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Original Article

Relationship between Work-Related Accidents and Hot Weather Conditions in Tuscany (Central Italy)

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Abstract: Nowadays, no studies have been published on the relationship between meteorological conditions and work-related mortality and morbidity in Italy. The aim of this study was to evaluate the relationship between hot weather conditions and hospital admissions due to work-related accidents in Tuscany (central Italy) over the period 1998–2003. Apparent temperature (AT) values were calculated to evaluate human weather discomfort due to hot conditions and then tested for work accident differences using non-parametric procedures. Present findings showed that hot weather conditions might represent a risk factor for work-related accidents in Italy during summer. In particular early warming days during June, characterized by heat discomfort, are less tolerated by workers than warming days of the following summer months. The peak of work-related accidents occurred on days characterized by high, but not extreme, thermal conditions. Workers maybe change their behaviour when heat stress increases, reducing risks by adopting preventive measures. Results suggested that days with an average daytime AT value ranged between 24.8°C and 27.5°C were at the highest risk of work-related accidents. In conclusion, present findings might represent the first step for the development of a watch/warning system for workers that might be used by employers for planning work activities.

Key words: Heat stress, Hospital admission, Air temperature, Apparent temperature

Introduction

The influence of thermal stress on morbidity and mortality is considered a direct health impact, quantifiable in epidemiology studies[1–5]. In Italy, only few studies addressed to this topic before summer 2003, when exceptional hot conditions occurred especially in central and northern regions, with catastrophic effects also above all over central and western Europe[6, 7]. However, studies were particularly focused on mortality and morbidity related to heat waves[8, 9], while effects of hot weather conditions on other diseases and healthy subjects were rarely studied[10, 11].

To our knowledge, no studies have been published on the relationship between meteorological conditions and work-related mortality and morbidity in Italy.

Italian Workers' Compensation Authority (INAIL—ISTITUTO Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro) recorded 977,803 work-related accidents in 2003; in industry and services occurred 881,676 accidents, including 1,263 deaths. In the period 1999–2003, the total number of work accidents decreased by 2%, but the figure reaches about 8% if the increase of employees in the five years under study is considered. Unortunately, nor the INAIL database, neither the hospital discharge data contain cases of work accidents related to heat stress, maybe because diagnoses of heatstroke are quite rare and heat exhaustions are usually not properly classified in emergency rooms in

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Italy. Furthermore, some occupational injuries might be induced by a previous lipothymia or loss of consciousness due to environmental factors, but discharge data only contain the ICD classification of traumatism in the principal diagnoses.

In Italy weather conditions during summer can be very dangerous for the health of people, especially when persistent periods with the African Anticyclone, characterized by very high air temperature (even during night), high humidity level and weak winds, occurred. During the hottest summer days the air temperature can even reach and pass 40°C and the daily average temperature is next 30°C. These weather patterns might be very critical especially for elderly who live alone, for unhealthy people and for workers which spend most time in place without air conditioning.

The objective of this study was to analyze the relationship between hot weather conditions, evaluated by using a biometeorological index (taking into consideration the combined effects of air temperature, relative humidity and wind velocity) and hospital admission for work-related accidents in a Florentine area characterized by a high concentration of trading and industrial enterprises.

Materials and Methods

Study site

Florence and Prato are Italian cities located in the region of Tuscany, in a closed valley bottom at the foot of the Apennines. Both cities have a Mediterranean semi-continental climate, with cold winters and hot summers. Florence (λ =11°16' E; Φ = 43°46' N) and Prato (λ =11°06' E; Φ = 43°53' N) are both at about 50 m above sea level (a.s.l.) and extend along the plain orientated in a SE-NW direction. These bordering cities are surrounded by hills to the South and mountains to the North, which rise to almost 1,000 m a.s.l. The plain between Florence and Prato is characterized by a large number of trading and industrial enterprises and the hospitals that serve this area are located in the two cities. In the area of Florence, 89,659 enterprises were recorded in 2004, 34.2% handicrafts enterprises, 28.6% trading enterprises, 18.3% industries and only 8.0% agriculture (source: the Florence Chamber of Commerce).

Meteorological data

Hourly meteorological data, for the warmer period of the year (from 1st June to 30th September) from 1998 to 2003, of air temperature (°C), relative humidity (%) and wind velocity (ms^{-1}), were obtained from the weather station located at 36 m a.s.l. in the plain between Florence and Prato (λ = 11°09' E; Φ = 43°49' N), where most of trading and industrial enterprises are located. This weather station is managed by the Istituto Idrografico e Mareografico of Pisa. Apparent temperature (AT) values were calculated on an hourly basis by using the Apparent Temperature Index[12], currently used by many weather forecast services around the world, i.e. in United States (National Weather Service and National Oceanic and Atmospheric Administration), Canada (Meteorological Service of Canada) and by the biometeorological service in Tuscany (Italy) managed by the Interdepartmental Centre of Bioclimatology. This biometeorological index combines air temperature, relative humidity and wind velocity, allowing to evaluate human weather discomfort due to hot conditions. However, it ignores the effects of radiation and so it is more suitable for describing potential discomfort conditions in shade. Daily biometeorological variables of maximum, mean 24-h and daytime AT (AT_{max}, AT_{24} and AT_{day} respectively) were assessed.

Hospital discharge data

Computerized inpatient discharge data for work-related accidents recorded in the five hospitals of Florence (Complesso Ospedaliero di Careggi, Ospedale di Santa Maria Nuova, Nuovo Ospedale di San Giovanni di Dio, Ospedale della S.M. Annunziata, Istituto Ortopedico Toscano) and the hospital of Prato (Ospedale Misericordia e Dolce) were provided by the Regional Health System of Tuscany (Sistema Sanitario Regionale della Toscana). Over the period of the study (1998–2003) only admissions occurred in summer months (from 1st June to 30th September) were considered. Discharge diagnoses were coded by professional nosologists according to International Classification of Diseases, Ninth Revision Clinical Modification (ICD-9-CM: 410–410.92).

The workers admitted to hospital due to at work accidents were 835 over the six summers of the study, 654 in Florence (78.3%) and 181 in Prato (21.7%); men were strongly prevalent (711 males vs 124 females; M:F 5.7:1) and the mean age was 39.2 yr (SD ± 12.2). Work accidents involved prevalently skilled workers (30%), followed by employees (22%) and self-employed people (12%).

Workers prevalently came from Italy (89.0%), followed by Albania (3.2%), Morocco (1.9%) and Rumania (1.3%). Deaths occurred in emergency room were 7.

Statistical analysis

Caused by the fact that work accidents were strongly reduced during weekend (Fig. 1a) and during August (Fig. 1b), all the statistical analyses were focused on working days

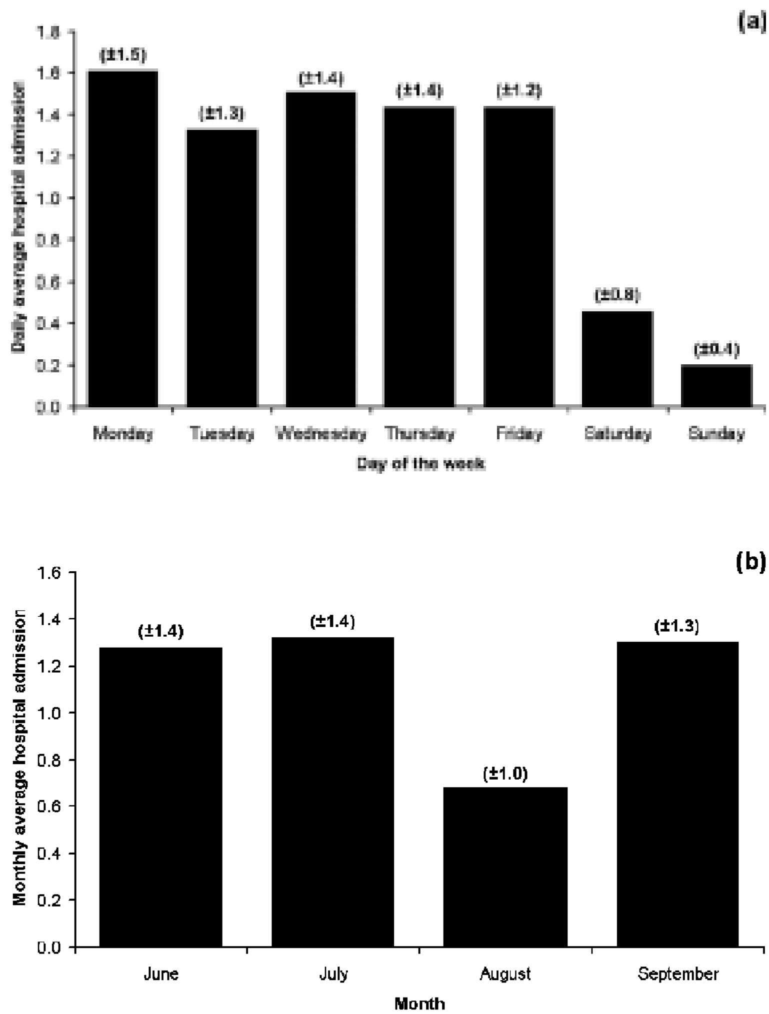

Fig. 1. Daily average hospital admissions for work accidents according to day of the week (a) and month (b).

In brackets standard deviations are indicated.

(from Monday to Friday) excluding August, when most people are on holiday.

The statistical distribution of hospital admissions for work-related accidents followed a Poisson distribution (Chi-square goodness of fit test); for this reason and because the small sample size, weather conditions were tested for work accident differences using non-parametric procedures. The Mann-Whitney U test and the Kruskal-Wallis H test were used after a categorization of independent variables (biometeorological variables) into quartiles (1st quartile: <25th percentile; 2nd quartile: from 25th to 50th percentile; 3rd quartile: from 50th to 75th percentile; 4th quartile: >75th percentile) (Table 1). To detect the possible time-lag phenomenon between exposure of workers to weather conditions and onset of disease, the comparisons were carried out considering hospitalizations occurred on the current day with specific weather conditions (lag=0) up to admissions occurred the following day (lag=1). Quartiles of daily AT_{max} and AT_{day} were considered independent variables for time-lag=0, taking into consideration average weather conditions occurred during daytime, when most of people are at work place. On the other hand, quartiles of daily AT_{max} and AT_{24} were used as independent variables for time-lag=1, using the previous daily average weather condition and considering both daytime and nighttime periods. Statistical analyses were carried out considering all three months together (June, July and September) and considering each month individually.

Table 1. Categorization of ATmax, ATday and AT24 into quartiles during whole period and during each month individually

Period	Biometeorological variables	Quartiles			
		1st quartile	2nd quartile	3rd quartile	4th quartile
Whole period	AT_{max} (°C)	< 25.7	25.7–28.6	28.6–31.7	≥31.7
	AT_{day} (°C)	< 22.1	22.1–24.9	24.9–28.3	≥28.3
	AT_{24} (°C)	< 19.9	19.9–22.5	22.5–25.1	≥25.1
June	AT_{max} (°C)	< 26.8	26.8–29.5	29.5–32.5	≥32.5
	AT_{day} (°C)	< 23.5	23.5–25.9	25.9–28.4	≥28.4
	AT_{24} (°C)	< 20.6	20.6–22.8	22.8–25.4	≥25.4
July	AT_{max} (°C)	< 28.5	28.5–31.4	31.4–33.5	≥33.5
	AT_{day} (°C)	< 25.6	25.6–27.8	27.8–29.7	≥29.7
	AT_{24} (°C)	< 23.5	23.5–25.0	25.0–26.5	≥26.5
August	AT_{max} (°C)	< 26.2	26.2–29.8	29.8–33.1	≥33.1
	AT_{day} (°C)	< 22.7	22.7–26.1	26.1–29.2	≥29.2
	AT_{24} (°C)	< 20.6	20.6–23.5	23.5–26.1	≥26.1
September	AT_{max} (°C)	< 23.0	23.0–26.0	26.0–27.7	≥27.7
	AT_{day} (°C)	< 19.8	19.8–21.9	21.9–23.6	≥23.6
	AT_{24} (°C)	< 18.5	18.5–19.7	19.7–21.2	≥21.2

Results

No significant variations of work accidents during working days (excluding Saturday and Sunday) (P=0.745) and during months (excluding August) (P=0.936) were observed.

Regarding the relationship between the risk of work accidents and daily weather conditions considering the whole period, the descriptive statistics showed a peak of accidents on days characterized by the 3rd quartile of daily AT_{max} (corresponding to days with an AT_{max} range of 28.6–31.7°C) and AT_{day} (days with an AT_{day} range of 24.9–28.3°C) (Table 2).

The Kruskal-Wallis H test revealed significant differences in work accidents distribution (lag=0) among AT_{max} (P<0.05) and AT_{day} quartiles (P<0.05) (Table 2). In particular the Mann-Whitney U test showed significant differences of work accidents between the 3rd quartile (with the highest average number of admissions) and the 4th quartile (containing the warmest days, but with the lowest average number of admissions) of AT_{max} (P<0.01) and AT_{day} (P<0.01) on the same day (lag=0). In addition, work accidents occurred on the 3rd quartile of AT_{max} were significantly different by those observed on the 1st quartile (days characterized by the lowest AT_{max} values) (P<0.05).

The application of the Kruskal-Wallis H test over each month individually showed significant differences in work accidents distribution (lag=0) only during June and only among AT_{day} quartiles (P<0.01) (Table 2). In this case the Mann-Whitney U test showed significant differences of work accidents between the 3rd quartile (days with an AT_{day} range of 25.9–28.4°C and with the highest average number of admissions) and both the coldest days (1st quartile) (P<0.05) and the warmest ones (4th quartile) (P<0.01). Significant differences where even observed between work accidents occurred on the 2nd quartile and those occurred on warmest days (4th quartile). No significant differences of hospitalizations for work accidents among AT_{max} and AT_{day} quartiles during the other months were observed (Table 2) and different trends where shown. In particular during July the highest peak of work accidents was observed on days corresponding to the 2nd quartile, while during the coldest month of September the maximum peak was observed on warmest days (the 4th quartile). This different and apparently contradictory pattern is explained by the Fig. 2, where for every month the mean value of AT_{day} on each quartile and the corresponding mean hospitalization for work accidents are reported. It is clearly shown that the maximum peak of work accidents in each month occurred on days characterized by a mean AT_{day} ranging between 24.8°C and 27.5°C.

No significant differences among AT_{max} and AT_{24} quartiles of work accidents occurred the following day (lag=1) were observed (data not shown).

Discussion

Present findings showed that hot weather conditions might represent a risk factor for accidents due to work in Italy

Table 2. The Kruskal-Wallis H test for the frequency distribution of hospital admissions for work accidents (time-lag=0) over each quartile of ATmax and ATday

In brackets standard deviations (SD) are indicated

Period	Biometeorological variables	Hospital admissions for work accidents (± SD) during each quartile				Time-lag	
						Lag=0	
		1st quartile	2nd quartile	3rd quartile	4th quartile	χ^2	P
Whole period	AT_{max} (°C)	1.5 (± 1.3)	1.7 (± 1.5)	2.0 (± 1.5)	1.4 (± 1.3)	9.3	0.025
	AT_{day} (°C)	1.6 (± 1.4)	1.7 (± 1.4)	1.9 (± 1.5)	1.4 (± 1.4)	8.3	0.039
June	AT_{max} (°C)	1.4 (± 1.3)	2.3 (± 1.6)	1.8 (± 1.3)	1.3 (± 1.6)	6.8	0.079
	AT_{day} (°C)	1.3 (± 1.2)	2.0 (± 1.6)	2.1 (± 1.3)	1.2 (± 1.5)	11.9	0.008
July	AT_{max} (°C)	1.7 (± 1.3)	2.1 (± 1.8)	1.5 (± 1.2)	1.4 (± 1.3)	2.5	0.473
	AT_{day} (°C)	1.8 (± 1.6)	1.9 (± 1.6)	1.6 (± 1.3)	1.4 (± 1.4)	1.2	0.755
September	AT_{max} (°C)	1.5 (± 1.3)	1.6 (± 1.4)	1.8 (± 1.6)	1.8 (± 1.2)	1.4	0.705
	AT_{day} (°C)	1.4 (± 1.3)	1.7 (± 1.3)	1.7 (± 1.3)	1.8 (± 1.3)	2.5	0.474

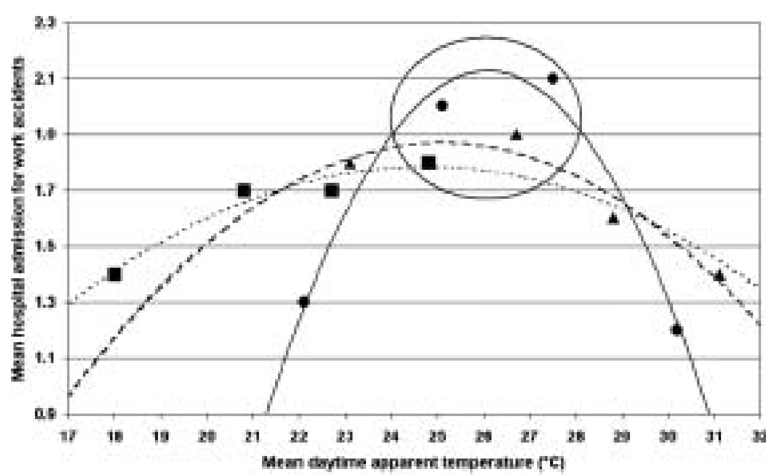

Fig. 2. Monthly distribution of mean hospital admissions for work accidents vs. mean value of AT_{day} on each quartile.

Circles, triangles and squares are June, July and September respectively. Continuous, dashed and dotted lines are AT_{day} trends during June, July and September respectively. The big circle shows the AT_{day} range in each month when the highest peaks of work accidents occurred.

during the summer season. In particular, the peak of work-related accidents in the Florentine area occurred on current days (lag=0) characterized by AT_{day} and AT_{max} values included in the 3rd quartile (days characterized by high and not extreme thermal conditions). Statistical analyses confirmed this observation, showing that the risk is significantly higher in the 3rd quartile compared to the 4th quartile, meaning that the susceptibility of workers to heat stress increased more in hot days than during days with extreme hot weather conditions. Extreme hot weather conditions have usually a great impact on human health, as showed by many studies on heat waves, in which mortality and morbidity increase according to rise of air temperature or heat stress[13, 14]. This unexpected result might be explained taking into consideration worker behavioural aspects. The thermal situation described by the 3rd quartile is just over average values typical of the summer period, when probably workers are very active in outdoor tasks, especially in the building industry. During summer many outdoor hard works are planned, because the rainy days are uncommon. Besides, during summer, most of people spend holiday out of the city allowing to carry out works faster and without obstacles. Workers are used to work in that conditions even if these are able to increase the risk of accidents, especially during intensive activity. On days characterized by weak or moderate heat discomfort workers commonly work during the worst period of the day (from 14:00 to 17:00) from a biometeorological point of view and with short rest breaks. Even when outdoor works are carried out just for half day, more frequent during weekends, the risk of heat stress could even increase because workers could remain outdoor after work, exposing themselves to heat discomfort for greater periods of time. However, they maybe change their behaviour when heat stress increases (reaching extreme values critical for human health), reducing risks by adopting preventive measures, i.e. working in the shade, drinking more water, beginning working activity earlier in the morning, and so on.

The monthly analysis showed significant differences in work accidents distribution among days with different AT_{day} range only in June. This could be explained by the fact that early summer warming days during June (AT_{day} range of 25.9–28.4°C), characterized by heat discomfort, are less tolerated by workers than warming days of the following summer months. A similar effect has been observed in an Italian study[9] where authors suggested that the lower levels of excess mortality in Rome during the July and especially the August 2003 heatwave, compared with the earlier episode in June, may be attributable to a reduction by late summer of the pool of susceptible people. Moreover, physiological adaptation to hot temperature might also plays an important role. It is well known, that thermoregulation takes at least two-three weeks to adapt to hot environmental conditions and exercise could represent an additional risk factor for heat-related disorders[15].

In the present study, the 3rd quartile of AT_{day} appears significantly associated to the rise of daily work-related accidents in June, while different, but not significant, trends were observed during July (the hottest month among those studied), with the highest peak of admission in the 2nd quartile and in September (the coldest month), with the maximum in the 4th quartile. However, comparing the mean monthly AT_{day} assessed for each quartile and the corresponding mean hospital admission for work accidents, the results suggested that days with an average daytime AT value ranged between 24.8°C and 27.5°C showed the highest risk of hospitalizations for work-related accidents (Fig. 2). Interestingly, apparent temperature values in which an increased mortality and/or morbidity rates was observed during heat waves, are by far higher[8, 13]; in this view, intensive work acitivity might play a critical role, as above mentioned. Furthermore, average AT_{day} between 24.8°C and 27.5°C might represent favorable weather conditions for extreme efforts contributing to heat stress susceptibility in the workplace.

The possible explanations of the significant relationship between hot environmental conditions and work accidents are speculative. It is arguable that the pathogenesis is similar to that of heat disorders, probably trough a reduction in skill and power performances. For example, several studies on endurance exercise showed that a power reduction is recorded when an hypohydration above 3% of body mass occurs[16] and the effect is more evident in hot environmental conditions[17]. The impairment of performances might make workers more predisposed to accidents.

The present study has several limits that should be considered. Firstly, hospital data on admissions due to work-related accidents did not provide any information about indoor or outdoor events; however, it is arguable that summer work period is more directed to outdoor tasks making workers more susceptible to heat stress. Furthermore, indoor and outdoor meteorological conditions are quite similar in many types of industry, i.e. building industry, that often lack of air conditioning. Secondly, Italian nosologists are not used to diagnose heat related diseases, especially when these are contributing factors in work related accidents. Thirdly, only the effect of heat stress on work-related accidents on the same and on the following day was considered. Previous studies showed that the effect of high temperatures on hospitalizations for cardiovascular diseases predominantly occurs within a few days after exposure[10, 18]. In the present preliminary study the authors focused the main attention over very short periods. Further studies should even consider the effect on work-related accidents over longer periods of time after exposure to specific biometeorological conditions.

In conclusion, present findings might represent the first step for the development of a watch/warning system for workers that might be used by employers for planning work activities (outdoor or indoor).

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