exposure to heat is frequently out their control (Schulte et al., 2016). This increased exposition has direct physiological health impacts and, furthermore, can lead to a decline in the performance of complex tasks as exposure to stressful thermal conditions can conduct to a decline in cognitive function (Yoon et al., 2021; Hancock and Vasmatzidis, 2003).

Considering that: 1) the measures implemented to prevent deaths associated with extreme temperatures are already demonstrating their effectiveness (Achebak et al., 2019); 2) significant evidence of the effect of an increasing trend in the frequency of occurrence of higher air temperatures is found in most of Spain (Castillo-Mateo et al., 2023); 3) occupational risk prevention services and public administrations are increasingly equipped with tools to predict extreme weather events (Serrano-Notivoli et al., 2022); 4) there are very few studies on the impact of the natural environment on occupational health in Spain, and 5) the European Trade Union Confederation (ETUC) (2022), the major trade union organisation representing workers at the European level, has highlighted that Spain is one of the three countries in Europe with the highest increase in deaths due to work-related accidents, the purpose of this study is to carry out a descriptive analysis of occupational accidents and to evaluate the association between heatwaves and work-related accidents in three Spanish provinces with different climatic characteristics.

2. Methodology

An ecological study with time series methodology was performed in Spain in the period between January 1st, 2005 and December 31st, 2021.

This study is based on anonymous data collected by the Ministry of Labour and Social Economy and, thus, is exempt from ethical compliance.

2.1. Area of study

This study analyses Spain's three most populated provinces: Madrid, Barcelona and Valencia (Fig. 1). In 2021, the province of Madrid had a population of 6,751,251 inhabitants, Barcelona had 5,714,730 inhabitants, and Valencia had 2,589,312 inhabitants.

The capital of the country is in Madrid, an inland region located in the center of peninsular Spain. According to the Köppen climate classification, its climate can be considered a transition between cold semi-arid (BSk) and Mediterranean (Csa). The service sector is the main work sector in the province, currently accounting for 79.5% of active workers, followed by industry and construction (8.8% and 5.6%, respectively). Of the working population, 80.3% are under 55 years of age and 7.3% under the age of 25 (Table 1).

Barcelona is a coastal region, located in northeastern Spain, in the

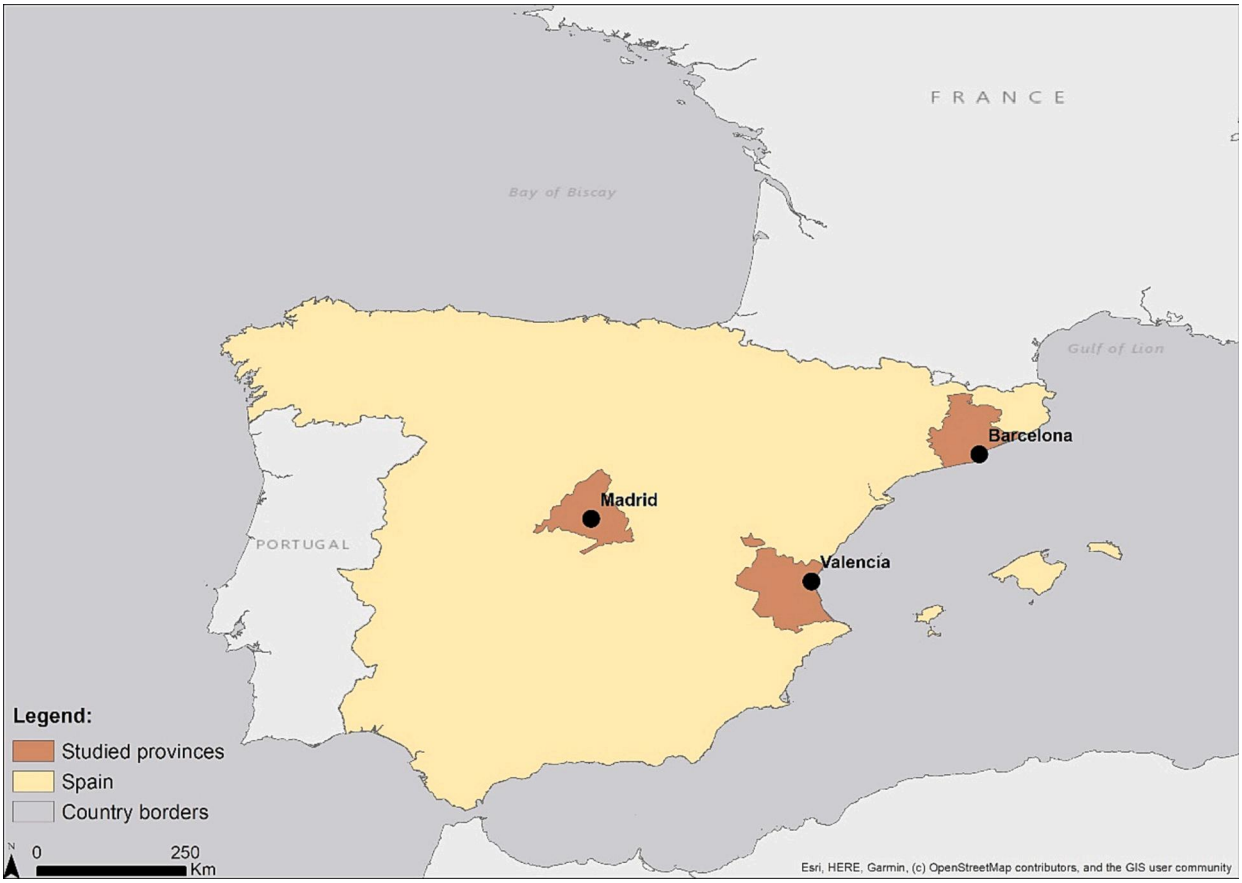


Fig. 1. Map of Spain with the study provinces (Madrid, Barcelona and Valencia) highlighted.

Table 1
Characterization of the working population in Madrid, Barcelona and Valencia in 2023.

	Madrid	Barcelona	Valencia
% of working population by activity sector			
Service sector	79.5	74.1	69.7
Industry	8.8	15.9	16.5
Construction	5.6	4.7	6.1
% of working population by age group			
< 25 yo	7.3	8.5	7.0
25–54 yo	73.0	71.9	72.4
> 54 yo	19.7	19.6	20.6
Employment rate by sex			
Men	60.4	58.5	59.3
Women	52.6	51.8	46.3

Source: National Statistics Institute (Instituto Nacional de Estadística, INE, 2023).

autonomous community of Catalonia, with a typical Mediterranean climate (Csa) according to the Köppen classification. In this province, the service sector accounts for 74.1% of active workers, industry 15.9% and construction 4.7%. Of the working population, 80.3% are under 55 years of age and 8.4% under the age of 25.

The last province analyzed is Valencia, which is coastal and located in the eastern part of the country. It is part of the autonomous community of Valencia, with a semiarid or steppe climate (BSk). In Valencia, the service sector represents 69.7% of active workers, followed by industry, 16.5%, and construction, 6.1%. The age of active people is slightly higher in this region than in Madrid and Barcelona, with 79.4% of the working population under 55 years of age and 7% under the age of 25. Data on the labour market for the three provinces has been taken from the National Statistics Institute (Instituto Nacional de Estadística, INE), taking the latest update in 2023 as a reference.

2.2. Meteorological data

The average daily temperature was collected from all the stations in Madrid, Barcelona and Valencia. Data from a measuring station with continuous series from January 1st, 1990 (necessary for the calculation of heatwaves) was selected from each province: "Madrid Cuatro Vientos", "Barcelona Airport" and "Valencia Airport". The data source was the State Meteorology Agency (Agencia Estatal de Meteorología, AEMET).

2.2.1. Heatwave definition categorization

It was considered a heatwave when daily mean temperatures above the threshold (95th percentile) of the climatological period (1990–2021) were recorded for at least three consecutive days, for each province. Similar criteria have been used before by Basagaña et al. (2011), in Barcelona, to estimate the exposure-response to heatwaves.

2.3. Data on occupational accidents

Daily data of work accidents that occurred in the three provinces under study was requested to the Ministry of Labour and Social Economy.

Accidents classified as relapses were excluded. For each case, the gender, age, date of accident, length of time in the position (in months), type of work (Annex I), place of accident and duration of medical leave (in days) were compiled.

In some workers the type of work or duration in the position was not specified, so in the descriptive analysis of these variables, these cases were excluded.

2.4. Statistical analysis

The accident rate per employed population was calculated. The absolute number of people employed by province since 2005 was not available, but the INE publishes the employment rate (the ratio between the total number of employed people and the population aged 16 and over). For this reason, the rate of occupational accidents per employed population for each province was calculated by a quotient whose numerator was the number of work-related accidents and the denominator the product of the annual employment rate by the annual population aged 16 years and up. The rate was expressed per 100,000 employees. The nonparametric Mann-Kendall Tau-B test was used to calculate the trend of the rate of work-related accidents and the Kruskal-Wallis test was used to evaluate the differences in the accidents according to month of the year.

In order to estimate the association between daily workplace accidents and heatwave events, we applied a Generalized Additive Model (GAM) combined with a Distributed Lag Non-linear Model (DLNM) with a quasi-Poisson distribution. The model is as follows:

$$\mathrm{Log}\ (\mu_t) = \alpha + \mathrm{cb}(\mathrm{HW}_t, \mathrm{lag}) + \mathrm{ns}(\mathrm{RH}_t, \mathrm{df}) +$$

$$\mathrm{ns}(\mathrm{time}_t, \mathrm{df}{*}17) + \eta\mathrm{month}\ \gamma\mathrm{dow}_t + \delta\mathrm{holiday}_t + \nu\mathrm{COVID}$$

where: μ_t is the daily number of workplace accidents on day t of observation; α is the intercept; HW is a binary variable that represents the heatwave event on day t (1 = heatwave days and 0 = days without heatwaves); *cb* is the *crossbasis,* modelled with a linear function and a natural cubic spline (*ns*) with two degrees of freedom (*df*) placed at equally spaced values in the log scale. The lag days were set as a maximum of 7 days. Potential confounders, such as RH, day of the week (dow), month, public holidays, and time, were considered in the model. The RH was modelled with ns and 1 df, the time was adjusted with ns and four df per year. Given the important changes in work conditions and characteristics in 2020 and 2021, due to COVID-19, a dummy variable was added to distinguish these periods.

A sensitivity analysis was carried out to calibrate the parameters and assess the robustness of the model by changing the df values for RH, long-term trends (time), and lag days. The model parameters were selected considering the Generalized Cross-Validation (GCV) Criterion, with lower values preferred.

We assessed the heatwave events impacts on workplace accidents for each province separately, and the analysis was restricted to the warm period (April to October). The cumulative relative risk (RR) with its 95% Confidence Interval (CI) was therefore estimated.

The statistical analyses were performed using R software version 4.2.3 (R Core Team, 2019) with the mgcv and dlnm packages (Gasparrini, 2011).

3. Results

3.1. Descriptive analysis of the variables in the study

3.1.1. Work-related accidents

In Madrid there were 1,701,042 work-related accidents in the 16 years analyzed, with 1,527,267 in Barcelona and 577,919 in Valencia. The highest percentage of accidents was concentrated in men (in Madrid, the percentage was 65.5% in men and 34.5% in women; in Barcelona, 67.7% in men versus 33.3% in women, and Valencia had 71.5% of work accidents in men and 28.5% in women).

The average age of workers as the time of accident in Madrid was 40.0 years old (38.2 in men, 40.4 in women), and in both Barcelona and Valencia it was 39.1 years (38.7 in men, 40.0 in women).

As for where the accidents occurred, in most cases it was in the usual workplace (72.3% of the accidents in Madrid, 75.2% in Barcelona and 77.8% in Valencia), followed by accidents in itinere, when going to or

Table 2
Characteristics of accidents in each work group (2005–2021)[1].

		n	% First month	Average age	Average medical leave (days)
Madrid	Production, transformation, warehouse jobs	483,490	7.9	37.5	21.1
	Earthmoving, construction, demolition	140,005	11.5	38.5	23.6
	Agricultural work, forestry, livestock, fish farming	23,058	5.7	40.1	22.6
	Services to companies or personnel and intellectual work	358,262	4.8	40.1	25.6
	Installation. maintenance. cleaning. waste management. monitoring jobs	358,633	5.7	40.6	23.8
	Circulation. sports and artistic activities	322,699	6.3	38.2	29.7
Barcelona	Production. transformation. warehouse jobs	506,726	7.9	38.3	21.8
	Earthmoving. construction. demolition	110,682	9.2	38.6	24.6
	Agricultural work. forestry. livestock. fish farming	19,696	5.8	40.4	24.1
	Services to companies or personnel and intellectual work	250,894	5.3	39.6	24.8
	Installation. maintenance. cleaning. waste management. monitoring jobs	298,033	5.6	41.0	24.7
	Circulation. sports and artistic activities	297,657	6.6	38.2	33.7
Valencia	Production. transformation. warehouse jobs	192,383	9.7	38.1	26.7
	Earthmoving. construction. demolition	50,346	12.3	37.9	27.4
	Agricultural work. forestry. livestock. fish farming	36,407	18.4	40.8	28.6
	Services to companies or personnel and intellectual work	74,623	6.0	40.7	30.8
	Installation. maintenance. cleaning. waste management. monitoring jobs	101,781	7.2	40.5	29.3
	Circulation. sports and artistic activities	94,606	8.5	38.4	37.4

from work (15.1% in Madrid, 15.5% in Barcelona and 11.9% in Valencia).

The average duration of the medical leave associated with the accident was 24.5 days in Madrid, 25.6 days in Barcelona and 29.7 days in Valencia.

In the three provinces, the type of work in which the highest percentage of accidents was found was in those that fall within the category "Production, transformation, warehouse work", representing 28.7% of the total accidents in Madrid, 34.2% in Barcelona and 35.0% in Valencia. The work grouped under "Installation, maintenance, cleaning, waste management, security" was the second with the most accidents, accounting for 21.3% in Madrid, 20.1% in Barcelona and 17.2% in Valencia.

In Table 2, based on the work group, the average age of the workers in each group who have had a work-related accident and the average duration of medical leave resulting from the accident is calculated. Moreover, within each work group the percentage of accidents occurs during the first month is estimated. It should be noted that in Madrid and Barcelona it is Group 2, the one dedicated to construction, where the highest percentage of accidents happen during the first month of work, while in Valencia, in the first month of work, the highest casualty rate occurs among workers in the primary sector.

The classification used by the Ministry of Labour and Social Economy of Spain is followed to define the groups, Annex 1.

3.2. Seasonal patterns of occupational accidents

The average annual accident rate was 33.2 work-related accidents/100,000 employees in Madrid (41.5 in men and 24.2 in women), 35.8 work-related accidents/100,000 employees in Barcelona (46.0 in men and 25.2 in women) and 31.8 work-related accidents/100,000 employees in Valencia (41.6 in men and 20.8 in women).

The total accident rate followed a downward and statistically significant trend throughout the study period in Madrid (MK tau = −0.593; $p = 0.001$) and Barcelona (MK tau = −0.480; $p = 0.007$), but in Valencia it is not statistically significant (MK tau = −0.303; $p = 0.091$). The evolution of rates over the period by gender is shown in Annex II.

Fig. 2-A shows how two phases differ that are delimited by the period's minimum rate (in Madrid 26.4 work-related accidents/100,000 employees, in Barcelona 28.6 work-related accidents/100,000 employees and in Valencia 22.8 work-related accidents/100,000 employees) that was recorded in the three provinces in 2012. In the first phase there is a marked downward trend, but between 2012 and 2021 the rate follows an upward pattern (statistically significant in the case of Valencia [MK tau =0.854; p = 0.001]).

It is worth highlighting the change in the difference in the rate of occupational accidents between 2005 and 2021 according to gender. In 2005, the rate in Madrid was 66.0 in men compared to 25.9 in women, while in 2021 it was 32.4 in men and 22.3 in women. In Barcelona, in 2005 the rate of work-related accidents was 72.8 in men compared to 28.5 in women, while in 2021 it fell to 31.3 in men and 21.9 in women. Finally, in 2005 in Valencia the rate in men was 80.1 and 28.2 in women, while in 2021 it was 32.7 in men and 20.5 in women. The difference in accident rates between men and women decreased significantly over the period in the three provinces ($p < 0.005$).

There are statistically significant differences ($p < 0.001$) in occupational accidents according to the month of the year in the three provinces analyzed. August is the month with the lowest average number of work-related accidents per day (209.3 in Madrid, 169.5 in Barcelona and 69.6 in Valencia), followed by December. February is the month that shows the highest average of work-related accidents per day (314.5 in Madrid, 283.3 in Barcelona and 107.8 in Valencia), Fig. 3-B.

3.3. Relationship between occupational accidents and heatwaves

Table 3 summarizes the descriptive statistics of the meteorological data for each province. Between 2005 and 2021, there were registered 291 days of heatwave events in Barcelona, 276 in Madrid and 176 in Valencia. Most of the heatwave events occurred during July and August.

Work accidents tend to increase during heatwaves in the three cities and this increase is higher at a cumulative lagged effect of 7 days, Fig. 3. Some differences were found between provinces: in Madrid and Barcelona at the day of exposure there was no significant increase with heat waves, but considering a cumulative lagged effect of two or more days the RR was significant; in Valencia the RR was higher than in Barcelona and Madrid both at day of exposure as at any lagged period, Table 4. The highest risk was recorded at lag 0–3 in Madrid and Barcelona and at lag 0–5 in Valencia.

4. Discussion

This study has four main strengths: to our knowledge, it is the first work that analyses the relationship between heatwaves in Spain and occupational accidents; second, the work is robust from a temporal-spatial perspective (it includes a period of 16 years and spatially evaluates the three most populated provinces in the country, with different climatic, demographic and economic characteristics); third, the results of the descriptive analysis are fundamental to be able to address prevention of work accidents; and forth very few studies on work-related health in our country have been published in international journals during the last decade.

We find that work-related accidents increase during heatwaves and

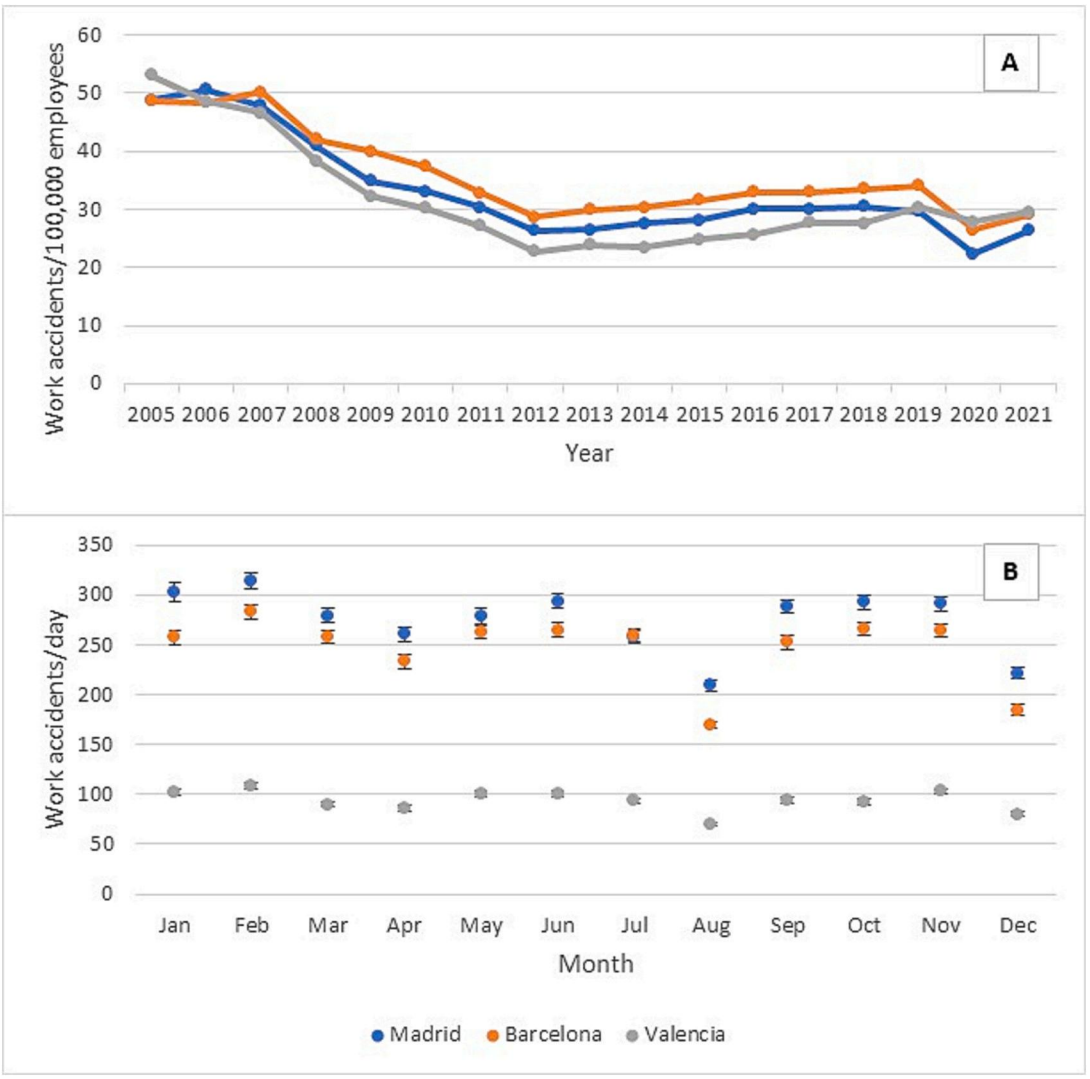


Fig. 2. Descriptive statistics of the temporal behaviour (annual and average monthly pattern) of work-related accidents from 2005 to 2021[2].

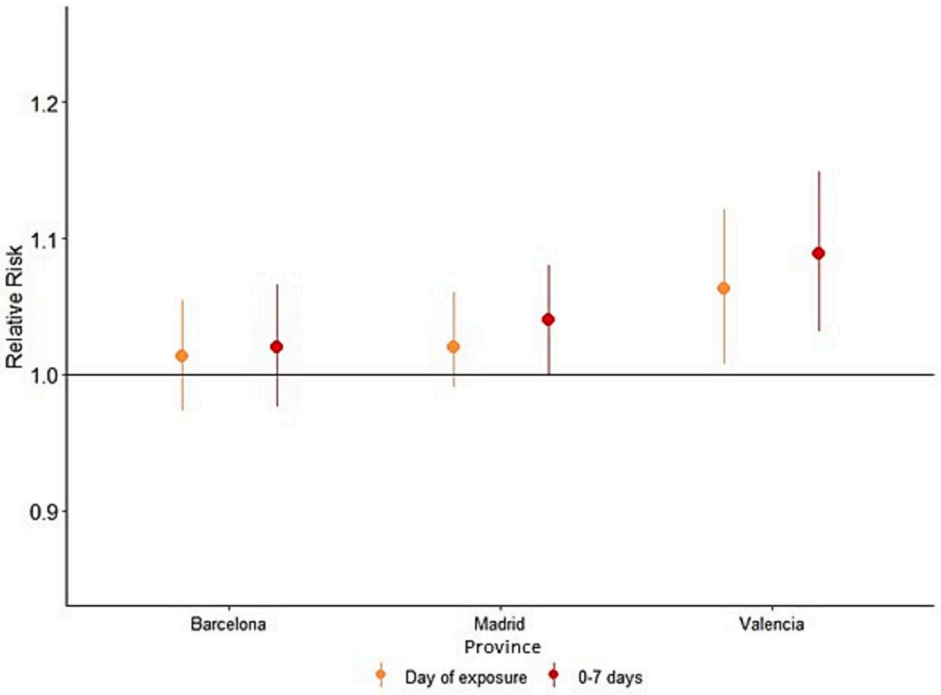


Fig. 3. Overall effects of heatwaves on workplace accidents over the day of exposure and lag 0–7 days in Barcelona, Madrid and Valencia (based on data from 2005 to 2021).

Table 3
Descriptive statistics of temperature data for Madrid, Barcelona and Valencia from 2005 to 2021.

Provinces	Mean	SD	Min	Median	Max	HW days	Number of HW
Barcelona	17,1	6,1	1,4	16,8	32,1	291	50
Madrid	15,6	7,8	-5,2	14,6	33,8	276	55
Valencia	17,8	6,3	0,0	17,6	32,5	176	31

Table 4
Cumulative relative risk of the overall association between heatwaves and workplace accidents in Madrid, Barcelona and Valencia, based on data from 2005 to 2021.

	Madrid	Barcelona	Valencia
Day of exposure	1.02 (0.99–1.06)	1.01 (0.97–1.05)	**1.06 (1.01–1.12)**
Lag 0–1	**1.04 (1.01–1.07)**	**1.04 (1.00–1.07)**	**1.06 (1.01–1.11)**
Lag 0–2	**1.04 (1.01–1.07)**	**1.05 (1.02–1.09)**	**1.06 (1.01–1.11)**
Lag 0–3	**1.05 (1.02–1.08)**	**1.06 (1.02–1.10)**	**1.08 (1.03–1.13)**
Lag 0–4	**1.04 (1.01–1.08)**	**1.05 (1.02–1.09)**	**1.11 (1.06–1.16)**
Lag 0–5	**1.04 (1.01–1.08)**	**1.05 (1.00–1.09)**	**1.13 (1.07–1.19)**
Lag 0–6	**1.04 (1.00–1.08)**	1.03 (0.99–1.08)	**1.12 (1.06–1.18)**
Lag 0–7	**1.04 (1.00–1.08)**	1.02 (0.98–1.07)	**1.09 (1.03–1.15)**

in the following days. High temperature is a risk factor for work because it affects the ability to concentrate and increases the risk of making mistakes (Otte Im Kampe et al., 2016), highlighting workers vulnerability, as even under extreme heat conditions, very often workers do not have the power to choose their working time or place being therefore under severe heat exposition; hence, this exposition may lie beyond individual education and decisions (Yoon et al., 2021).

The risk of accidents due to exposure to high temperatures and work-related accidents has been studied over recent years, finding a significant relationship that coincides with our results (Riccò, 2018; Marinaccio et al., 2019). Specifically, Yoon et al. (2021) have described that heat exposure is a risk factor for workers who do their activity in both indoor and outdoor environments. For outdoor workers high metabolic heat production, task accomplishment, high ambient and radiant heat and, sometimes, high humidity, result in a high human heat strain that combines with personal protective equipment (Ebi et al., 2021). Flouris et al. (2018), in a meta-analysis developed with data from 30 countries, identified that nearly a third of all workers had negative health effects associated with occupational heat stress, including an increased risk of hyperthermia and cardiovascular failure or collapse, and increased risk of acute kidney disease.

Cumulative exposure to heat has been associated with increased stress, mental health outcomes (Almendra et al., 2019) and sleep disturbance (Altena et al., 2023). These factors combined can result in an increased stress over several days that may result in increasing risk of work-related accidents. Our results suggest a lag structure of the heat wave impact in accidents where the highest risk is identified, 3 (Barcelona and Madrid) or 5 (Valencia) days after the heatwave; the variation between provinces might stem from differences in climate among regions, potentially influencing the physiological adaptability of workers. Additionally, the disparities could be attributed to the specific professional sectors in which the work accidents occurred (variations were found among the studied regions; see Table 2). However, further studies, stratified by profession, are needed to better understand this phenomenon and its regional differences in Spain. Moreover, although our results found a significant correlation between workplace accidents and heatwaves, we lack data on workers' lifestyle habits, medical history, and working conditions (such as salary and work hours). This limitation must be acknowledged due to the role of these factors in the well-being of workers and occupational health (Böckerman et al., 2012; Jurek and Rorat, 2017).

In this work we found a markedly higher rate of work-related accidents in men than in women (in Valencia, the average annual rates in men are double the average in women). Nevertheless, it should be noted that the difference in rates between men and women has been decreasing over the years; in 2005 the female rate represented <40% of the male rate in the three provinces analyzed, while in 2021 (the last year studied) it represents >60% of the rate for men, see Annex II.

Traditionally, a higher incidence of occupational accidents in men has been described (Rommel et al., 2016), attributed, as explained by

Einarsdóttir and Rafnsdóttir (2021), to the different types of professional activity that men and women develop and, from a gender perspective, to traditional differences in the roles taken on by men and women. In some models of masculinity, it is assumed that the male worker must show strength and sometimes he confronts dangerous situations without taking the necessary safety measures.

In Spain, the data published by the INE on the working population in the country, show that, in 2021, 18.1% of men but only 7.8% of women worked manufacturing; in the construction sector the difference is also very marked (11% of men compared to 1.4% of women). Both the manufacturing industry and construction industries accumulate a high accident rate.

Furthermore, when interpreting the results, it should be taken into account that accident rates are calculated based on the employment rate published by the INE and from data on the population aged 16 years and older. As explained in the methodology, absolute data on the employed population is not available for all the years of the study. Given that women have a longer life expectancy than men and are generally not actively working in the last years of life, this can slightly alter the outcome and should be recognized as a limitation.

The smaller difference between sexes in recent years is a novel result that is consistent with the findings of a recent study done in Iceland. This study focuses on the young working population (aged 13 to 19) and finds no differences in accidents suffered by gender, although there are indeed differences in the type of injuries (Einarsdóttir and Rafnsdóttir, 2021).

In Spain, one of the factors that could explain the smaller difference between genders in work-related accidents in recent years may be the unequal impact of the pandemic on working life. Backhaus and his team (Backhaus et al., 2023) have done a study in which they analyzed data from 27 EU Member States between 2015 and 2020, and they have concluded that in the pandemic psychosocial working conditions deteriorated for all workers, but more markedly for women. In the previously cited work done in Iceland, the study sample is from 2018, before the pandemic began, and the absence of sex-related differences in accidents is attributed to there not being any segregation in type of employment between men and women; this may also explain our results.

There is a downward trend in occupational accidents over the 16 years of the study. The minimum recorded in 2012 may be due to the economic crisis Spain went through in which some of the sectors with the highest accident rates abruptly decreased their activity. Between 2012 and 2019 there is a growing trend that is interrupted in the last two years of the study. The decrease in the accident rate in 2020 and 2021 should be interpreted with caution due to the pandemic. In Spain, Covid-19 is recognized as a work-related accident when contracted by personnel working in healthcare or socio-sanitary facilities (provided that the worker has been exposed to that specific risk during the provision of their services). For workers from other sectors, Covid-19 is recognized as a work-related accident when it is proven that the disease was contracted solely due to the execution of their job (*Law 10/2021, of July 9, 2021, on Remote Working*, 2023). Those cases classified as work accidents were included in our database which would lead us to expect an increase in the incidence rate, not the decrease found. However, workers affected by a Temporary Employment Regulation (ERTE) in the contexts of COVID-19 have been considered employed in official statistics, although they were workers who had stopped their activity. Likewise, during 2020 telecommuting was established in many professional sectors of Spain; those workers did not have to travel to get to their workplace, as well as that they did their work from their home, could justify the more recent decrease in accidents.

Finally, although some authors have described a seasonal pattern in accidents in specific sectors, such as construction (Chia-Wen, 2012), this pattern is not found in the seasonal analysis of occupational accidents in Spain. Our results do detect inter-monthly differences maintained over the period that can be attributed to changes in the type of employment. For example, the decrease in August may be due to the increase in workers in the service sector (for example, in the hospitality or tourism industry), coinciding with the decrease in construction. In addition, August is a month in which it is common in Spain for a high percentage of the population to be on holiday.

In Spain, Royal Decree-Law 4/2023, 2023 was published in May 2023, which proposes a new framework for prevention of occupational risks during spells of high temperatures, including the prohibition of doing certain jobs during the hours of the day in which adverse weather events occur, in those cases where proper protection of the worker cannot otherwise be guaranteed.

This work, with updated data but prior to the entry into force of the new law, will allow preparation of subsequent comparative studies to evaluate the impact of the measures approved in the regulation.

CRediT authorship contribution statement

Ana Santurtún: Conceptualization, Data curation, Methodology, Investigation, Visualization, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Sara Lopes Moraes:** Methodology, Investigation, Formal analysis, Validation, Visualization, Writing – original draft. **Pablo Fdez-Arroyabe:** Conceptualization, Data curation, Writing – original draft. **María Obregón:** Investigation, Writing – original draft. **Ricardo Almendra:** Conceptualization, Methodology, Investigation, Formal analysis, Validation, Visualization, Writing – original draft, Supervision.

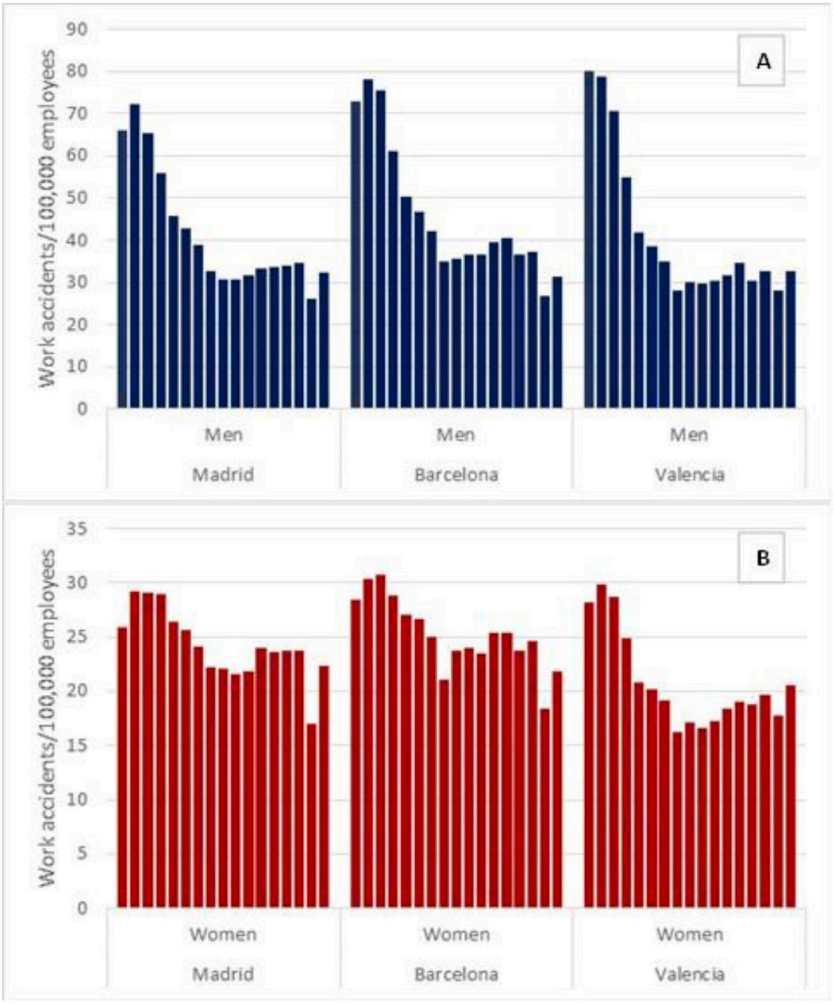
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Annex 1

Types of work according to the guide to complete the section on work-related accidents from the Ministry of Labour and Social Economy of Spain.

Code	Description
10	**Production. transformation. warehouse jobs**
11	Production. transformation. processing – of all kinds
12	Warehousing – of all kinds
19	Other known types of work by Group 1 not mentioned above
20	**Earthmoving. construction. demolition**
21	Earthmoving
22	New construction – buildings
23	New construction – factory work. roads. bridges. dams. ports
24	Remodelling. repair. aggregation. maintenance – all types of construction
25	Demolition of all types of construction
29	Other known types of work by Group 2 not mentioned above
30	**Agricultural work. forestry. livestock. fish farming**
31	Agricultural work – working the land
32	Agricultural work – with vegetables. horticulture
33	Work with livestock – with live animals
34	Forestry work
35	Work on fish farms. fishing
39	Other known types of work by Group 3 not mentioned above
40	**Services to companies or personnel and intellectual work**
41	Services. health care. assisting people
42	Intellectual activities. offices. teaching. Information processing
43	Commercial activities – purchasing. sales. related services
49	Other known types of work by Group 4 not mentioned above
50	**Installation. maintenance. cleaning. waste management. monitoring jobs**
51	Installation. placement. preparation
52	Maintenance. repair. adjustment. overhaul
53	Cleaning of premises. of machines – industrial or manual
54	Waste management. disposal. treatment of all types of waste
55	Monitoring. inspection of manufacturing processes. premises. means of transport
59	Other known types of work by Group 5 not mentioned above
60	**Circulation. sports and artistic activities**
61	Circulation. including in transportation
62	Sports and artistic activities
69	Other known types of work by Group 6 not mentioned above



Annex 2. Rate of occupational accidents per 100,000 employees in the three provinces of the study by gender (A: Men; B: Women). Each bar represents the annual rate from 2005 to 2021 (one bar per year).

[1]Specifically, this includes the absolute number of accidents in the 16 years of the study (n), the percentage of accidents in the first month in the job (the percentage of accidents that occurred in the first month is calculated over the total accidents that happened in the work group), the average age of workers who underwent an accident at work and the average number of days of medical leave resulting from the accident.

[2]Represented in the upper part (A) is the annual rate of work-related accidents/100.000 employees between 2005 and 2021 in the three provinces (Madrid in blue. Barcelona in orange and Valencia in grey). The lower part (B) shows the average number of accidents/day per month of the year between 2005 and 2021.

Data availability

The authors do not have permission to share data.

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