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Effects of temperatures and heat waves on occupational injuries in the agricultural sector in Italy

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Abstract:

The effects of heat on health have been well documented while less is known on the effects among agricultural workers. Our aim is to estimate the effects and impacts of heat on occupational injuries in the agricultural sector in Italy at national level.

For each of the 8,068 Italian municipalities occupational injuries in the agriculture sector from the Italian national workers' compensation authority (INAIL) and daily mean air temperatures from Copernicus ERA5-land for a five-year period (2014-2018) were considered. Distributed lag non-linear models (DLNM) were used to estimate the relative risk and attributable injuries for increases in daily mean air temperatures between the 75th and 99th percentile as well as during heatwaves. Analyses were stratified by age, professional qualification and severity of injury.

A total of 150,422 agricultural injuries were considered and the overall relative risk of injury for exposure to high temperatures was 1.13 (95%CI: 1.08; 1.18). A higher risk was observed among younger workers (15-34 years) (1.23 95% CI: 1.14; 1.34) and occasional workers (1.25 95% CI: 1.03; 1.52). A total of 2050 heat-attributable injuries were estimated in the 5-year study period.

Workers engaged in outdoor and labour-intensive activities in the agricultural sector are a greater risk of injury and these results can help target prevention actions for climate change adaptation.

Keywords: work-related injuries; occupational injuries, agricultural sector; temperatures, heat waves, timeseries studies

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1. Introduction

Temperatures across Europe and the Mediterranean basin are constantly rising, with the last 10 summers registering above average values as reported by Copernicus Climate Services (Copernicus bulletin 2022 https://climate.copernicus.eu/seasonal-review-europes-record-breaking-summer). Summer 2022 registered a record +2.8°C above the climatological average (1991-2020) and +0.4°C higher than the previous year record. As reported in the latest IPCC report, climate change is a matter of fact and extreme climatic events, and increasing temperatures have been shown to have adverse impacts on human health in terms of as abnormally elevated temperatures and heatwaves (HW), that have already increased human mortality and morbidity with different impacts depending on age, gender and socioeconomic characteristics (IPCC, 2022), will continue in the future with more frequent occurrences. There is a growing body of emerging studies on the impact of climate change on the occupational sector, and the negative consequences concern capacity and costs in the production process, health costs, and workers' health (Kjellstorm et al.2019, Orlov et al. 2020).

Adverse effects of heat and climate change on human health has documented in numerous epidemiological studies all over the world (Song et al., 2017, Xu et al. 2016) and some of them posed the accent of the impact of extreme heat on workers' health (Fatima et al. 2021, Spector 2019, Varghese 2018, Xiang 2014). In fact, workers employed in specific occupational sectors working outdoors can be particularly exposed to extreme events and physical fatigue for prolonged periods of time, that can lead to heat stress (Foster et al. 2020, Flouris 2018, Gao et al., 2018; McCarthy et al., 2018, Dutta 2015) with consequences not only on the productivity and occupational costs (Morressey et al.2021, Borg 2021, Kjellstrom et al., 2016) but also on work capacity (Cheung et al., 2016) with possible consequences on occupational injuries (Binazzi et al., 2019, Spector et al. 2019). Moreover, an Australian survey (Xiang et al., 2016) found that the perception of heat-related risk on workplaces is underestimated by workers, so it is crucial to strengthen their awareness of the risks and define adequate prevention strategies.

Evidence of the increasing risk of occupational injuries associated to high temperatures has been found in different geographical settings (Marinaccio et al. 2019, Martínez-Solanas et al. 2018, MA et al. 2019, McInnes et al.2018, Adam-Poupart et al., 2015; Ricco, 2018; Spector et al. 2016, Tawatsupa et al., 2013, Varghese et al. 2019). More recently reviews have not only confirmed the association between occupational injuries and heath exposure but also summarized the evidence on vulnerability factors and sectors most at risk (Fatima et al. 2021, Lee et al. 2012, Bonafede et al., 2016; Binazzi et al. 2018, Levi et al., 2018; Spector et al., 2019; Varghese et al., 2018; Xiang et al., 2013).

In Italy, several studies have been conducted on heat related work injuries. A study conducted in Tuscany evaluated the association between heat and hospital admissions due to work-related accidents and found an increase in admissions on days with high apparent temperature (Morabito et al. 2006). A study conducted in three Italian cities (Rome, Milan and Turin) showed an association between high temperatures and occupational injuries among workers employed in the construction, transportation and energy sectors (Schifano et al. 2019). Most recently, Marinaccio et al. conducted a national study on temperature related occupational injuries and found a significant relative risk of 1.17 (95% CI: 1.14–1.21) for increases in mean temperature above the 75th percentile and focused on differences among economic sectors (Marinaccio et al. 2019). Nevertheless, an Italian study on the evaluation of both injury risks and impacts in the agricultural sector at national level has not been carried out.

The aim of this study is to estimate the association between daily air temperatures and occupational injuries in the agricultural sector from 2014 to 2018 in Italy using national compensation claims. Furthermore, we will estimate the relative risk and attributable injuries for heat exposures and identify individual vulnerability factors among agricultural workers.

2. Materials and Methods

Workers' compensation data

Data on 150,422 work-related injuries occurring in Italy between 2014-2018 were extracted from the Italian workers' compensation authority (INAIL) archives. Starting from claims for occupational injuries over the whole national territory, we selected only agriculture-related ones and we built daily counts of events for each of the 8,068 municipalities of Italy using a record-linkage procedure by geographical place where injury occurred. Anonymization procedures were applied in order to ensure privacy.

The collected data includes gender, age at injury, professional qualification (labourer, self-employed, occasional) and information on the duration of leave, considered as a proxy of severity of the injury.

Occupational injuries occurring while travelling (road accidents) and injuries occurring among individuals aged less than 15 years and over 85 years of age were excluded.

Meteorological data

Mean daily air temperature data was retrieved from ERA-5 Land climate reanalysis data (Sabater et al. 2021) available from the Copernicus Climate data Store (CDS) and was considered as exposure variable.

For each of the 8,068 Italian municipalities the daily mean air temperature was calculated as the average mean temperature of all the grid cells included in the spatial domain of the municipality weighted by area of inclusion.

A time series dataset of daily injuries and daily mean temperatures for each municipality for the entire 5-year study period was constructed.

Statistical analysis

Analyses of this work were produced with three different methodologies but with the common background of Distributed Lag Nonlinear Model (DLNM) approach to take into account both the potential non-linear shape of the dose response curve and the delayed effect of the exposure on the outcome (Gasparrini 2014; Gasparrini and Leone 2014).

The relationship between mean air temperature and injuries was modelled with a B-spline and one knot at 50th percentile of region-specific temperature distributions, and the lag-response with a categorical variable (lag window 0–2). An over-dispersed Poisson generalized linear regression model was used for the analyses, and time-varying covariates were fitted as potential confounders of the relationship in study:

- summer population decrease (a 3-levels variable with value “2” for the 2-week period around the 15th of August; “1” from 16 July to 31 August with the exception of the aforementioned 2-week period; “0” elsewhere)
- public holidays (a 4-levels variable with value “1” on isolated days; “2” on Christmas, Easter and New Year's Day; “3” on the days surrounding Christmas, Easter and New Year's Day; “0” elsewhere)
- a four-way interaction by municipality, year, month and day of the week to control for long term time trends and seasonality.

Effect estimates

To estimate the exposure-response curve and the relative risks a two-stage approach was considered. Firstly, for each of the 19 Italian regions (Valle d’Aosta region was excluded due to limited observations), we applied specific over-dispersed Poisson generalized linear regression models previously described, while in the second stage we combined the regional estimates to obtain an overall dose-response curve and effect-estimates by applying a multivariate meta-analytical regression (Gasparrini et al, 2012).

Results are expressed as the Relative Risk (RR) and 95% Confidence Intervals (95% CI) of work-related injuries in the agricultural sector for increases in mean temperature between the 75th and 99th percentile.

Effect modification was evaluated by stratifying the analysis by age group (15-34, 35-60 and 61+ years), injury severity (defined as duration of leave in days and categorized as: 0-14, 15-29, 30-60, 61+ days) and professional qualification (labourer, occasional, self-employer).

Impact estimates (attributable injuries)

In order to account for the impact of heat on occupational injuries in the agricultural sector, we estimated the number of attributable injury cases associated to the same temperature interval, and relative 95% empirical Confidence Interval (95% eCI) and according to the methodology described in Gasparrini and Leone (Gasparrini, Leone 2014). Moreover, we estimated the number of attributable cases by age, injury's severity and professional qualification variables.

Heatwaves

To evaluate the effect of extreme events in summer, we restricted the analysis to the warm months (May to September) and estimated the risk of occupational injury on heatwave days.

Firstly, for each municipality we defined heatwave (HW) days, as three or more consecutive days of mean air temperature above the municipality-specific 90th percentile in the warm months. Secondly, we estimated the regional risk of injury on heatwave days compared to non-heat wave days adjusted for day of the week and a two-way interaction term between municipality and year, and controlled for seasonal time trends with a spline modelled on the days of the warm period. Then we meta-analysed regional estimates to obtain an overall RR and relative 95% CI. Finally, we calculated the attributable number of injuries occurring on HW days.

All analysis were performed using the R statistical software version 4.1.3 (http://R-project.org).

3. Results

During the study period (2014-2018) a total of 150,422 occupational injuries in the agricultural sector were reported in the 19 Italian regions (Table 1), with a decreasing trend over time both for annual and summer counts. The same trend was observed in each region (Table A1). Figure 1 shows the total the number of occupational injuries for each region during the study period with the highest percentage of injuries in the northern regions of Emilia-Romagna Lombardia, Veneto, Toscana in the centre and Sicilia in the South (regional values are reported in Appendix Table A2). The gender distribution of injuries is predominantly male (78%) also due to the higher proportion of males employed in the agricultural sector. More than 50% of injuries occurred in the 35-60 years old age group in all the regions, while a higher number of injuries was observed among the younger age group (15-34 years) in Friuli-Venezia Giulia, Calabria, Puglia and Sicilia. Considering the duration of leave, considered as proxy of injury severity, 30% of the agricultural injuries were non-severe (<14 days leave) with a declining trend by increasing severity. Injuries by professional qualification were heterogeneous among regions, with more than 50% of total observations occurring among self-employment workers, with highest proportion in Abruzzo (80%) and Molise (84%) and lowest in Calabria (16%), where we observed the highest percentage (46%) of occasional workers' injuries that are around 14% at national level in Italy and only 4% in Veneto. Labourers' claims were around 27% nationally, ranging from 12% in Abruzzo and Molise to 42% in Lombardia.

Figure 1 illustrates the mean air temperature in the study period at municipal resolution showing a north-south gradient with higher temperatures in the southern regions. The mean air temperature in the five-year period was of 12.9°C, with the highest value in 2018 and the lowest in 2016 (Table 1 and Appendix Table 2A). The complex orography and its' geographical location in the Mediterranean, influence the climate of Italy and its regions. Mean temperatures in the northern regions vary from 6.8°C in Trentino-Alto Adige, 13.5°C in Central regions and 15.6 in the South, with the maximum value in Puglia (16.8°C). Similarly, the percentiles considered in the analysis range from 12.6°C to 22.4°C for the 75th percentile and from 21.5°C to 29.8°C for the 99th, respectively in the coldest (Trentino-Alto Adige) and in the warmest (Puglia) region (Table 1).

Considering heat waves during the warm season (May to September), around 15% of the days were identified as heatwaves, with an annual average of 24 HW days per year ranging between 5 in 2014 and 38 in summer 2015. The average temperature during a heat wave was of 24.9°C.

Figure 2 shows the exposure-response curve of the association between daily mean air temperature and risk of agriculture-related injuries, the vertical lines represent the mean temperature percentile interval (75th and 95th) between which we estimate the risk heat related occupational injuries. The figure shows a linear association between temperature and agricultural injuries with increasing risks as temperatures rise.

The relative risks (RR) of work-related injury in the agricultural sector, associated to an increase in temperature between the 75th to 99th percentile, are reported in Figure 3. The overall RR was 1.13 (95% CI 1.08- 1.18) and a greater risk of injury was observed among young workers aged 15 and 34 years (RR 1.23, 95%CI: 1.14-1.34), occasional and self-employer workers (RR 1.25, 95%CI: 1.03-1.52 and RR 1.15, 95% CI: 1.08-1.23, respectively). Furthermore, agricultural workers have a greater risk of experiencing a non-severe (RR 1.21, 95% CI: 1.10, 1.33) or a mild injury (RR 1.14, 95% CI: 1.02, 1.29) than severe ones (RR 1.13, 95% CI: 1.01, 1.25 for 30-60 days of leave and RR 1.04, 95% CI: 0.93, 1.16 for more than 61 days).

The risk of work-related injuries in the agricultural sector during HW days (3 or more consecutive days above the warm season 90th percentile) was 6% higher than on non-HW days (Figure 3).

Table 2 reports the number of injuries attributable to increases in the daily mean air temperature between the 75th to the 99th percentile during the study periods. Overall, 2050 heat-attributable injuries were estimated (average of 410 per year). Considering worker subgroups, the greatest impact was observed among the 35-60 years old workers and considering employment type, as expected the self-employed category had the greatest number of heat-related injuries.

Figure 1. Daily mean air temperature and occupational injuries in the agricultural sector in Italy in the period 2014-2018. Air temperature is express at municipal resolution, while injuries are at regional level. 223 224 225

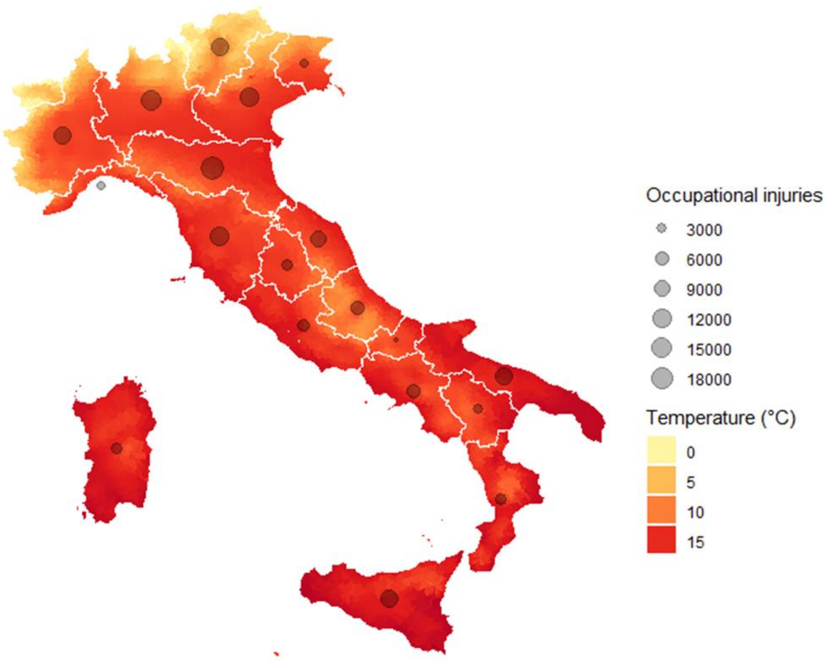

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Figure 2. Meta-analytical exposure-response curve between daily mean air temperature and occupational injuries in the agricultural sector in Italy in the period 2014-2018. Estimates are express as Relative Risks (thick lines) and 95% confidence bands.

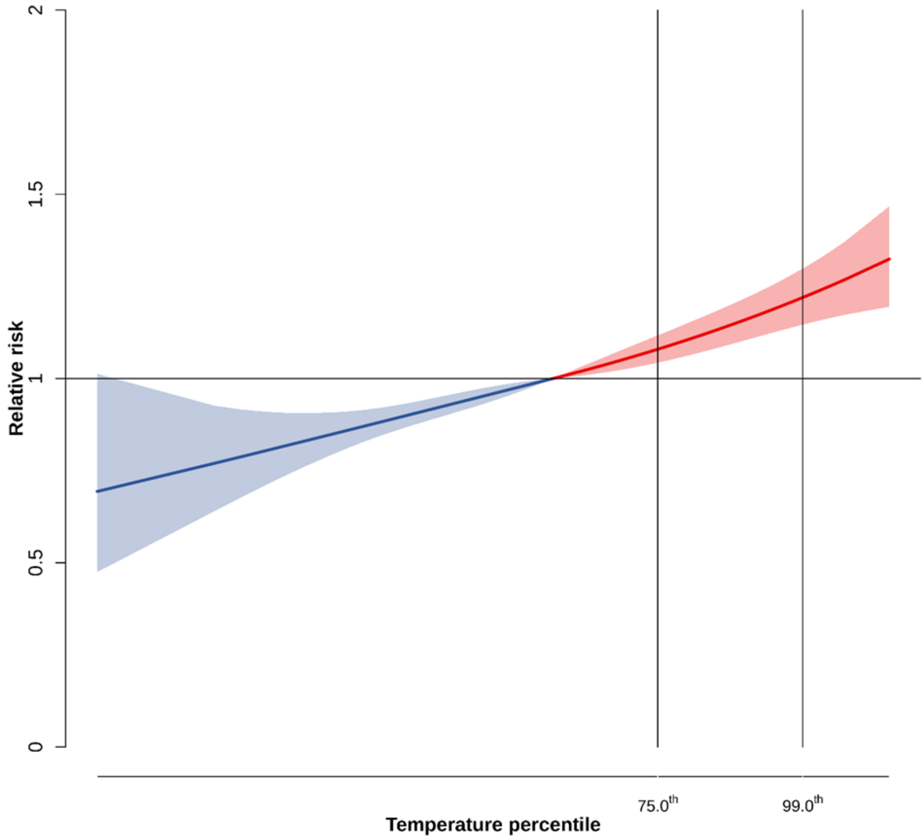

Table 1. Descriptive statistics of occupational injuries in the agricultural sector, mean temperature and heat waves in Italy in the study period (2014-2018).

	Annual		Summer (May-Sep)	
	Freq	Percentage	Freq	Percentage
Total	150422	100	66025	100
Year				
2014	33362	22.2	14555	22.0
2015	31846	21.2	14002	21.2
2016	30033	20.0	13126	19.9
2017	28453	18.9	12342	18.7
2018	26728	17.8	12000	18.2
Sex				
Male	117874	78.4	51339	77.8
Female	32548	21.6	14686	22.2
Age (years)				
15-34	27085	18.0	12103	18.3
35-60	94122	62.6	41243	62.5
61+	29215	19.4	12679	19.2
Days of leave				
0-14	45421	30.2	20636	31.3
15-29	36413	24.2	16001	24.2
30-60	36054	24.0	15507	23.5
61+	32534	21.6	13881	21.0
Professional qualification				
Labourer	41377	27.5	18896	28.6
Occasional	21687	14.4	9690	14.7
Self-employed	87345	58.1	37434	56.7
Termperature	**Annual average**		**Summer (May-Sep) average**	
Mean	13.0		19.7	
Min	-24.7		-5.8	
1°	-4.6		7.0	
25°	7.2		16.6	
50°	12.9		19.7	
75°	19.0		23.2	
99°	28.0		29.1	
Max	35.0		35.0	
Heatwave days			**N. days (%)**	**Average temperature**
Yes	-	-	10301 (15.3)	15.3
No	-	-	55944 (84.7)	84.7

Figure 3 – Relative Risks (and 95% empirical confidence intervals) of work-related injuries in the agricultural sector for increases in daily mean temperature between 75th to 99th percentile (period 2014-2018).

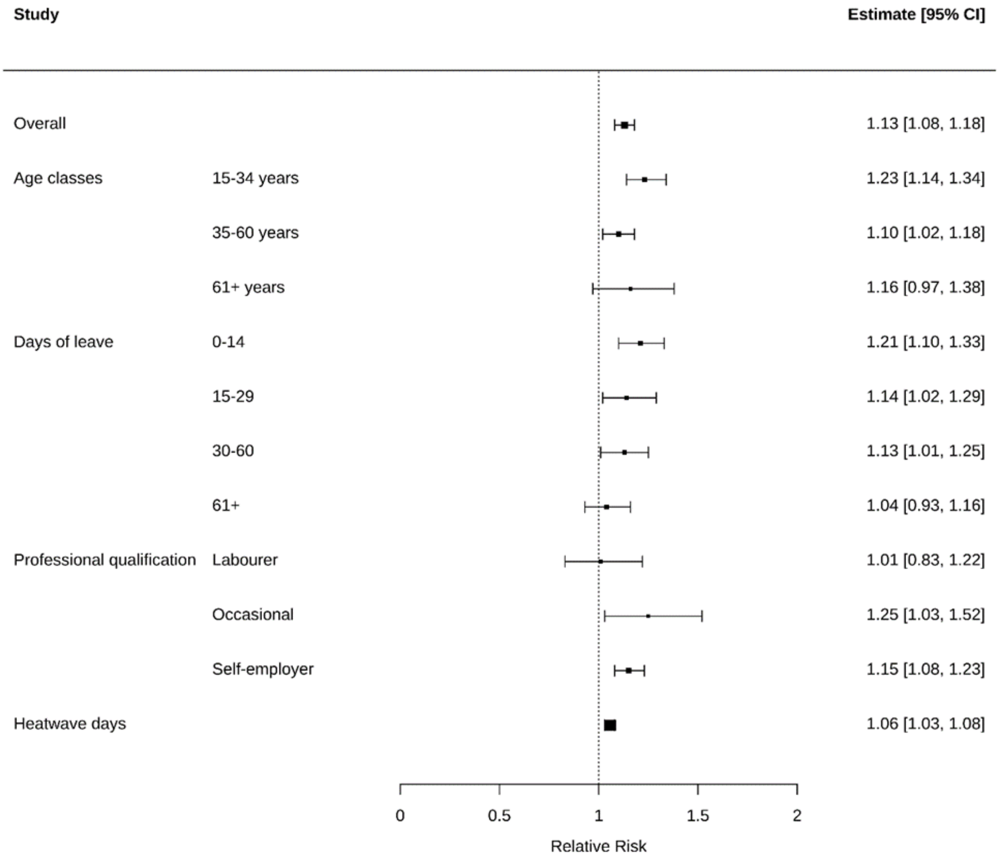

Table 2 – Number of Heat attributable injuries (and 95% empirical confidence intervals) in Italy for increases in mean temperature between the 75th to 99th percentile in the period 2014-2018.

	Full period			
	RR (95%CI)	Attributable injuries	95%eIC	
Overall	1.13 (1.08-1.18	2050	1632	2455
Age (years)				
15-34	1.23 (1.14-1.34)	396	346	446
35-60	1.10 (1.02-1.18)	1258	1024	1487
61+	1.16 (0.97-1.38)	464	405	521
Days of leave				
0-14	1.21 (1.10-1.33)	739	618	852
15-29	1.14 (1.02-1.29)	578	492	660
30-60	1.13 (1.01-1.25)	485	404	565
61+	1.04 (0.93-1.16)	337	260	409
Professional qualification				
Worker	1.01 (0.83-1.22)	748	664	831
Occasional	1.25 (1.03-1.52)	405	352	460
Self-employer	1.15 (1.08-1.23)	1051	801	1300
Heatwave days*	1.06 (1.03-1.08)	608	-72	1237

*Heatwave days are defined as 3 or more consecutive days of mean temperature above the 90th percentile in summer months (May-Sept)

4. Discussion

In this study, we explored the relationship between daily mean air temperature and the risk of injuries for agricultural workers in Italy from 2014 to 2018. We found a 1.13 (95% CI 1.08- 1.18) risk of injury for exposures between 75th and 99th percentile of air temperature in the whole study period.

Many studies investigated the association between air temperature and occupational injuries, with the majority considering heat stress and HWs, but few of them focused on the agricultural sector (Fatima et al. 2021, Lee et al. 2012, Bonafede et al., 2016; Binazzi et al. 2018, Levi et al., 2018; Spector et al., 2019; Varghese et al., 2018; Xiang et al., 2013). Although all studies found a positive association between high temperatures and work-related injuries, comparisons are difficult because of differences in study design, statistical techniques, HW definitions, geographical or climatological settings and sectors/activities included.

The physiological link between heat exposure and workers concerns both health and productivity (Flouris et al. 2018) and depends on individual characteristics (Foster et al. 2020) but also on outdoor conditions, worsening under sun exposition (Ioannou 2021), that can be, however, mitigated by practices like hydration, work-rest cycles and ventilated clothing (Ioannou et al. 2021b). In this context, the Worklimate project based in Italy is developing a heat stress forecasting system for outdoor workers, developing informative and training material for employers and workers on the risks and response measures (https://www.worklimate.it/en/).

An increasing risk in injuries for agricultural workers have been previously shown in specific geographic Italian areas in the North, both in the autonomous province of Trento in the first decade of 2000s (Riccò et al. 2018) and in the Po River Valley in the second one (Riccò et al. 2020). In Spain the agricultural sector shows the highest percent risk difference (almost 30%) of injury associated to extreme temperatures in the 99th percentile versus the minimum occupational injury percentile (Martinez-Solànas et al. 2019). In Australia several studies conducted in difference cities and regions have been conducted: in Brisbane a RR of 1.91 (95%CI: 0.72–5.03) was found for "agriculture, forestry and fishing" at extremely hot temperatures (99th percentile) (Varghese et al. 2019a) while in Adelaide the RR for "agriculture, forestry, fishing and hunting" category was equal to 4.01 (95% CI: 1.24–12.9). On the other side of the world, a study conducted in Washington State, USA (Spector et al. 2016) found an odds ratio of 1.10 (95% CI 1.01, 1.20) for outdoor traumatic injuries among agricultural workers due to apparent temperature values above 33°C compared to lower ones (<25°C). Our results are consistent with the literature and meta-analytical results (Fatima et al. 2021) in demonstrating a positive association between heat and agricultural workers' injuries.

Although several studies on occupational injuries investigated effect modification of the association with high temperatures few of them focused on risk factors for agricultural workers. Riccò et al. reported the highest odds ratio in very young workers (<20 years old) related to >95th percentile of mean air temperature with a fluctuating trend among other age groups (Riccò et al. 2020b). Our estimates report higher risks in the 15-34 and 61+ years age groups, respectively of 1.23 and 1.16, statistically significant only in the first case and consistently with the variability of Riccò's trend. A meta-analysis reported a higher risk (RR:1.009, p-value:<0.001) for young workers (age <35 years), possibly attributable to inexperience (Fatima 2021) but, on the other hand, there are evidences of higher risks among elderly workers, due to physiological mechanisms (Barnett et al., 2010, Flouris et al., 2018) and comorbidities (Kenny et al. 2010). In 35-60 years old workers, we found a risk of 1.10, that is lower than the overall estimate but provides the highest number of attributable injuries, probably due to underestimation of risks for over self-confidence as consequence of matured experience by workers (Dumrak et al., 2013). About effect modification related to injuries' severity, only one case-crossover study, previously mentioned on agricultural workers in Washington State (Spector et al. 2016), considered the number of leaving days as proxy and found greater odds ratios in mild-severe and severe injuries (25-29, 30-33, 34 or more) respect to not-severe ones (<25). This result is in contrast with our estimates, in fact we observed a decreasing risk at increasing severity of injury. In the context of professional qualification of agricultural workers, we found higher risks for occasional and self-employer workers and self-employers also have the highest impact on injuries. It is plausible that both these categories could experience lack of training, in the first one because of the temporary nature of work, in the second one due to absence of colleagues with more experience.

The definition of HW days varies among studies and sensitivity analyses suggested to not directly compare studies that use different definitions (Xu et al. 2016). However, two studies investigated the effect of HWs' days on occupational injuries in Australia, both defining HWs as 3 consecutive days with maximum temperature over 35°C and obtained contrasting results. In fact, the first one, conducted in Adelaide (Xiang et al. 2014) found a positive incidence rate ratio of 1.45 for "agriculture, forestry and fishing" sector comparing HW days to not-HW days, while a second one (Varghese et al. 2018) found out a relative risk of 0.98 for "agriculture, forestry, fishing and hunting" workers. Contrasting results came out also when considering the severity of HW days defined by the EHF index (Varghese et al. 2018), with negative risks for low and high-severity HW days and positive for moderate ones. We choose to define HWs as three or more consecutive days of daily mean air temperature over 90th percentile, consistently with previous studies conducted in Italy and the Italian Heat Health Watch Warning System (HHWWS) (D'Ippoliti et al. 2010, Michelozzi et al. 2010) and found a weaker risk during HW days in summer months compared to the overall effect of heat in the total period but it must be noted it is for heat wave days and not temperature intervals.

The strengths of this work lie, in the coverage of the outcome, that include all the Italian claimed injuries occurred in the agricultural sector, and, on the other, on the high spatial resolution of the exposure, including rural areas. Moreover, both injuries and temperature data are detailed at municipal level. For the first time, we provide estimates of attributable injuries in the agricultural sector by age, days of leave, professional qualification and HW days. However, it is also worth mentioning limitations as the impossibility in including the irregular workers not registered in the INAIL database, underestimating the number of injuries, and a great heterogeneity in agricultural processing between regions and different functions of workers.

In summary, our findings on the relationship between heat and occupational injuries in the agricultural sector show that high temperatures exert an effect on the risk of occupational injuries, that is higher when considering young, occasional or self-employed workers, while the greatest impact is experienced by 35-60 years old workers.

It must be taken into account that climate change will have consequences occupational health and work productivity around the world (IPCC, 2022; Goa et al. 2020). A recent study estimated that Under RCP8.5 by 2100, global GDP declines by 1.4% due to heat stress (Orlov et al. 2020). It was estimated that in Italy the labour productivity loss will more than double in 20 years from 300 million dollars in 2010 to 650 in 2030 (DARA and the Climate Vulnerable Forum). Furthermore, it has been estimated that in Southern Europe in 2030 the total hours of work lost due to heat stress will double with respect to

1995 and for Italy the same result is expected in the agricultural sector (Kjellstorm et al. 2019). Specific adaptation and protective strategies to protect workers in the context of climate change need to be promoted. Warning systems for specific occupational settings, improving thermal characteristics of working environments, reducing physical activity in work settings, use of protective clothing, hydration and colling spaces need to be implemented and provided as well as research on monitoring heat exposure and physiological heat stress and evaluating preventive actions need to be enhanced.

5. Conclusions

Heat has a significant impact on occupational injuries in the agricultural sector and adequate prevention measures need to be introduced to reduce risks and respond to future climate change. The results of this study could be useful in implementing prevention actions and working conditions in the agricultural sector, that is one of the sectors at highest risk due to climate change.

Conflicts of Interest: The authors declare they have no conflict of interest.

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Appendix A

Table A1 - Descriptive statistics of occupational injuries in the agricultural sector by region, in Italy in the study period (2014-2018).

		Year									
		2014		2015		2016		2017		2018	
Regions	**Total**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Piemonte	10710	2414	22.5	1040	22.0	968	20.2	882	18.6	821	16.7
Lombardia	13771	1414	23.1	1281	20.9	1271	20.0	1132	18.8	1079	17.2
Trentino	10533	1089	22.8	984	20.5	916	18.9	893	18.6	958	19.3
Veneto	13114	1298	22.0	1262	21.5	1182	19.9	1103	18.7	1084	17.9
Friuli	2444	243	20.6	247	22.4	221	20.4	216	18.9	205	17.8
Liguria	2466	247	22.4	233	21.9	204	19.9	197	18.9	169	16.9
Emilia-Ro	19299	1989	22.2	1872	21.6	1760	19.7	1603	18.4	1668	18.1
Toscana	12794	1215	22.3	1174	21.8	1045	19.7	996	18.5	1006	17.6
Umbria	4301	418	22.4	399	21.9	360	19.2	295	18.6	317	18.0
Marche	9574	886	22.7	922	21.2	816	20.1	723	18.9	699	17.0
Lazio	5367	511	23.3	513	22.4	383	18.5	434	18.9	406	16.9
Abruzzi	6590	612	22.4	611	22.0	532	19.8	517	19.3	455	16.4
Molise	1619	174	24.1	149	20.0	136	20.5	118	17.5	136	17.9
Campania	5631	513	22.2	510	19.7	517	20.6	505	19.0	488	18.5
Puglie	11136	899	20.4	984	20.5	968	20.9	850	18.9	905	19.2
Basilicata	2909	308	22.4	290	21.2	258	19.6	251	20.9	201	15.8
Calabria	3726	345	20.4	319	20.1	368	22.1	375	20.8	279	16.6
Sicilia	10043	817	20.2	836	19.7	856	20.9	856	20.1	817	19.2
Sardegna	4395	500	24.5	376	20.5	365	19.3	396	19.4	307	16.3

		Age group (years)						Professional qualification					
		15-34		35-60		31+		Labourer		Occasional		Self-remployer	
Regions	**Total**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Piemonte	10710	2043	19.1	6023	56.2	2644	24.7	1880	17.6	548	5.1	8281	77.3
Lombardia	13771	3111	22.6	8523	61.9	2137	15.5	5783	42.0	696	5.1	7292	53.0
Trentino	10533	1917	18.2	6115	58.1	2501	23.7	1867	17.7	593	5.6	8073	76.6
Veneto	13114	2455	18.7	7825	59.7	2834	21.6	4186	31.9	566	4.3	8361	63.8
Friuli	2444	555	22.7	1458	59.7	431	17.6	844	34.5	152	6.2	1447	59.2
Liguria	2466	451	18.3	1668	67.6	347	14.1	633	25.7	169	6.9	1664	67.5
Emilia-Ro	19299	3302	17.1	11361	58.9	4636	24.0	5022	26.0	2872	14.9	11404	59.1
Toscana	12794	2319	18.1	7759	60.6	2716	21.2	4885	38.2	1068	8.3	6839	53.5
Umbria	4301	676	15.7	2638	61.3	987	22.9	1295	30.1	446	10.4	2558	59.5
Marche	9574	932	9.7	5486	57.3	3156	33.0	2025	21.2	537	5.6	7012	73.2
Lazio	5367	1072	20.0	3399	63.3	896	16.7	1477	27.5	696	13.0	3191	59.5
Abruzzi	6590	651	9.9	4264	64.7	1675	25.4	799	12.1	542	8.2	5249	79.7
Molise	1619	170	10.5	1157	71.5	292	18.0	188	11.6	74	4.6	1357	83.8
Campania	5631	808	14.3	4154	73.8	669	11.9	1413	25.1	850	15.1	3368	59.8
Puglie	11136	2435	21.9	7675	68.9	1026	9.2	2358	21.2	4782	42.9	3996	35.9
Basilicata	2909	440	15.1	2061	70.8	408	14.0	748	25.7	752	25.9	1409	48.4
Calabria	3726	785	21.1	2663	71.5	278	7.5	1398	37.5	1718	46.1	610	16.4
Sicilia	10043	2291	22.8	6757	67.3	995	9.9	2913	29.0	4451	44.3	2677	26.7
Sardegna	4395	672	15.3	3136	71.4	587	13.4	1663	37.8	175	4.0	2557	58.2

Table A2 - Descriptive statistics of air temperature by region, in Italy in the study period (2014-2018).

	Mean	SD	Percentiles	
			75°	99°
Piemonte	11.1	8.0	17.4	26.6
Lombardia	12.1	8.0	18.5	28.0
Trentino Alto Adige	6.4	7.9	12.6	21.5
Veneto	12.7	8.0	19.1	28.6
Friuli Venezia Giulia	11.8	7.7	18.0	26.9
Liguria	13.2	6.4	18.6	25.4
Emilia Romagna	13.7	7.7	19.8	29.0
Toscana	13.9	6.9	19.5	27.5
Umbria	13.4	7.2	19.1	27.9
Marche	13.9	7.1	19.6	28.1
Lazio	13.8	7.0	19.5	27.7
Abruzzo	12.0	7.3	17.7	26.9
Molise	12.9	7.1	18.6	27.2
Campania	14.7	6.7	20.2	27.9
Puglia	16.8	6.7	22.4	29.8
Basilicata	13.7	7.2	19.5	28.6
Calabria	15.3	6.3	20.5	27.9
Sicilia	16.2	6.4	21.6	28.9
Sardegna	15.9	6.4	21.4	28.6

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