Original article

Air temperatures and occupational injuries in the agricultural settings: a report from Northern Italy (Po River Valley, 2013-2017)

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Summary. *Introduction:* High environmental temperatures are associated with an increased risk for occupational injuries (OIs), particularly where environmental exposure and heat sources in the workplace, are associated with internal heat generation by strenuous muscular work. As a consequence, Agricultural Workers (AWs) are among the most heavily affected occupational groups. *Methods and aims:* The aim of this study was to assess the relationship between environmental temperatures and OIs in AWs from the Po River Valley in the Northern Italy (27,736,158 total inhabitants; mean agricultural workforce of 312,195.6 individuals). Data about OIs from 2013 to 2017, and daily weather for the administrative unit of occurrence were retrieved. Days were classified by a) mininum (Tmin) / maximum (Tmax) air temperatures; b) average day temperature (Tday); c) daily temperature variation (TV), d) relative humidity. Risk for daily OIs was calculated as correspondent Odds Ratios (OR) through a Poisson regression model. *Results:* Estimated incidence for OIs was 66.3/1,000 workers-year. In regression analysis, for every Tday percentile increase equal to 2.5, an OR 1.007 (95% CI, 1.003 to 1.010) was reported. More precisely, higher risk for OIs was associated to Tmax > 25°C (OR 1.143, 95%CI 1.125-1.160) and to Tmax > 25°C + Tmin > 20°C (OR 1.158, 95%CI 1.138-1.179), Tmin < 0°C were associated with a significantly reduced risk (OR 0.879, 95%CI 0.850-0.910), with the notable exception of older age groups (OR 1.348, 95%CI 1.254; 1.449). During timeframes characterized by Tmax > 35°C (i.e. HW time period), the risk was higher during the first day (OR 1.266; 95%CI 1.206-1.330), and again from the fourth day onwards (OR 1.090; 95%CI 1.048 – 1.133). Analysis of TV identified an increased risk for occupational injuries in days characterized by higher variability, and particularly for TV ranging 4.0 – 4.9 (OR 1.042, 95%CI 1.017 – 1.068), and equals to 5.0 or greater (OR 1.143, 95%CI 1.118 – 1.167). Also increased relative humidity was associated with higher risk for OIs (OR 1.096, 95%CI 1.081-1.126, and OR 1.154, 95%CI 1.135-1.173 for relative humidity 70 – 89%, and ≥ 90%). *Conclusions:* Our findings recommend policymakers to develop appropriate procedures and guidelines, in particular for the HW time periods. (www.actabiomedica.it)

Key words: agricultural workers, climate change, heat exposure, occupational injuries, hot weather, heat wave

1. Introduction

In the last decade, mean annual air temperatures are globally getting hotter, eventually affecting living and working environments (1–4). More specifically, the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has estimated an increase of 0.78°C for average global temperatures between the 1850-1900 and the 2003-2012 time periods (5), with a significant surge in both magnitude and frequency of extreme events such as heatwaves (HWs), with an even higher risk for population living in Mediterranean-like climates (6,7).

In recent years, an increasing base of evidence has linked high environmental temperatures with an increased risk of occupational injuries (1–4), particularly in occupational settings characterized by a combination environmental exposure, heat sources in the workplace, and internal heat generation by physical activity associated with strenuous muscular work (3,8–14).

Some recent reports have stressed that risk of heat-related health effects may be particularly increased in outdoors workers, and particularly among agricultural workers (AWs), for several reasons (1,3,14,15,6–13). First and foremost, the majority of agricultural activities are performed outdoors, and AWs are often poorly protected against meteorological factors such as extreme heat and solar radiation (16–18). Second, many agricultural tasks still require strenuous manual work, as an extensive mechanization requires economic resources that are often beyond the financial capacity of agricultural entrepreneurs. Third, not only health and safety training in the agricultural settings are frequently inappropriate, but also the risk perception is often inadequate. Hence, many workers may continue to work beyond a safe heat exposure limit as they are unaware of the risks associated with the heat exposure, or have inappropriate knowledge of the preventive measures, as avoiding the hottest hours of the day for most strenuous physical exertion, or increasing the water intake during the HWs (7,16,17). In this regard, agricultural workforce includes a large share of part-time and seasonal workers, i.e. subjects who otherwise would spend little time outdoor, potentially overlooking the risks associated with occupational heat exposures. Eventually, higher temperatures may force the workers to reduce the use of personal protective equipment, ultimately increasing the risk for incidents associated with the exposure to chemicals and pesticides (16–18).

As climate change effects gradually worsen, the importance of understanding the impact of air temperatures on the agricultural workforce has become an ever-greater concern. Focusing on a South-Western Europe area characterized by a highly developed agricultural sector, with a high ratio of self-employed farmers, and where the occupational health and safety preventive practices are strictly regulated, the primary objective of this study was therefore to evaluate the relationship between high air temperatures, temperature variability, extreme climate events and occupational injuries.

2. Methods

2.1. Settings

This retrospective study was carried out in Northern Italy and covered a 5-year time period from 2013 to 2017. Northern Italy roughly consists of eight Italian administrative Regions characterized by the flow of the Po river with its main influents: Aosta Valley, Piedmont, Liguria, Lombardy, Emilia Romagna, Veneto, Friuli Venezia Giulia, and Trentino Alto Adige/Südtirol; it covers a total area of 120,260 km^2 (46,430 sq mi), with a total population of 27,736,158 habitants (2018 estimate). According to available labor force statistics, between 2013 and 2017, primary sector employed around 2.7% of Italian workforce (i.e. an average of 312,000 adult-age subjects). The climate in Northern Italy is mainly humid subtropical, especially in the Po River Valley, while a humid continental climate is predominant in the surronding subalpine valleys. Other climates include Mediterranean climate profile in the coastal areas, while Alpine foothills are characterized by Oceanic climate. Winter is long, rainy and rather cold, with high seasonal temperature variation between Summer and Winter months. The coldest month is usually January, with a mean temperature that in the Po River Valley ranges from -1°C to 1°C, but morning lows can occasionally reach -30°C to -20°C in the Alpine Region and -14°C/-8°C in the Po River Valley. During summer season, average temperatures usually range between 22°C and 24°C (but temperature higher than 24°C in the administrative region of Emilia Romagna are rather possible), with daily maximum temperatures that may be higher than 35°C.

2.2. Meteorological data

Meteorological data, including daily average (Tday), minimum (Tmin), maximum (Tmax) temperatures, air relative humidity, atmospheric pressure, wind speed and solar irradiation for the study period were obtained for each provincial capital from the competent Regional Environmental Protection agencies. When more weather stations were available for the same timeframe, mean values were calculated. Temperature data of the provincial capital were assigned to all occupational injuries that occurred in each municipality of the province.

Exposure groups were defined as follows:

2.1.1. Extreme temperatures. As otherwise suggested, calendar days were initially categorized by Tmin and Tmax in: Frost days (i.e. days with Tmin < 0°C), Summer days (i.e. days with Tmax > 25°C), Summer days/Tropical Nights (i.e. days with Tmax > 25°C and Tmin > 20°C). Days not included in the aforementioned definition were classified as "*Neutral days*". Currently, there is no universal definition of a HW, although it may be broadly defined as a prolonged period of excessive heat. In our working definition, HWs event was defined by 3 or more consecutive days having Tmax ≥ 35°C.

2.1.2. Temperature Variability (TV). TV can account for both intra- and inter-day temperature variations by calculating the standard deviation (SD) of the minimum and maximum temperatures over consecutive exposure days. TV was calculated for the current and preceding day (TV_{0-1} = SD (Tmin day0, Tmax day0, Tmin day1, Tmax day1)) (19), and calendar days were then categorized as follows: 0.0 to 0.9, 1.0 to 1.9, 2.0 to 2.9, 3.0 to 3.9, 4.0 to 4.9, 5.0 or greater.

2.1.3. Average daily temperatures. Two distinctive models for the Tday analysis were applied. Initially, Tday values were categorized in 40 consecutive 2.5 percentiles (< 2.5th to ≥ 97.5th percentile), that were then grouped into the following categories: <5th, 5-24th, 25-74th, 75–94th and ≥ 95th percentiles.

2.1.4 Relative humidity. Similarly to the air temperature, calendar days were also categorized by average relative humidity (i.e. the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature) as follows: < 70%, 70 – 90%, ≥ 90%.

2.3. Occupational injuries

Italian Law (Presidential Decree no. 1124/1965, art. 2) defines as an "occupational injury" every event having physically traumatic nature (for example, falling from a height, being hit by an object, crushed by a weight, burnt by a fire or chemical substance, etc.) occurring because of the work that the employee has carried out. National Institute for Insurance against Workplace Accidents and Occupational Disease (in Italian, INAIL) is the national authority receiving claims for occupational injuries over the whole territory. INAIL insurance is compulsory in the activities that the law defines as risky, with the notable exception of certain occupational groups (i.e. armed forces, police workers, autonomous tradespeople, etc.) benefiting from specific insurance systems. INAIL institutional database includes therefore any compensation claim on events occurring at work and causing a trauma to one or more people involving subjects insured by such authority. An anonymized archive of the INAIL database if available as Open Data (https://dati.inail.it/opendata/default/Infortuni/index.html): as stated by the licence agreement Italian Open Data License v2.0 (https://www.dati.gov.it/content/italian-open-data-license-v20), users are therefore free to share, modify, use and re-use the database, data, and information if the sources are correctly identified. Open database does include following information: gender, age, age, nationality, economic sector, duration of sick leave, and incorporated reference to the geographical site (municipality-level detail) and calendar date of the events. On the contrary, it does not include an extensive definition/description of the event.

In order to perform our analyses, we retrieved all occupational injuries occurring the index North Italian administrative Regions, from the agricultural economic sector, regardless of their severity (whether fatal or not), and excluded all cases that occurred: (a) on to way to/from the workplace (in Italian, "*in itinere*"); (b) lacked basic information on the place of event. Moreover, events (c) still in the validation phase were similarly excluded. As activities of the primary sector are diffusely performed across the calendar year, we retrieved data on all available events.

2.4. Ethics and data sharing

The study included only a retrospective assessment of data available through an Institutional Database, whose content was totally anonymized, thus guaranteeing personal data protection. Therefore, the study did not require preliminary evaluation by the local Ethical Committee.

2.5. Statistical analysis

Continuous variables were initially tested for normal distribution (D'Agostino and Pearson omnibus normality test): where the corresponding p value was < 0.10, normality distribution was assumed as rejected and variables were compared through Mann-Whitney or Kruskal-Wallis test for multiple independent samples. On the other hand, variables passing the normality check (D'Agostino and Pearson $p \geq 0.10$) were compared using the Student's t-test or ANOVA, where appropriate. Daily rates of occupational injuries were calculated for the study period (for all Northern Italy and by single Region), by year, by season, by calendar month, and eventually for the exposure groups as previously described. We assumed that the recorded events (i.e., OIs) were mutually independent, and although influenced by demographic factors and by the extent of the activities performed in that time period, eventually related to air temperatures.

Initially, association of daily rates of occupational injuries with air temperature and TV was assessed in a linear regression analysis model. Then, in order to adjust crude rates for factors having a presumptive effect on the outcome variable injury rate, Odds Ratios (ORs) with their respective 95% Confidence Intervals (95%CI) were calculated through a Poisson regression model that included the aforementioned exposure categories as the effector variables, and meteorological data (i.e. atmospheric pressure, wind speed and solar irradiation) as covariates, being further stratified for sex, age groups and geographical region of origin (i.e. Italian born-people vs. Foreign born-people).

Exposure models were assessed, as follow: (1) 25-74th Tday percentile vs. <5th, 5-24th, 75–94th and ≥ 95th percentiles; (2) "neutral days" vs. "frost days", "summer days", "summer days/tropical nights"; (3) days having Tmax < 35° vs. time periods characterized Tmax ≥ 35°C in a series equal or longer than 3 consecutive days (i.e. HW events). In the latter model, first day (day1), second day (day2), third day (day3), and following days (day4+) were considered separately; (4) TV_{0-1} 0.0 – 0.9 vs. 1.0 – 1.9, 2.0 – 2.9, 3.0 – 3.9, 4.0 – 4.9, 5.0 or more; (5) Relative humidity < 70% vs. 70-90%, > 90%.

All the analyses were controlled for the number of agricultural workers actually active at the time of the reported injury. The models did not include factors such as heat sources in the workplace, noise exposure, type of employment, etc., as not available from the reports. All the analyses were performed in SPSS 25 (IBM Corp. Armonk, NY).

3. Results

As shown in Table 1, between 2013 and 2017 a total of 103,055 injuries occurred among a mean agricultural workforce of 312,195.6 individuals (range 291,322 in 2013 – 326,182 in 2016), with a rate of 66.3 injuries per 1,000 workers per year (average of 56.4 events/day, 1.76/10,000 workers/day). The higher share of accidents was reported for Piedmont (26,938, 26.1%), followed by Emilia Romagna (23,478, 22.8%), while the higher daily incidence rates were reported by Trentino Alto Adige/Südtirol (3.3/10,000 workers) and Piedmont (2.61/10,000 workers), followed by Emilia Romagna (1.82/10,000 workers), Aosta Valley (1.46/10,000 workers), Liguria (1.36/10,000 workers), Veneto (1.31/10,000 workers), and eventually Lombardy and Friuli Venezia Giulia (1.29/10,000 workers and 1.17/10,000 workers, respectively). The majority of accidents occurred during the summer season (53.6%), being more frequently reported in the months of Sep-

Table 1. Characteristics of the 103,055 occupational injuries (2013-2017) retrieved for Northern Italy

Characteristics		Cases (No./103055, %)
Age group	*< 20*	1037, 1.0%
	20 - 29	11151, 10.8%
	30 - 39	15275, 14.8%
	40 - 49	23903, 23.2%
	50 - 59	26609, 25.8%
	≥ 60	25080, 24.3%
Country of origin	*Italian Born*	89412, 86.8%
	Foreign Born	13643, 13.2%
Sex	*Male*	87001, 84.4
	Female	16054, 15.6%
Year	*2013*	22424, 21.8%
	2014	21770, 21.1%
	2015	21099, 20.5%
	2016	19428, 18.9%
	2017	18334, 17.8%
Month	*January*	7512, 7.3%
	February	7436, 7.2%
	March	8833, 8.6%
	April	8294, 8.0%
	May	8766, 8.5%
	June	9268, 9.0%
	July	9935, 9.6%
	August	8957, 8.7%
	September	9981, 9.7%
	October	9362, 9.1%
	November	7914, 7.7%
	December	6797, 6.6%
Season	*Winter*	47854, 46.4%
	Summer	55201, 53.6%
Region	*Valle d'Aosta*	517, 0.5%
	Piemonte	26938, 26.1%
	Lombardia	15831, 15.4%
	Liguria	2793, 2.7%

(continued)

Table 1 ***(continued)***. Characteristics of the 103,055 occupational injuries (2013-2017) retrieved for Northern Italy

Characteristics		**Cases (No./103055, %)**
	Veneto	15789, 15.3%
	Trentino-Südtirol	14624, 14.2%
	Friuli Venezia Giulia	3066, 3.0%
	Emilia Romagna	23478, 22.8%
Outcome	*Alive*	102704, 99.7%
	Dead	351, 0.3%
	Prognosis ≥ 40 days	23525, 22.8%
	Long term/Permanent	18318, 17.8%

tember (9.7%) and July (9.6%). Most injuries occurred in male subjects (84.4%), of Italian origin (86.8%), of older age groups (50.1% were aged 50 years or more). Focusing on the reported outcomes, the occupational injury had a prognosis ≥ 40 days in 22.8% of cases, while 17.8% reported any long-term sequelae, including death (0.3%). Overall, a total of 3,158,371 days of sick leave were included in the analyses (404.7/1,000 worker/year), with a mean of 2.0 days of sick leave by worker and a mean length of the sick leave equal to 30.7 days ± 52.6.

Focusing on the meteorological characteristics of the days of occurrence (Table 2), 61.6% of accidents occurred in neutral days, with 21.0% occurring in summer days, 12.1% in summer days with tropical nights not included in heat wave time period, that in turn accounted for 2.0% of total sample, while only 3.4% of accidents were reported during frost days. Similarly, 51.1% of accidents were reported for days characterized by Tday ranging from 25th to 74th percentile, while 21.9% occurred in days having Tday ranging from 75th to 94th percentile, and 5.7% with extreme high average temperatures (≥ 95th percentile). A total of 21,892 injuries occurred during colder days, with 4.1% of total events for lower Tday value (< 5th percentile) and 17.2% for days characterized by Tday 5th to 24th percentile. Interestingly, nearly 80% of injuries occurred in days characterized by higher relative humidity (i.e. 41.3% for days having relative humidity ranging 70 to 89%, 38.4% in days with relative humidity ≥ 90%).

Focusing on the daily occurrence rates, compensation claims were more frequently reported in days characterized by extreme temperatures (summer days with tropical nights, 2.01/10,000 workers), being lower for frost days (1.53/10,000 workers). Highest rates were identified in days fulfilling our working definition of heat wave, being higher in the first day (2.29/10,000 workers), then decreasing to 1.89/10,000 workers in the second day, to 1.80/10,000 workers in the third day, and eventually re-ascending to 1.97/10,000 workers for the following days. Also considering average temperatures, daily rates increased accordingly exposure levels. More precisely, occurrence rates ranged from 1.45 injuries/10,000 workers/day for Tday < 5th percentile, to 1.99 injuries/10,000 workers/day for Tday ≥ 95th percentile. When TV was taken in account, not only daily rates of occupational injuries were also well correlated (Figure 1; $r = 0.221$ for TV_{0-1}), being higher for days characterized for higher TV and lower for days affected by less variability, particularly for TV_{0-1} 4.0 – 4.9 (1.72/10,000 workers/day), and TV_{0-1} ≥ 5.0 (1.88/10,000 workers/day). A similar trend was discernable for relative humidity, with lower incidence (1.65/10,000 workers/day) for days with lower relative humidity, increasing to 1.80/10,000 workers/day and 1.91/10,000 workers/day for days characterized by relative humidity of 70-89% and ≥90%.

Interestingly, significantly more days were compensated for colder exposures, either assessed by maximum and minimum temperatures as frost days (33.2

Table 2. Occurrence of the 103055 occupational injuries (2013-2017) included in the analysis, broken down by meteorological characteristics of the index day. Comparisons were performed by means of analysis of the Analysis of the Variance (ANOVA) with Dunn's post hoc test. Reference category for post hoc test is reported accordingly. Note: Heat Waves were defined as three or more consecutive days having Tmax ≥ 35°). Temperature variability was calculated as Standard Deviation for (Tmin day0, Tmax day0, Tmin day+1, Tmax day+1)

Meteorological characteristics	No., %	Notification rate / 10,000 workers (95%CI)	ANOVA P value	No. of Compensated days (95%CI)	ANOVA P value
Classification by Average air temperature (Tday)			< 0.001		< 0.001
< 5th percentile	4177, 4.1%	1.45 (1.32: 1.57)	< 0.001	33.4 (31.7; 35.1)	0.002
5 - 25th percentile	17715, 17.2%	1.52 (1.32; 1.58)	< 0.001	31.8 (31.0; 32.5)	0.016
25 - 75th percentile	52634, 51.1%	1.80 (1.76; 1.84)	Reference	30.4 (30.0; 30.9)	Reference
75 - 94th percentile	22613, 21.9%	1.93 (1.87; 2.00)	0.001	30.2 (29.5; 30.9)	0.928
≥ 95th percentile	5916, 5.7%	1.99 (1.86; 2.12)	0.015	29.1 (27.8; 30.4)	0.224
Relative Humidity			< 0.001		0.040
< 70%	20925, 20.3%	1.65 (1.61; 1.70)	Reference	30.6 (29.9; 31.3)	Reference
70 – 89%	42585, 41.3%	1.80 (1.76; 1.85)	0.023	30.2 (29.7; 30.7)	0.632
≥ 90%	39454, 38.4%	1.91 (1.84; 1.98)	< 0.001	31.2 (30.6; 31.7)	0.302
Classification by Minimum (Tmin) / Maximum (Tmax) air temperatures			< 0.001		0.001
Neutral day (Tmax > 0°, < 25°C)	63447, 61.6%	1.74 (1.71; 1.78)	Reference	30.8 (30.4; 31.2)	Reference
Frost day (Tmax < 0°C)	3475, 3.4%	1.53 (1.40; 1.68)	0.014	33.2 (31.4; 35.0)	0.025
Summer day (Tmax > 25°C)	21648, 21.0%	1.99 (1.92; 2.06)	< 0.001	30.7 (29.9; 31.4)	0.992
Summer day, tropical night (Tmax > 25°C, Tmin > 20°)	12790, 12.4%	2.01 (1.92; 2.10)	< 0.001	29.4 (28.6; 30.3)	0.017
Heat Wave, 1st day	497, 0.5%	2.29 (1.99; 2.61)	< 0.001	30.6 (25.8; 35.4)	1.000
Heat Wave, second day	410, 0.4%	1.89 (1.46; 2.31)	0.958	27.8 (23.4; 32.2)	0.788
Heat Wave, third day	393, 0.4%	1.80 (1.27; 2.32)	0.923	30.4 (25.7; 35.0)	1.000
Heat Wave, fourth day or more	795, 0.8%	1.97 (1.47; 2.48)	< 0.001	28.8 (25.5; 32.2)	0.852
Temperature Variability			< 0.001		0.028
0.0 - 0.9	10330, 10.0%	1.65 (1.56; 1.74)	Reference	30.4 (29.4; 31.3)	Reference
1.0 - 1.9	3520, 3.4%	1.51 (1.37; 1.64)	< 0.001	32.0 (30.1; 33.9)	0.331
2.0 - 2.9	6843, 6.6%	1.48 (1.39; 1.57)	< 0.001	30.6 (29.4; 31.8)	0.999
3.0 - 3.9	12181, 11.8%	1.70 (1.62; 1.77)	0.109	31.9 (30.9: 33.0)	0.094
4.0 - 4.9	17073, 16.6%	1.72 (1.65; 1.79)	< 0.001	30.8 (30.0; 31.5)	0.952
5.0 or greater	53108, 51.5%	1.88 (1.84; 1.93)	< 0.001	30.3 (29.9; 30.7)	1.000

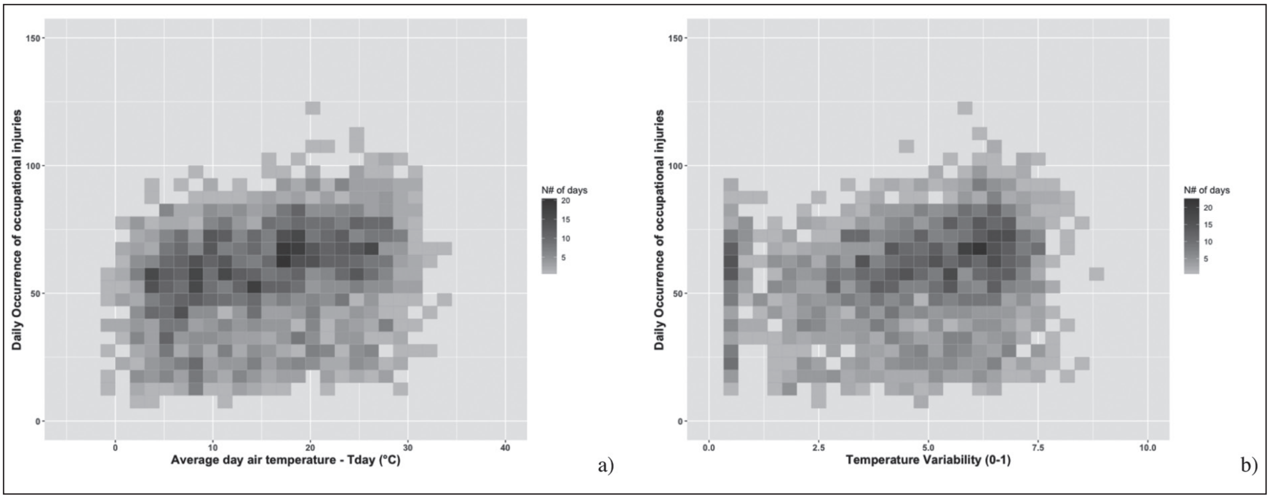

Figure 1. Figure 1. Density plot for total occupational injuries vs. correspondent average day air temperature (Tday; a)), and temperature variability for the current and preceding day (TV_{0-1} = SD (Tmin day0, Tmax day0, Tmin day1, Tmax day1); b). A significant correlation was found for both models (i.e. Pearson's r = 0.263, p < 0.001 for Tday vs. daily occupational injuries, and Pearson's r = 0.221, p < 0.001 for TV_{0-1} vs. daily occupational injuries)

days vs. 30.8 for neutral days, p = 0.025) or by average air temperatures (i.e. 33.4 for < 5^{th} percentile and 31.8 days for 5^{th} to 25^{th} percentile, p = 0.002 and 0.016 when compared with days ranging 25^{th} to 75^{th} percentile, 30.4 days), and lower for days characterized by higher average temperatures (i.e. summer days with tropical nights; 29.4 days, p = 0.016). On the contrary, no similar trend was associated with increasing relative humidity.

In regression analysis**,** for every Tday percentile increase equal to 2.5 (Figure 2), 1.007 (95% CI, 1.003 to 1.010) times more occupational injuries occurred in the eight assessed regions (p < 0.001). More precisely (Table 3), a significantly higher risk for OIs was associated to the Summer days (OR 1.143, 95%CI 1.125-1.160) and to Summer days with tropical nights (OR 1.158, 95%CI 1.138-1.179), while frost days were associated with a significantly reduced risk (OR 0.879, 95%CI 0.850-0.910). Stratification of the analyses by gender and migration background (Table 3), showed a similar trend with the notable exception of female workers, and workers aged 30-39 years (Table 4), as both subsets not beneficed from a protective effect of colder days (OR 0.966, 95%CI 0.888-1.051), and mainly older age groups, apparently affected by higher risk for occupational injuries (OR 1.348; 95%CI 1.254-1.449).

During HW time period, and considering the study population as a whole, the risk was significantly higher during the first day (OR 1.266; 95%CI 1.206-1.330), becoming similar to the neutral days during second and third days, and again increasing form the fourth day onwards (OR 1.090; 95%CI 1.048 – 1.133). On the contrary, no increased risk was identified among female workers (OR 1.205, 95%CI 0.959-1.514), while older age groups (≥ 60 y.o.) not only did not show any increased risk for occupational injuries during the 1^{st} day of HW (OR 1.019, 95%CI 0.781-1.328), but exhibited a sort of "resistance" to the events in later days (OR 0.675, 95%CI 0.484-0.928 for 4^{th} days or more) (Table 4).

Moreover, assuming days having Tday 25-74^{th} percentiles as reference ones, colder days were significantly associated with reduced risk of occupational injuries (OR 0.814, 95%CI 0.800-0.829 for Tday < 5^{th} percentile; OR 0.849, 95%CI 0.842-0.859 for Tday 5 to 24^{th} percentile), while the risk for OIs increased with higher exposure groups (OR 1.077, 95%CI 1.068 – 1.086 for 75-94^{th} percentiles, 1.115, 95%CI 1.098-1.131 for ≥ 95^{th} percentiles).

Similarly, analysis of TV identified a reduced risk for occupational injuries in days characterized by lower variability (OR 0.903, 95%CI 0.869-0.938; and OR

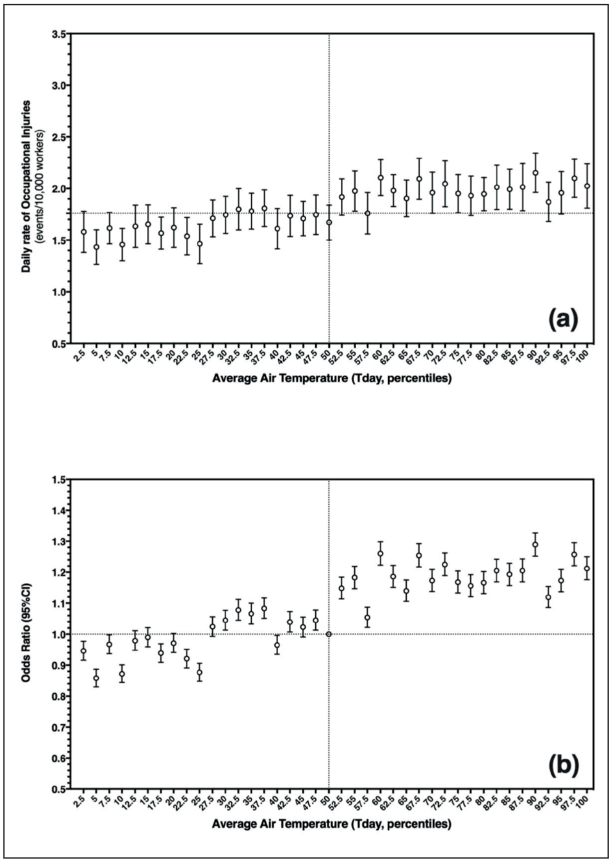

Figure 2. Daily occurrence of occupational injuries, (a) as number of events / 10,000 workers / day, and (b) risk calculated of their occurrence as Odds Ratio (OR) with correspondent 95% confidence intervals (95%CI), by average air temperature (Tday) assessed by increases of 2.5 percentiles. Vertical dotted line represents median value for Tday, horizontal dotted line marks mean incidence value (1.76 / 10,000 workers / day; (a)) or OR = 1.00.

Table 3. Risk for occupational injuries by meteorological characteristics of the index day. Reference categories are reported accordingly. Odds Ratio (OR) with their correspondent 95% confidence intervals (95%CI) were calculated by means of a Poisson Regression analysis including solar irradiation, relative humidity, atmospheric pressure, and wind speed as covariates. Heat Waves were defined as three or more consecutive days having Tmax ≥ 35°). Temperature variability was calculated as Standard Deviation for (Tmin day0, Tmax day0, Tmin day+1, Tmax day+1)

Meteorological characteristics	OR (95%CI)
Classification by Average air temperature (Tday)	
25 - 75th percentile	Reference
< 5th percentile	0.814 (0.800; 0.829)
5 - 25th percentile	0.849 (0.842; 0.859)
75 - 95th percentile	1.077 (1.068; 1.086)
> 95th percentile	1.115 (1.098; 1.131)
Classification by Minimum (Tmin) / Maximum (Tmax) air temperatures	
Neutral day (Tmax > 0°, < 25°C)	Reference
Frost day (Tmax < 0°C)	0.879 (0.850; 0.910)
Summer day (Tmax > 25°C)	1.143 (1.125; 1.160)
Summer day, tropical night (Tmax > 25°C, Tmin > 20°)	1.158 (1.138; 1.179)
Heat Wave, 1st day	1.266 (1.206; 1.330)
Heat Wave, second day	1.040 (0.985; 1.098)
Heat Wave, third day	0.992 (0.938; 1.048)
Heat Wave, fourth day or more	1.090 (1.048; 1.133)
Temperature Variability	
0.0 - 0.9	REF
1.0 - 1.9	0.903 (0.869; 0.938)
2.0 - 2.9	0.888 (0.861; 0.916)
3.0 - 3.9	1.023 (0.996: 1.051)
4.0 - 4.9	1.042 (1.017; 1.068)
5.0 or greater	1.143 (1.118; 1.167)

0.888, 95%CI 0.861-0.916 for TV 1.0-1.9 and 2.0-2.9, respectively) while and increased risk was associated with highest variability, i.e. TV equals to 5.0 or greater (OR 1.143, 95%CI 1.118 – 1.167). On the contrary, sub-maximal TV (i.e. 4.0-4.9), even apparently increased for the whole population (OR 1.042, 95%CI 1.017-1.068), actually affected only subjects of male sex (OR 1.052, 95%CI 1.025-1.081), Italian origin (OR 1.045, 95%CI 1.018-1.073), and age groups 40-49 y.o. (OR 1.102; 95%CI 1.050-1.156).

Eventually, occurrence of occupational injuries increased with higher exposure to relative humidity (OR 1.096, 95% 1.081-1.111; and OR 1.154, 95%CI 1.135-1.173, for exposure to 70-89% and ≥ 90% relative humidity), both in overall analyses and by subgroups (Table 3-4).

Table 4. Risk for occupational injuries by meteorological characteristics of the index day, by age groups. Reference categories are reported accordingly. Odds Ratio (OR) with their correspondent 95% confidence intervals (95%CI) were calculated by means of a Poisson Regression analysis including solar irradiation, relative humidity, atmospheric pressure, and wind speed as covariates. Heat Waves were defined as three or more consecutive days having Tmax ≥ 35°). Temperature variability was calculated as Standard Deviation for (Tmin day0, Tmax day0, Tmin day+1, Tmax day+1)

	Odds Ratio (95% Confidence Intervals)						
	All casese	**< 20 y.o.**	**20 – 29 y.o.**	**30 – 39 y.o.**	**40 – 49 y.o.**	**50 – 59 y.o.**	**≥ 60 y.o.**
Classification by Average air temperature (Tday)							
25 – 75th percentile	Reference	Reference	Reference	Reference	Reference	Reference	Reference
< 5th percentile	0.814 (0.800; 0.829)	0.688 (0.486; 0.974)	0.751 (0.680; 0.829)	0.819 (0.755; 0.888)	0.838 (0.786; 0.894)	0.824 (0.755; 0.876)	0.785 (0.736; 0.837)
5 – 25th percentile	0.849 (0.842; 0.859)	0.742 (0.618; 0.892)	0.814 (0.773; 0.858)	0.860 (0.823; 0.899)	0.836 (0.807; 0.866)	0.866 (0.837; 0.895)	0.858 (0.829; 0.888)
75 – 95th percentile	1.077 (1.068; 1.086)	1.362 (1.175; 1.578)	1.092 (1.042; 1.145)	1.079 (1.036; 1.124)	1.060 (1.026; 1.095)	1.058 (1.026; 1.091)	1.099 (1.065; 1.134)
> 95th percentile	1.115 (1.098; 1.131)	1.564 (1.234; 1.982)	1.085 (0.999; 1.178)	1.143 (1.067; 1.225)	1.106 (1.046; 1.170)	1.153 (1.094; 1.215)	1.079 (1.021; 1.140)
Classification by Minimum (Tmin) / Maximum (Tmax) air temperatures							
Neutral day (Tmax > 0°, < 25°C)	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Frost day (Tmax < 0°C)	0.879 (0.850; 0.910)	0.879 (0.850; 0.910)	0.864 (0.832; 0.897)	0.966 (0.888; 1.051)	0.898 (0.866; 0.931)	0.752 (0.679; 0.833)	1.348 (1.254; 1.449)
Summer day (Tmax > 25°C)	1.143 (1.125; 1.160)	1.143 (1.125; 1.160)	1.130 (1.112; 1.150)	1.210 (1.164; 1.258)	1.130 (1.112; 1.149)	1.224 (1.174; 1.276)	1.301 (1.207; 1.403)
Summer day, tropical night (Tmax >25°C, Tmin >20°)	1.158 (1.138; 1.179)	1.158 (1.138; 1.179)	1.144 (1.122; 1.167)	1.238 (1.184; 1.295)	1.144 (1.121; 1.166)	1.258 (1.198; 1.320)	1.127 (1.052; 1.208)
Heat Wave, 1st day	1.266 (1.206; 1.330)	1.266 (1.206; 1.330)	1.270 (1.154; 1.397)	1.205 (0.959; 1.514)	1.233 (1.120; 1.356)	1.440 (1.148; 1.807)	1.019 (0.781; 1.328)
Heat Wave, 2nd day	1.040 (0.985; 1.098)	1.040 (0.985; 1.098)	1.039 (0.935; 1.155)	1.042 (0.815; 1.332)	1.011 (0.909; 1.123)	1.229 (0.961; 1.571)	0.963 (0.736; 1.261)
Heat Wave, 3rd day	0.992 (0.938; 1.048)	0.992 (0.938; 1.048)	0.976 (0.875; 1.088)	1.107 (0.873; 1.405)	1.016 (0.915; 1.129)	0.864 (0.645; 1.158)	0.863 (0.678; 1.097)
Heat Wave, 4th day or more	1.090 (1.048; 1.133)	1.090 (1.048; 1.133)	1.061 (0.982; 1.145)	1.219 (1.032; 1.440)	1.063 (0.986; 1.147)	1.231 (1.027; 1.474)	0.674 (0.484; 0.928)

(continued)

Table 4 ***(continued)***. Risk for occupational injuries by meteorological characteristics of the index day, by age groups. Reference categories are reported accordingly. Odds Ratio (OR) with their correspondent 95% confidence intervals (95%CI) were calculated by means of a Poisson Regression analysis including solar irradiation, relative humidity, atmospheric pressure, and wind speed as covariates. Heat Waves were defined as three or more consecutive days having Tmax ≥ 35°). Temperature variability was calculated as Standard Deviation for (Tmin day0, Tmax day0, Tmin day+1, Tmax day+1)

	Odds Ratio (95% Confidence Intervals)						
	All casese	**< 20 y.o.**	**20 – 29 y.o.**	**30 – 39 y.o.**	**40 – 49 y.o.**	**50 – 59 y.o.**	**≥ 60 y.o.**
Temperature Variability							
0.0 - 0.9	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1.0 - 1.9	0.903 (0.869; 0.938)	0.801 (0.515; 1.243)	0.790 (0.701; 0.891)	0.914 (0.829; 1.006)	0.952 (0.882; 1.029)	0.881 (0.816; 0.950)	0.911 (0.843; 0.984)
2.0 - 2.9	0.888 (0.861; 0.916)	1.019 (0.736; 1.411)	0.872 (0.795; 0.956)	0.848 (0.783; 0.917)	0.909 (0.854; 0.968)	0.912 (0.858; 0.968)	0.883 (0.830; 0.940)
3.0 - 3.9	1.023 (0.996: 1.051)	1.160 (0.875; 1.538)	1.014 (0.937; 1.097)	0.987 (0.923; 1.056)	1.025 (0.971; 1.082)	1.022 (0.970; 1.077)	1.040 (0.986; 1.096)
4.0 - 4.9	1.042 (1.017; 1.068)	1.106 (0.846; 1.446)	0.993 (0.922; 1.07)	1.000 (0.939; 1.065)	1.046 (0.994; 1.100)	1.102 (1.050; 1.156)	1.026 (0.976; 1.079)
5.0 or greater	1.143 (1.118; 1.167)	1.584 (1.260; 1.990)	1.121 (1.053; 1.195)	1.096 (1.039; 1.157)	1.127 (1.078; 1.177)	1.158 (1.110; 1.207)	1.162 (1.114; 1.213)
Relative Humidity							
< 70%	Reference	Reference	Reference	Reference	Reference	Reference	Reference
70 – 89%	1.096 (1.081; 1.111)	1.306 (1.136; 1.503)	1.137 (1.078; 1.197)	1.132 (1.084; 1.182)	1.134 (1.095; 1.174)	1.156 (1.119; 1.195)	1.179 (1.140; 1.220)
≥ 90%	1.154 (1.135; 1.173)	1.500 (1.272; 1.768)	1.127 (1.090; 1.185)	1.056 (1.019; 1.095)	1.089 (1.059; 1.120)	1.094 (1.065; 1.123)	1.104 (1.074; 1.135)

Discussion

In our retrospective analysis, occupational injuries in AWs were associated with higher environmental temperatures, assessed as average and maximal daily values. An increased risk for occupational injuries was also identified for the first day of HWs, for HWs lasting 4 days or more, for higher TV, and also associated for days characterized by higher relative humidity. Interestingly enough, we found some kind of protective "*cold effect*": even though colder days were apparently associated with a reduced incidence of occupational injuries, reported events were associated with a longer prognosis, that may represent a proxy for more severe accidents. Still, it should be stressed that older age groups find in "frost days" a significantly increased risk for injuries. A possible explanation may be found in the demographics of AWs in Italy: as Italian agricultural workforce includes a large share of older workers, that are often the owner of the agricultural enterprise, they are more likely to perform some activities also during the winter season, when employees and temporary workforce are more frequently unemployed (7, 16-17).

However, such results are consistent with available reports suggesting that both high daily temperatures and HWs events might elicit an increased incidence of occupational injuries, particularly in the agricultural settings (1,6,7,12,15,20–22). Consistently with a previous report from the Trentino province, that hinted towards an increased risk for occupational injuries in days having highest Tday and Tmax (7), this larger report remains otherwise contradictory with most of previous studies, in which an "inverted U"-shaped curve relationship was rather suggested. In other words, while previous studies identified the highest risk for work-related accidents in days characterized by severe but not extreme thermal conditions, in our study agricultural injuries were slightly but consistently more frequently reported in days associated with extreme hot weather (1,15,21,22). These results have been often described through the lens of behavioral adaptations to severe climates: i.e. being aware of the risks associated with working during the hottest days and/or the hottest hours of the day, workers would restrain from most strenuous activities (21-23). Not coincidentally, our estimates identified a seemly reduced risk of occupational risk in older workers for prolonged heat wave time period. In other words, it is plausible that while older age groups may be particularly affected by the consequences of lower temperatures, mainly in terms of external, non-biological effects (e.g. frozen, slippery surfaces; uneven and muddy terrain, etc.), they may exhibit a sort of "*healthy worker effect*" (i.e. progressive selection of workers less sensitive to higher, extreme, temperature) during HW (7, 9-10).

While comparing our results with available base of evidence, it should be stressed that while our understanding of HW and related health effects is prevalently based on western countries (24), most of available occupational studies have been drawn from Asian or Australian experiences (1-2, 11-14), with the notable exception of Italian workplaces (1-2, 6-7,20-23). In this regard, an Italian nationwide study based on similar data with a different timeframe had similarly identified a positive association between occupational exposures and work-related injuries, with a significant effect of both moderate and extreme temperature (23). More precisely, while such figures hinted towards an increased risk for injuries in both extremes (severe heat and severe heat), again older workers were particularly more likely to occupational accidents in colder days, as in our report.

Several explanations for similarities but also for heterogeneities may be found as follows. First at all, while the aforementioned study of Marinaccio *et al.* benefited from a very detailed spatial resolution of thermal exposure (i.e. 1 km^2) (23), our estimates were necessarily coarse as based on administrative units. As previously stated, administrative units of Northern Italy are quite heterogenous in terms of overall size, and climate as well, with subsequent uncertainties in the estimates of the outcomes (6,7,17). Second, it should be stressed that while the risk for occupational injuries was significantly lower in colder days than in neutral ones for age groups < 60 y.o., the reported prognosis (a proxy for the assessment of their severity) was contrariwise more dismal, eventually stressing the high risk for the more severe outcomes of older workers in such settings. Third, out sample oversampled older age group: we focused on the primary sector, that is usually characterized by an aged workforce, and 50.1% of the cases we analyze occurred in AWs aged 50 years or more (17,23,25). Fourth, our analysis focused on the AWs from the Administrative regions of the Po River Valley: despite obvious differences in cultures and environmental characteristics, such approach possibly narrowed the impact of the well-known heterogeneity of Italy in terms of socio-economic development, that eventually encompasses kind and frequency of agricultural works, as well as health and safety preventive measures (7,17,25). In facts, time clustering of agricultural works follows crop growth, with significant differences both in characteristics of cultures and their managing when comparing Northern and Southern regions (1,26).

However, our results should be cautiously interpreted. First at all, while AWs are obviously exposed to the environmental heat/cold because of their daily tasks, most of the agricultural activities are clustered during the warm season, when workforce significantly increases, eventually including a large number of temporary workers, whose higher risk for occupational injuries has been previously reported (1,15,23). As a consequence, rather than a direct effect of higher environmental temperatures, occurrence of occupational accidents may be somehow associated with the clustering of agricultural tasks. On the other hand, the timing of certain field works such irrigation and/or spraying of pesticides is not always very flexible, following the time-table imposed by crops and cultivations. More specifically, a series of warm days, particularly when associated with reduced rainfalls, increases the requirements for artificial irrigation, forcing AWs to perform their activities even in uncomfortable settings, even during HWs, sustaining the rationale for an increased risk of occupational injuries (1,15,21,22,27).

Second, available data lack information about non-registered seasonal agricultural workers, particularly from peripheral regions such as Trentino Alto Adige/Südtirol, where the workforce may be transitorily inflated by a large influx of migrants from nearby countries (6,15,17,23). As a consequence, the estimates about the total number of subjects employed in agricultural activities at time of recorded accidents may be largely inaccurate, with consequently imprecise assessment of incidence and actual risk of occupational injuries, particularly during the summer seasons, when agricultural workforce swells, particularly in regions characterized by crops whose managing may be only limitedly mechanized, i.e. wine harvesting and fruit picking (1,6,15,17,21–23). In other words, as we are assessing a somehow dynamic (i.e. seasonal) working population throughout the lens of the more rigid (i.e. yearly-based) denominator of total workforce, estimates may appear higher during summer when they may not actually be. Therefore, also the somehow protective effect of lower temperatures, that are obviously clustered during the winter season, may be rather a consequence of the seasonality of the total workforce than biologically based.

Third, the share of self-employed AWs in the administrative regions we assessed is largely heterogenous: some evidences suggest that self-employed AWs would be at somehow increased risk for occupational injuries, avoiding recommended preventive measures for various reasons including economic interests, and inappropriate understanding of the actual health and safety risks (16–18,28,29). As the number of self-employed AWs increases in the older age groups, again such factor may contribute to explain the heterogeneities we reported across the sub-analyses, particularly for lower temperatures in the winter season, when the share of self-employed over the total workforce is likely to increase (7).

Fourth, data on occupational injuries were retrieved from an institutional database, whose reliability may have been affected by reporting bias (e.g. minor accidents, but also more severe injuries from family-based agricultural enterprises may have been underreported in order to avoid an increase of the insurance annual fees). On the contrary, as we deliberately included all recorded accidents, not only overall figures may have been inflated by events that have no actual causation in environmental exposures. However, a more focused analysis of heat/cold-related injuries and illness was impossible because of the lack of specific diagnoses (or even their proxies) in the raw data, and similarly available data lacked an accurate description of the events, including even a summary description of the accident, but also of environmental (e.g. heat sources, extent of exposure to solar radiation, etc.) and individual risk factors (e.g. the level of physical activity performed at the time of the event, the PPE possibly worn at time of the injury, hydration status, drug assumed before the event, etc.). On the other hand, it is noteworthy that our exposure obviously model included only outdoor exposures, missing data on indoor and internal exposures, whose burden may particularly significant in agricultural workers (16–18,20,28,29).

Also meteorological data should be assumed as a rough proxy of the actual exposure: as climate factors significantly associated with heat-related health effects such as air humidity and solar irradiation may strikingly fluctuate over a restricted area (7), assessment of environmental factors based on administrative unit may lack the appropriate definition we need (23,30,31). Such inaccuracies are potentially magnified by the source of data: even though Regional Environmental Protection Agencies should apply standard requirements for the assessment of climate factors, the lack of a central validation may impair the homogeneity of data (2,23).

Eventually, our data did not assess the potential effect of preventive public health measures to protect workers against HW, that have been only recently and not homogenously implemented across Italian Regions. For instance, since 2018 and during the summer season, National Health Institute and the National Health Ministry collectively report a simple and effective bulletin that stratify the risk for environmental temperatures and particularly HW in a time lag of 3 days (http://www.salute.gov.it/portale/caldo/homeCaldo.jsp). Also more appropriate early warning systems such as the HEAT-SHIELD Platform (https://heatshield.zonalab.it/) (32-33) have been implemented. Such multilingual platform is based on probabilistic medium-range forecasts that provide a map showing the weekly maximum probability of exceeding a specific heat stress condition, for each of the four upcoming weeks. Therefore, it provides the forecast of the personalized local heat-stress-risk based on workers' physical, clothing and behavioral characteristics (including heat acclimatization) and the work environment (outdoors in the sun or shade), that in turn may allow an appropriate planning and management of all outdoor activities (32-33). Still, daily practice shows that not only such early warning systems are limitedly known to the general workforce, but also their managing by Italian Regions is strikingly heterogeneous and generally unsatisfying (34).

Conclusions

In conclusion, increased and severe-high environmental temperatures were associated with increased daily rates of occupational injuries in AWs from Northern Italy. This increased trend was apparently consistent across the models we assessed, and was mirrored by a decrease of the severity of occupational injuries, suggesting that severe cold exposures may elicit fewer but more severe events. Still, sub-analyses identified specific patterns for older groups, that collectively suggest the need for a more personalized approach to occupational health and safety prevention. As climate projections hint towards higher variability of environmental temperatures, with increased frequency and severity of extreme events such as the HWs, our results are also of valuable interest for policymakers. In facts, our results stress the opportunity to implement appropriate regulation and guidelines countering the unrestricted exposure of AWs to uncomfortable climates. More precisely, our results stress the potential importance of appropriate early alarm systems. Such platforms may allow a mid-range planning of outdoor activities, avoiding more strenuous and at-risk task during hottest days, or at least hottest ours of higher-risk days.

Disclaimer: This paper describes the results of a retrospective analysis from open, anonymous and aggregate data. The Italian legislation does not entail an ethical approval in this type of study and for this reason a formal ethical clearance was not required. Patient data were preventively anonymized by the source company, and no specific activity on human subjects was undertaken. Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article. The facts, conclusions, and opinions stated in the article represent the authors' research, conclusions, and opinions and are believed to be substantiated, accurate, valid, and reliable. However, as this article includes the results of personal researches of the Authors, presenting correspondent, personal conclusions and opinions, parent employers are not forced in any way to endorse or share its content and its potential implications.

References

1. Messeri A, Morabito M, Bonafede M, et al. Heat Stress Perception among Native and Migrant Workers in Italian Industries—Case Studies from the Construction and Agricultural Sectors. Int J Environ Res Public Health 2019;16(7): pii: E1090. doi: 10.3390/ijerph16071090
2. Bonafede M, Marinaccio A, Asta F, et al. The association between extreme weather conditions and work-related injuries and diseases. A systematic review of epidemiological studies. Ann Ist Super Sanità. 2016;52(3):357–67. doi: 10.4415/ANN_16_03_07.
3. Xiang J, Bi P, Pisaniello D, et al. Health Impacts of Workplace Heat Exposure: An Epidemiological Review. Ind Health. 2014;52:91–101. doi: 10.2486/indhealth.2012-0145
4. Mcinnes JA, Akram M, Macfarlane EM, et al. Association between high ambient temperature and acute work-related injury: a case-crossover analysis using workers' compensation claims data. Scand J Work Env Heal. 2017;43(1):86–95. doi: 10.5271/sjweh.3602
5. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker TF, Qin D, Plattner GK, Tignor M, SK Allen, Boschung J, Nauels A, Xia Y, Bex V MP, editor. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2013.
6. Riccò M, Garbarino S, Bragazzi NL. Migrant Workers from the Eastern-Mediterranean Region and Occupational Injuries : A Retrospective Database-Based Analysis from North-Eastern Italy. Int J Env Res Public Heal. 2019;16(4): pii: E673. doi: 10.3390/ijerph16040673..
7. Riccò M. Air temperature exposure and agricultural occupa-

tional injuries in the autonomous province of Trento (2000-2013, North-Eastern Italy). Int J Occup Med Environ Health. 2018;31(3):317-331. doi: 10.13075/ijomeh.1896.01114
8. Lucas RAI, Epstein Y, Kjellstrom T. Excessive occupational heat exposure : a significant ergonomic challenge and health risk for current and future workers. Extrem Physiol Med. 2014;3:14. doi: 10.1186/2046-7648-3-14
9. Crowe J, Nilsson M, Kjellstrom T, et al. Heat-Related Symptoms in Sugarcane Harvesters. Am J. Ind. Med 2015;58(5):541-548. doi: 10.1002/ajim.22450
10. Kjellstrom T, Holmer I, Lemke B. Workplace heat stress, health and productivity-an increasing challenge for low and middle-income countries during climate change. Glob Health Action. 2009;2: 10.3402/gha.v2i0.2047 doi: 10.3402/gha.v2i0.2047
11. Singh S, Hanna EG, Kjellstrom T. Working in Australia's heat: Health promotion concerns for health and productivity. Health Promot Int. 2015;30(2):239-50. doi: 10.1093/heapro/dat027
12. Xiang J, Bi P, Pisaniello D, et al. The impact of heatwaves on workers' health and safety in Adelaide, South Australia. Environ Res 2014;133:90–95. doi: 10.1016/j.envres.2014.04.042
13. Xiang J, Hansen A, Pisaniello D, et al. Extreme heat and occupational heat illnesses in South Australia, 2001-2010. Occup Environ Med. 2015;72(8):580–586. doi: 10.1136/oemed-2014-102706
14. Varghese BM, Hansen A, Bi P, et al. Are workers at risk of occupational injuries due to heat exposure? A comprehensive literature review. Saf Sci 2018;110(Part A):380–392. doi: 10.1016/j.ssci.2018.04.027
15. Messeri A, Binazzi A, Morabito M, et al. Evaluation of the impact of heat stress on the occurrence of occupational injuries: Meta-analysis of observational studies. Am J Ind Med. 2019;62(3):233-243. doi: 10.1002/ajim.22946
16. Riccò M, Vezzosi L, Gualerzi G. Health and Safety of Pesticide Applicators in a high income agricultural setting: a knowledge, attitude, practice, and toxicity study from North-Eastern Italy. J Prev Med Hyg. 2018;59(3):E200-E211. doi: 10.15167/2421-4248/jpmh2018.59.3.934
17. Riccò M, Vezzosi L, Bragazzi NL, et al. Heat-Related Illnesses among Pesticide Applicators in North-Eastern Italy (2017). J Agromedicine. 2020; 25(1):52-64. doi: 10.1080/1059924X.2019.1606745
18. Riccò M, Razio B, Poletti L, et al. Knowledge, attitudes, and sun-safety practices among agricultural workers in the Autonomous Province of Trento, North-Eastern Italy (2016). G Ital Dermatol Venereol 2017; Epub ahead of print. doi: 10.23736/S0392-0488.17.05672-3:
19. Guo Y, Gasparrini A, Armstrong BG, et al. Temperature variability and mortality: A multi-country study. Environ Health Perspect. 2016;124(10):1554–1559. doi: 10.1289/EHP149
20. Riccò M, Vezzosi L, Balzarini F, et al. Air temperatures and occupational injuries in the construction industries: a report from Northern Italy (2000-2013). Ind Health. 2020; 58(2):182-192. doi: 10.2486/indhealth.2018-0268
21. Morabito M, Cecchi L, Crisci A, et al. Relationship between work-related accidents and hot weather conditions in Tuscany (central Italy). Ind Health. 2006;44(3):458–464. doi: 10.2486/indhealth.44.458
22. Morabito M, Iannuccilli M, Crisci A, et al. Air temperature exposure and outdoor occupational injuries: A significant cold effect in Central Italy. Occup Environ Med. 2014;71(10):713–716. doi: 713-6. doi: 10.1136/oemed-2014-102204
23. Marinaccio A, Scortichini M, Gariazzo C, et al. Nationwide analysis on the effect of outdoor temperature on occupational injuries in Italy. Environ Int 2019;133(PtA):105176. doi: 10.1016/j.envint.2019.105176. 24.
24. Campbell S, Remenyi TA, White CJ et al. Heatwave and health impact research: a global view. Health and Places 2018;53:210-218. doi: 10.1016/j.healthplace.2018.08.017
25. Riccò M, Razio B, Panato C, et al. Knowledge, Attitudes and Practices of Agricultural Workers towards Tetanus Vaccine: a Field Report. Ann Ig 2017;29(4):239-255. doi: 10.7416/ai.2017.2156
26. Bozzola M, Massetti E, Mendelsohn R, et al. A Ricardian analysis of the impact of climate change on Italian agriculture. Eur Rev Agric Econ. 2018;45(1):57-79. doi: 10.1093/erae/jbx023
27. Mirabelli MC, Quandt SA, Crain R, et al. Symptoms of heat illness among Latino farm workers in North Carolina. Am J Prev Med. 2010;39(5):468–71. doi: 10.1016/j.amepre.2010.07.008
28. Ghafari M, Cheraghi Z, Doosti-Irani A. Occupational risk factors among Iranian farmworkers: a review of the available evidence. Epidemiol Health 2017; 39:e2017027. doi: 10.4178/epih.e2017027
29. Gatto M, Cabella R, Gherardi M. Climate change: the potential impact on occupational exposure to pesticides. Ann Ist Super Sanità. 2016;52(3):374–385. doi: 10.4415/ANN_16_03_09
30. Martínez-Solanas È, Basagaña X. Temporal changes in temperature-related mortality in Spain and effect of the implementation of a Heat Health Prevention Plan. Environ Res 2019;169:102-113. doi: 10.1016/j.envres.2018.11.006
31. Martinez-Solanas E, Basagana X. Temporal changes in the effects of ambient temperatures on hospital admissions in Spain. PLoS One. 2019;14(6):e0218262. doi: 10.1371/journal.pone.0218262
32. Casanueva A, Burgstall A, Kotlarski S, et al. Overview of Existing Heat-Health Warning Systems in Europe. Int J Environ Res Public Health. 2019;16(15). pii: E2657. doi: 10.3390/ijerph16152657.
33. Morabito M, Messeri A, Noti P, et al. An Occupational Heat–Health Warning System for Europe: The HEAT-

SHIELD Platform. Int J Environ Res Public Health. 2019; 16(16). pii: E2890. doi: 10.3390/ijerph16162890.
34. Riccò M, Razio B, Poletti L, et al. Risk perception of heat related disorders on the workplaces: a survey among health and safety representatives from the autonomous province of Trento, Northeastern Italy. J Prev Med Hyg 2020;61(1):E48-E59 doi: 10.15167/2421-4248/jpmh2020.61.1.727

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