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Characterising the impact of heatwaves on work-related injuries and illnesses in three Australian cities using a standard heatwave definition-Excess Heat Factor (EHF)

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Abstract

Background and Aims: Heatwaves have potential health and safety implications for many workers, and heatwaves are predicted to increase in frequency and intensity with climate change. There is currently a lack of comparative evidence for the effects of heatwaves on workers' health and safety in different climates (sub-tropical and temperate). This study examined the relationship between heatwave severity (as defined by the Excess Heat Factor) and workers' compensation claims, to define impacts and identify workers at higher risk.

Methods: Workers' compensation claims data from Australian cities with temperate (Melbourne and Perth) and subtropical (Brisbane) climates for the years 2006 to 2016 were analysed in relation to heatwave severity categories (low and moderate/high severity) using time-stratified case-crossover models.

Results: Consistent impacts of heatwaves were observed in each city with either a protective or null effect during heatwaves of low-intensity while claims increased during moderate/high-severity heatwaves compared with non-heatwave days. The highest effect during moderate/high-severity heatwaves was in Brisbane (RR 1.45, 95% CI: 1.42-1.48). Vulnerable worker subgroups identified across the three cities included: males, workers aged under 34 years, new workers, labour hire workers, those employed in medium and heavy strength occupations, and workers from outdoor and indoor industrial sectors.

Conclusion: These findings show that work-related injuries and illnesses increase during moderate/high-severity heatwaves in both sub-tropical and temperate climates. Heatwave forecasts should signal the need for heightened heat awareness and preventive measures to minimise the risks to workers.

Keywords: Heatwave, Morbidity, Workers health and safety

Introduction

Extreme heat events (heatwaves) represent the most common cause of weather-related deaths in Australia and the United States (1-3). Individuals are usually acclimatised to their local weather, in physiological, cultural and behavioural terms, within a certain thermal coping range (4). However, continuing extreme heat with long duration and severity can overstretch limits of tolerance, leading to adverse health outcomes and even death. Effects are typically manifested on the same day, or within a few days, of exposure (4).

Many studies have examined population health effects of heatwaves in terms of increased morbidity and mortality (5, 6). Studies have also indicated that workers engaged in strenuous physical activities in hot conditions may be at particular risk of both illness and injury (7). Cumulative heat exposure can contribute to fatigue, loss of concentration, decline in vigilance, reduced psychomotor performance and reduced use of personal protective equipment (PPE), all of which can increase the risk of work-related injuries and illnesses as outlined in a recent review (8). These effects can be compounded if there is a lack of relief due to high overnight temperatures. To our knowledge, the impact of heatwaves on work-place injuries has been examined in only five studies to date, with mixed results. Studies in Italy (9), Adelaide, Australia (10) and Melbourne, Australia (11) have shown an increased risk, while two other studies in Adelaide (7, 12) found no statistically significant increased risk of occupational injuries during heatwaves.

The wider literature on the effects of heatwaves on population health documents several challenges in comparing the effects of heatwaves across different regions (5, 6, 13). For one, despite the general agreement on heatwaves being periods of prolonged and unusually hot weather, there is no universal definition of a heatwave (14), as there is no consensus on what defines “prolonged” or excessively hot in different areas and climates (15). The use of an absolute temperature threshold for every location would be unwise due to factors that may have different impacts in different communities or locations. These include population acclimatisation, adaptation, underlying demographics, meteorological characteristics such as temperature distribution and humidity levels, and extent of urbanisation (16). For example, temperatures which are considered to be unusually high in tropical or subtropical locations may occur more commonly during hot summers in temperate locations. A variety of heatwave metrics have been used in the literature ranging from temperature only metrics (mean, maximum or minimum temperature), to thermal composite indices that incorporate effects of temperature and humidity (apparent temperature or humidex or heat index) (5). Besides this variation, the intensity of heatwaves measured by temperature thresholds (range: 90 to 99th percentile), and duration of heatwaves in length (2 to 4 days) also varies according to definition (17-19).

The lack of a universal heatwave definition can be a challenge for emergency services and government agencies who want to use an indicator that is easily operated and understood by the community they serve. In an attempt to address the lack of a national heatwave definition, the Australian Bureau of Meteorology (BOM) developed a metric called the "Excess Heat Factor" (EHF) that can be applied consistently across different locations and provide an indication of heatwave severity and intensity (15). According to this metric, heatwave conditions occur at a location when there is a significant temperature anomaly (both short-term and long-term) specific for that particular location. The EHF index has been used in several studies in Australia (20-24) and elsewhere (25, 26). These studies suggest that EHF is a useful indicator of heat-health impacts, and therefore a potential heat warning indicator of heat-related occupational injuries and illnesses (10).

Although several multi-city studies have investigated the relationship between heatwaves and health outcomes (mortality/morbidity) in Australia (27-30), no research to our knowledge has been conducted to compare the occupational health impacts of heatwaves across different cities. The aims of this study are: (i) to examine the association between workers' compensation claims data and heatwave exposure (as defined by EHF), for cities with sub-tropical and temperate climates; and (ii) identify vulnerable workers by demographics, type of work (physical demands), occupation and industry of employment and working environment (indoor versus outdoor). With the increasing frequency, duration and intensity of heatwaves across Australia (31), it is vital to understand the impacts on workers, so that industries can better prepare for the challenges of a warmer climate on occupational health and safety.

Methods

Study area

This study was conducted in three major Australian cities with different climatic characteristics (Brisbane, Melbourne and Perth). Brisbane, the state capital of Queensland (Qld), is located on the central eastern coast and has a sub-tropical climate with dry, mild winters and hot, humid summers (32). Melbourne is located on the southern coast, in the state of Victoria (Vic), and has a temperate oceanic climate (i.e. warm summers and cool wet winters) and is also known for its changeable weather conditions. Perth, the capital of Western Australia (WA), is located on the south-west coast of Australia and has a Mediterranean climate with hot, dry summers and cool wet winters (33). These three cities combined have a population of 8.5 million (or 34% of the Australian population) and a total workforce of about 3.7 million, which is 38% of the total employed workforce in Australia. We restricted our analyses to metropolitan areas in these cities, where the majority of people live and work (34).

Data collection

Workers' compensation data

In Australia, workers experiencing a work-related injury or illness are entitled to be supported financially for their medical and health care expenses while they are unable to perform their normal duties. This support is provided by compulsory workers' compensation insurance schemes regulated by the relevant jurisdictions. The details of workers making a claim are captured within a jurisdictional database of work-related injuries and illness for that jurisdiction. The National Dataset for Compensation-Based Statistics (NDS3) is compiled by Safe Work Australia (SWA), the national regulatory agency, from case-level claims data supplied by each jurisdiction (35). This dataset contains claims made by the majority of Australian workers, but excludes specific subgroups such as: self-employed and self-insured workers, Commonwealth government employees, military personnel within the Australian Defence Force and police officers in WA (35, 36).

All accepted workers' compensation claims (as determined by the insurer) that occurred in the three Australian states (Qld, Vic and WA) between January 1, 2006, and March 30, 2016, were extracted from the NDS3. We included all claims regardless of their severity either as 'minor' (< 1 week work time lost) or 'major' (≥ 1 week work time lost) claims. Although there are similarities in the way claims are made and recorded across these jurisdictions, there exists some structural and functional differences in policy and practice (37, 38). For example, claims made while "commuting to and from work" are compensable with restrictions in Qld, but are not compensable in Vic and WA (38). Hence, to establish three comparable jurisdictional-level cohorts, we excluded such claims.

In the NDS3 dataset, each accepted claim includes information on the injured workers age and gender (demographics), industry and occupation (employment), and details of their injury (date, nature, mechanism, body location and agency of injury). However, there is no information on potential workplace heat exposure based on the location of work (outdoor or indoor), the availability of air-conditioning or acclimatisation status or physical demands of the occupation. As outdoor workers were identified to be at higher risk of weather-related heat exposure previously (7), these workers were identified using two classifications, one at the industrial level and other at the occupational level. Industries were broadly classified as outdoor or indoors based on groupings used by Xiang et al. (2014)(7). In an attempt to broadly define occupations and heat exposure levels (e.g. indoor or outdoor), we followed the approach taken by a study in Melbourne (39) whereby a 'cross-walk' was performed between the Australian and New Zealand Standard Classification of Occupations (ANZSCO) (40) and the Canadian National Occupational Classification (NOC) (41). This method has been validated previously (39). The potential classifications of workplace temperature exposures at the occupational level obtained from this cross-walk included 'regulated indoors'; 'unregulated indoors and outside'; 'in a vehicle or cab' and 'multiple locations'. Also obtained from this cross-walk were the occupational physical job demands (strength) classified as 'limited'; 'light'; 'medium' and 'heavy'.

Meteorological data

Daily weather data obtained from the Australian BOM included: maximum (T_{max}), minimum (T_{min}), and mean (T_{mean}) temperature data for each city. These data were obtained using the BOM's operational low resolution (0.25 ^{o} x 0.25^{o}) daily temperature analyses. Data were obtained for the following monitoring stations: Brisbane- (BOM site number: 040913); Melbourne – (BOM site number: 086071) and Perth – (BOM site number: 009225). These stations were considered as representative weather stations for these metropolitan areas and have been used in previous studies (21, 33, 42-44).

Heatwave definition

The excess heat factor (EHF) is an intensity measure that categorises heatwaves by their severity (15). The calculation of the EHF is based on a three-day averaged daily T_{mean}, in relation to the 95th percentile of long-term average temperatures, and the recent (prior 30-day) temperatures, for a particular location. This estimate accounts for both historical averages and short-term acclimatization. EHF intensity is normalised to generate an index of heatwave severity that can be used for comparison between different locations (15). The details on calculation of this metric are provided in Appendix A (15). We obtained daily gridded EHF and EHF severity data for the BOM monitoring sites mentioned above. We then categorised heatwaves using the following EHF severity levels (EHF_{sev}):

- No heatwave: daily $EHF_{sev} \leq 0$;
- Low-intensity: daily $EHF_{sev} > 0$ and < 1;
- Moderate-severity: daily $EHF_{sev} \geq 1$ and < 2, and
- High-severity: daily $EHF_{sev} \geq 2$.

However, as there were very few days of $EHF_{sev} \geq 2$ during the study period, we combined the moderate and high-severity HW days (i.e. daily $EHF_{sev} \geq 1$).

Study design and statistical analysis

The risk of work-related injury and illness during heatwave days, defined by EHF_{sev} , compared with non-heatwave days, was assessed using a time-stratified case-crossover study design. This approach, whereby each case serves as their own control, was chosen to account for the lack of site-specific denominator data (i.e. the number of workers), as well as its strength in controlling for known and unknown time-invariant individual confounders (45, 46). In contrast to other studies using a monthly or 28-day strata (11, 39, 47), we used a shorter 7-day strata to adjust for known weekly changes in worker numbers that arise over a short-period of time due to, for instance, labour strikes, power outages, co-worker absence or changes in work practices (11, 39). The analyses were restricted to the warm months of each year (November to March) to control for the effects of seasonality (28). A generalised linear model with a Poisson distribution was used to estimate the relative risks. Public holidays were adjusted for with three separate binary indicator variables (Christmas Day, New Years' Day and other holidays). Days of the week were adjusted for by including a categorical "day of the week" variable using Friday as the reference day. Relative risks (RRs) with 95% confidence intervals (CIs) are reported for heatwave days of low-intensity, and moderate/high-severity, compared with non-heatwave days during the same warm season. The lagged effects (days 1 and 2) for EHF_{sev} on total compensation claims were also explored. As a marked lag effect was not found, these results are not presented.

Ethical clearances were obtained from the ethics committees of The University of Adelaide, the Queensland University of Technology, The University of Western Australia and Monash University.

Results

Exposure

The number of heatwave days at each severity level as well as the corresponding three-day average daily T_{max} for each city are in Table 1. Melbourne had the highest number of moderate/high-severity heatwave days, while low-intensity heatwave days were highest in Brisbane. The three-day average daily T_{max} during moderate/high-severity heatwave days were highest in Perth (39.9 ^{o}C) and Melbourne (37.8 ^{o}C).

Outcomes

Overall, 746,655 workers' compensation claims were reported in the three cities during the study period (1 January 2006 to 30 March 2016). There were 243,963 (33%) claims in Brisbane, 241,376 (32%) in Melbourne and 261,316 (35%) in Perth. Of these, 11,693 (4.8%), 10,946 (4.5%) and 12,207 (4.6%) occurred during 197, 183 and 186 heatwave days, respectively, as defined by EHF_{sev} (i.e. EHF_{sev} >0). Across the three cities, the majority of claims were among males (66%), experienced workers (88%) and those aged 34 to 54 years (47%). Industries such as "Manufacturing", "Healthcare and Social assistance", "Construction" and "Retail trade" accounted for about half (51%) of all claims.

Heatwaves and workers' compensation claims

Overall effect

There was a consistent trend of increasing compensation claims with heatwave severity across the three cities. In Brisbane and Melbourne, a small reduction in risk (RR 0.97, 95% CI: 0.94-0.99) was observed during low-intensity heatwaves, while in Perth a null effect (RR 1.01, 95% CI: 0.97-1.02) was observed. However, significant increases in claims during moderate/high-severity heatwave days were seen for all three cities with the highest effect estimate in Brisbane (RR 1.45; 95% CI: 1.42-1.48), followed by Perth (RR 1.26, 95% CI: 1.24-1.29), and Melbourne (RR 1.25, 95% CI: 1.22-1.28).

Higher associations were seen for 'minor claims' (≤ 1week of time-lost) compared with 'major claims' during moderate/high-severity heatwaves (Table 2).

Effect by workers' demographics, work and work environment characteristics

The results of stratified analyses of claims are shown in Table 2. Across the three cities, there were increases in claims during moderate/high-severity heatwaves for almost all worker characteristics, i.e. age, gender and work experience, and consistent with the overall trend, the highest effect was in Brisbane. Also, in all three cities claims were more pronounced during moderate/high-severity heatwaves among male workers, young workers (aged 15-24 and 25-34 years), apprentice/trainees, and workers in labour hire arrangements.

Analysis of work characteristics revealed that moderate/high severity heatwaves affected workers regardless of their work physical demands, with a stronger effect for 'heavy-strength' occupations in Brisbane (RR 1.56, 95% CI: 1.50-1.63) and Melbourne (RR 1.32, 95% CI: 1.26-1.39) and 'medium-strength' occupations in Perth (RR 1.32, 95% CI: 1.28-1.36).

Stratified analyses by work environment characteristics showed significant increase in claims during moderate/high-severity heatwaves whether work was carried out 'mostly outside' or 'inside' based on industry classification (results not shown). Similar effects were also observed when workers were classified based on occupational classifications of workplace temperature exposures as working in 'regulated indoors' or 'unregulated indoors and outside' or 'in a vehicle or cab' (Table 2).

Discussion

The principal finding of this study is that the risk of work-related injuries and illnesses was found to significantly increase during moderate/high-severity heatwaves ($EHF_{sev} \geq 1$) across all three cities, albeit with different effect sizes. Additionally, the worker subgroups impacted by moderate/high-severity heatwaves were fairly consistent across three cities. These findings suggest that even though workers in these cities with different climates may have adapted to their local weather conditions, they may nonetheless be vulnerable to the effects of heatwaves as defined by EHF. Overall our results are consistent with previous occupational health studies (9-11, 39, 47-50) suggesting that working in hot conditions can be associated with occupational injuries. Our findings are also in agreement with previous multi-city population health studies (5, 27, 28) where consistent increases in mortality risks were observed in Brisbane, Melbourne and Sydney during heatwaves. However, in Melbourne and Brisbane a significant protective effect of low-intensity heatwaves on work-related injuries and illnesses was found, while in Perth a null effect was observed. As most of the heatwaves at each location are of low-intensity, people generally have adequate capacity to cope with this level of heat (15). While we do not have any clear explanation for the protective effect observed, a similar effect of low-intensity heatwaves on mortality has been reported previously (23).

In this study, the city-specific effect of moderate/high-severity heatwaves on work-related injuries and illnesses ranged from a 25% increase in Melbourne to 45% in Brisbane. These differences in the size of the effect estimates across the cities might be due to differences in climatic as well as non-climatic factors, such as the demographic characteristics of the workforce, the nature of work-related heat exposure, workplace adaptation measures and responses to extreme heat (e.g. heat policies) (13, 51, 52).

Our finding of the greater risk to workers during moderate/high-severity heatwaves in Brisbane is consistent with previous heat-health studies that have found greater population health impacts (both morbidity and mortality) with more intense and longer duration heatwaves (52-56). Although the population of Brisbane might be acclimatised to extended periods of warmer temperatures during summer (52, 54, 57, 58), the rarity of 'unusually' hot days (defined by EHF_{sev}) may explain why they are at risk (27, 52, 54, 59). Furthermore, being a sub-tropical city, the effects of heat stress can be due to the combined effect of air temperature and humidity. For example, the average relative humidity ranged from 69% to 71% during heatwaves of moderate/high-severity over the warm-season. As a result, workers can feel much hotter than the actual environmental temperature when relative humidity is high as it impairs the evaporation of sweat, thus accelerating the increase of body temperature (60, 61). Impaired sweating is also likely to contribute to decreased grip, possibly leading to injury. Although EHF does not take humidity into account explicitly, its use as a heatwave forecasting service in tropical environments has been previously demonstrated by BOM (62).

Notwithstanding the differences in exposure metric used, our findings for Melbourne are in general agreement with a previous study (11), which reported that the risk of serious occupational injuries (up to 10 days of work lost) increased up to the 90^{th} percentile of temperature ($33.3^{o}C$) and declined at extreme temperatures. Consistent with previous population health studies in Perth (21, 22, 33) that have found significant increases in morbidity and mortality during heatwaves, our study showed that workers are at risk of work-related injuries and illnesses during moderate/high-severity heatwaves in Perth.

Overall, these findings build upon our previous work in Adelaide (10) where we examined the effects of heatwaves (defined using EHF_{sev}) on work-related injuries and illnesses in Adelaide, a city with temperate climate in Australia, and found a significant increase in claims during moderate-severity heatwaves (RR 1.08, 95%CI: 1.01-1.17) and non-significant decline during high-severity heatwaves (RR 0.91, 95%CI: 0.78-1.06). The findings from the present study based on moderate/high-severity heatwaves in Melbourne, Brisbane and Perth are similar to those from Adelaide. The effect observed at high-severity heatwaves in Adelaide could be due to the reduced statistical power because of the rarity of such events.

Consistent increases in risks were observed for workers across the three cities regardless of gender, age group and experience. However, pronounced effects were seen amongst males, younger age groups (< 35 years), apprentice/trainees and labour hire workers. Reasons for increased susceptibility in males and young workers have been previously discussed in the literature (48, 50). Young workers, with less experience, are more likely to work in high-risk occupations and/or strenuous work and are less likely to slow down or self-pace. Other possible reasons may include: lack of awareness of workplace rights and responsibilities, workplace peer pressures and low compliance towards preventive measures (39, 48). In the case of male workers, it is known that they are more likely to work in physically demanding and heat exposed occupations and are also more likely to be risk-takers (48, 50). Apprentices/trainees may be at risk due to lack of experience, acclimatisation, training and competency. Workers in labour hire arrangements have been shown to be at greater injury risk than 'direct hire' workers due to the type of work assigned and lack of proper workplace health and safety practices. An inquiry into labour hire workers in Victoria has revealed that occupational health and safety standards are lower in the labour hire sector where these workers often work in dangerous working environments, without being provided with adequate personal protective equipment (PPE), supervision, inductions or job-specific training (63). This highlights the need to especially consider the health and safety of these workers.

To categorise work as indoor or outdoor, we have used two classifications, one at the industrial sector level and the other at the occupational level. Notwithstanding the exposure misclassification inherent in grouping workers according to industrial sectors, we found that indoor as well as outdoor industries were at risk during heatwaves. This contrasts with the findings of Xiang et al, (2014) (7) who found only outdoor industries at risk during heatwaves in Adelaide. Outdoor heat may add to the exposure levels in indoor work environments where workers may already be exposed to heat-generating processes (for e.g., food preparation/services and manufacturing) (50). A recent study of complaint calls made to the safety regulator in South Australia identified that most of the calls were from indoor workplaces (warehouses, factories and kitchens) (64). On the other hand, limited awareness of heat stress, reduced acclimatisation due to reliance on, or failure of, cooling systems in place may explain why workers in indoor industries with office environments and sedentary work such as 'Administrative and support services' and 'Professional, scientific and technical services' were at risk (65-67). Similar findings have also been reported in Quebec (50).

Consistent with McInnes et al, (2017) (39) using the occupational level classification of work as indoor or outdoor, we found that workers in 'regulated indoors' and 'working in a vehicle or cab' were at increased risk of work-related injuries and illnesses during moderate/high-severity heatwaves. Besides work location, another important effect modifier in the heat-health relationship is the nature of work undertaken which can be strenuous and repetitive in both outdoor and indoor industries (51, 68). Indeed, our findings by physical workloads that show workers in medium (somewhat physically demanding) and heavy strength (very physically demanding) occupations are at risk, confirms this observation.

Our findings are of benefit and have implications for policymakers and industry leaders, by highlighting how the risks to workers' health and safety increase during exposure to prolonged and unusual heat across different locations in Australia. A recent review of policies and guidance documents in Australia has revealed that none of the jurisdictional regulators currently have any guidelines or regulations for specific outdoor temperature thresholds at which precautions need to be taken or when work should cease (69). At the population level, higher thresholds are used for extreme heatwave warnings to avoid message fatigue. However, our findings have shown that occupational injuries and illnesses occur in moderate/high-severity heatwaves (EHF $\geq$ 1). This indicates that workplaces should be aware of the potential risks to workers' health and safety during hot as well as extreme conditions. In Australia 'heatwave assessment maps' and 'forecast maps' are provided by the BOM (70) that may be useful for workplaces undertaking risk assessment for predicted periods of hot weather when work may need to be modified or rescheduled (70).

This study has a number of strengths. To the best of our knowledge, this is the first multi-city study in Australia to compare heatwave effects on work-related injuries and illnesses using a standard definition of heatwave severity based on local climatic conditions. We have included both major and minor claims. The results provide a more complete picture of how heatwaves affect workers' health and safety by exploring immediate and contributing factors (e.g. those relating to the worker, work undertaken and work environment) to the occurrence of injuries and illnesses.

There are several limitations. First, the study population consisted of workers who had an accepted compensation claim, while rejected or ineligible claims and injuries for which a claim was not lodged, were not included. Therefore, using workers' compensation data alone are likely to underestimate the true burden of injuries and illnesses (71). Nevertheless, the NDS3 dataset provides useful national level data to investigate the epidemiology of occupational injuries. Second, workers' personal exposure to ambient heat was not known as we used data from a single weather monitoring station in each city. This introduces the likelihood of exposure misclassification which typically leads to an underestimation of the risk estimates. Further studies using personalised heat exposure measures are needed to establish precise exposure-response relationships. Furthermore, the EHF metric does not directly incorporate measures of humidity, which was expected to limit its utility in Brisbane. Nevertheless, Nairn & Fawcett (2014) have argued that humidity is indirectly factored in the calculation of EHF due to its relationship with minimum temperature, in that higher humidity leads to higher minimum temperature (15). From our results, it appears that EHF is a useful metric for both temperate (Melbourne, Perth) and humid (Brisbane) locations. Lastly, cautious interpretation is needed for some results where subgroup sample size was small, and we cannot rule out the possibility of some erroneous inferences due to multiple comparisons.

Conclusions

In conclusion, our results show that work-related injuries and illnesses increase in both subtropical and temperate locations during moderate/high-severity heatwaves with the greatest effect in Brisbane. The impacts of exposure to prolonged periods of extreme heat are not limited to workers in very physically demanding occupations and outdoor industrial sectors, but also extend to less demanding occupations and indoor industrial sectors as well. In the context of a warming climate, these findings have important implications for workforce policies and practices, suggesting that prevention strategies along with workplace heatwave action plans are needed to prevent heat-related occupational injuries and illnesses.

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Table 1 Number of heatwave days (n) and corresponding average daily maximum temperatures (ADT_{max}, in ºC, for 3 day average) by city, for warmer months (November to March, 2006-2016).

		Heatwave severity*					
		No heatwave		Low		Moderate/High	
City	Total	n (%)	ADT_{max}	n (%)	ADT_{max}	n (%)	ADT_{max}
Perth	1602	1416 (88.4%)	29.3	161 (10.0%)	36.5	25 (1.5%)	39.9
Brisbane	1602	1406 (87.8%)	28.8	173 (10.8%)	32.1	23 (1.4%)	33.9
Melbourne	1602	1419 (88.6%)	24.8	157 (9.8%)	32.8	26 (1.6%)	37.8

*severity defined on the basis of normalised EHF intensity: No heatwave: $EHF_{sev} < 0$; Low: $0 > EHF_{sev} < 1$; Moderate/High: $EHF_{sev} \geq 1$.

Table 2 Relative risks of workers' compensation claims by heatwave severity (low and moderate/high) in Brisbane, Melbourne and Perth metropolitan areas during warmer months (November to March, 2006 to 2016).

	Perth					Brisbane					Melbourne				
Exposure (EHFseverity)[*]	**Non-H/W**	**Low-intensity**		**Moderate/high severity**		**Non-H/W**	**Low-intensity**		**Moderate/High severity**		**Non-H/W**	**Low-intensity**		**Moderate/High severity**	
	(n)	**(n)**	**RR (95%CI)**	**(n)**	**RR (95%CI)**	**(n)**	**(n)**	**RR (95%CI)**	**(n)**	**RR (95%CI)**	**(n)**	**(n)**	**RR (95%CI)**	**(n)**	**RR (95%CI)**
Total	99781	10840	1.01 (0.97-1.02)	1367	1.26 (1.24-1.29)	91199	10381	0.97 (0.94-0.99)	1312	1.45 (1.42-1.48)	88638	9478	0.97 (0.94-0.99)	1468	1.25 (1.22-1.28)
Claim severity															
Minor claims	66064	7053	1.00 (0.97-1.03)	877	1.28 (1.24-1.31)	33574	3729	0.97 (0.92-1.02)	464	1.98 (1.91-2.05)	22401	2407	0.96 (0.91-1.01)	404	1.47 (1.41-1.54)
Major claims	33717	3787	1.01 (0.96-1.05)	490	1.24 (1.20-1.28)	57625	6652	0.97 (0.94-1.01)	848	1.23 (1.20-1.26)	66237	7071	0.97 (0.94-0.99)	1064	1.19 (1.16-1.22)
Gender															
Male	69058	7541	1.00 (0.97-1.03)	940	1.29 (1.26-1.32)	57829	6711	0.98 (0.94-1.02)	844	1.50 (1.46-1.54)	56141	6042	0.96 (0.93-0.99)	949	1.29 (1.25-1.33)
Female	30723	3299	1.01 (0.96-1.05)	427	1.20 (1.16-1.24)	33370	3670	0.96 (0.91-1.01)	468	1.35 (1.30-1.40)	32224	3436	0.97 (0.93-1.01)	519	1.18 (1.15-1.23)
Age group (years)															
15-24	19963	2168	1.01 (0.95-1.06)	254	1.29 (1.23-1.35)	15298	1717	0.94 (0.88-1.01)	221	1.55 (1.47-1.63)	10596	1106	0.96 (0.89-1.04)	186	1.27 (1.19-1.35)
25-34	22217	2361	0.98 (0.93-1.03)	297	1.27 (1.22-1.33)	19312	2284	0.98 (0.92-1.04)	271	1.56 (1.49-1.63)	18113	1947	0.93 (0.88-0.99)	325	1.31 (1.24-1.37)
35-54	42914	4696	1.01 (0.97-1.05)	599	1.26 (1.22-1.30)	43251	4843	0.97 (0.93-1.01)	602	1.42 (1.37-1.46)	44336	4701	0.97 (0.93-1.01)	750	1.26 (1.22-1.30)
>55	14687	1615	1.01 (0.95-1.07)	217	1.21 (1.15-1.28)	13338	1537	0.99 (0.93-1.07)	218	1.30 (1.23-1.37)	15593	1724	1.01 (0.94-1.07)	207	1.18 (1.12-1.24)
Worker experience															
Apprentice/Trainee	1944	208	1.02 (0.85-1.22)	24	1.35 (1.18-1.56)	2847	332	1.05 (0.88-1.24)	35	1.74 (1.54-1.97)	1634	184	1.01 (0.83-1.23)	20	1.41 (1.21-1.64)
Other	70641	8115	0.99 (0.96-1.02)	1006	1.26 (1.23-1.29)	88209	10030	0.97 (0.94-0.99)	1275	1.44 (1.41-1.47)	86836	9281	0.97 (0.94-0.99)	1446	1.25 (1.22-1.28)
Labour hire status															
Labour hire worker	1977	209	0.96 (0.81-1.16)	35	1.56 (1.35-1.80)	4447	481	1.01 (0.88-1.16)	51	1.58 (1.43-1.74)	5163	539	0.91 (0.81-1.02)	88	1.52 (1.39-1.67)
Other	2805	294	0.94 (0.81-1.10)	52	1.37 (1.21-1.55)	86589	9878	0.97 (0.94-0.99)	1259	1.44 (1.41-1.47)	83287	8924	0.97 (0.94-0.99)	1379	1.24 (1.21-1.27)
Potential workplace temperature exposure															
Regulated indoors	67993	7350	0.99 (0.97-1.03)	936	1.24 (1.21-1.27)	59879	6860	0.97 (0.94-1.01)	872	1.45 (1.41-1.48)	61695	6595	0.96 (0.93-0.99)	1046	1.25 (1.22-1.28)
Unregulated indoors and outside	1062	125	1.03 (0.82-1.29)	25	1.35 (1.10-1.66)	1139	126	1.01 (0.79-1.29)	14	1.14 (0.93-1.40)	508	45	0.67 (0.46-0.98)	12	1.35 (0.99-1.84)
In a vehicle or cab	5617	608	1.01 (0.91-1.13)	84	1.32 (1.21-1.44)	5904	676	0.96 (0.86-1.07)	90	1.47 (1.35-1.59)	6277	640	0.93 (0.84-1.03)	110	1.21 (1.12-1.31)
Multiple locations	24843	2735	1.01 (0.96-1.06)	319	1.32 (1.26-1.37)	24088	2695	0.96 (0.91-1.02)	336	1.46 (1.40-1.52)	19609	2137	1.01 (0.95-1.06)	297	1.29 (1.23-1.35)

Physical demands															
Limited (≤ 5kg)	20470	2223	1.02 (0.96-1.08)	257	1.22 (1.16-1.27)	20312	2231	1.01 (0.95-1.07)	275	1.33 (1.28-1.40)	23736	2564	0.98 (0.93-1.04)	386	1.21 (1.17-1.27)
Light (5-10kg)	18565	1993	1.01 (0.95-1.06)	270	1.16 (1.10-1.22)	14881	1719	0.99 (0.93-1.07)	198	1.32 (1.25-1.39)	17501	1930	0.99 (0.94-1.06)	313	1.20 (1.14-1.26)
Medium (10-20kg)	38285	4142	0.98 (0.94-1.02)	543	1.32 (1.28-1.36)	33178	3814	0.96 (0.91-1.01)	491	1.50 (1.45-1.56)	29982	3203	0.97 (0.92-1.01)	490	1.28 (1.24-1.33)
Heavy (>20 kg)	22195	2460	1.02 (0.96-1.08)	294	1.29 (1.24-1.35)	22639	2593	0.95 (0.90-1.01)	348	1.56 (1.50-1.63)	16870	1720	0.91 (0.86-0.97)	276	1.32 (1.26-1.39)

Shaded cells denote statistical significant differences based on the 95% confidence interval. *severity defined on the basis of normalised EHF intensity: No heatwave (Non-H/W): $EHF_{sev} < 0$ (reference category); Low: $0 > EHF_{sev} < 1$; Moderate/High: $EHF_{sev} \geq 1$.