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The impact of extreme heat events on mortality in Hong Kong: A 10-year time-series study (2006-2015)

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Background

Climate change and aggravated urban heat island effect increased the frequency, intensity, and duration of extreme heat events in cities. Numerous epidemiological studies suggested that extreme heat events are the predominant contributor to heat-related mortality (Kravchenko et al., 2013), whereas standards in defining extreme heat events to evaluate associated health risks in local context are generally lacking. In Hong Kong, the extremely high building and population density exacerbate the vulnerability to extreme heat events, particularly to vulnerable population groups like elderly people, children and people with chronic diseases. Studies suggested that there is excess mortality during daytime extreme heat events (D'Ippoliti et al., 2010) (Chan et al., 2012) while our previous study also highlighted the noticeable mortality risk during consecutive hot nights (Ho et al., 2017). However, as most of the typical definitions of extreme heat events use daily maximum temperature as an indicator, the assessment of extreme heat events may not be able to accurately describe a population's typical routine of heat exposure.

This paper aims to provide a useful reference for an accurate and applicable definition of extreme heat events in Hong Kong. Based on the city-wide ecological information on mortality and hourly air temperature from 2006 to 2015, the impacts of different types of extreme heat events were assessed in terms of their duration and timing. In particular, the difference and interactive effect of extreme heat events between daytime and nighttime were also examined.

Methods

A time-series daily dataset of mortality, temperature, and air quality of Hong Kong from 2006 to 2015 was collected. Daily counts of all-cause deaths with records of death date, cause, and place were obtained from the Census and Statistics Department. Based on the hourly temperature record acquired from the Hong Kong Observatory, two indicators, namely `Very Hot Days`

(VHDs: daily maximum temperature ≥ 33°C) and Hot Night (HN: daily minimum temperature ≥ 28°C), were calculated to define extreme hot weather in Hong Kong. Three durations of extreme heat events were observed for daytime and nighttime independently: 1-2, 3, >3 consecutive VHDs and HNs respectively. With an extreme heat event during daytime and nighttime defined as the occurrence of at least three consecutive VHDs and HNs respectively, the timing of a new extreme heat event was grouped into 1) 1-3 days after the previous heat event; 2) >3 days after the previous extreme heat event. Furthermore, two VHDs with no HN (2D0N), one HN (2D1N), or two HNs (2D2N), as well as three VHDs with no HN (3D0N), one HN (3D1N), two HNs (3D2N), and three HNs (3D3N) in between were identified to capture the interactive effect between daytime and nighttime extreme heat events. Daily average concentration of seven air pollutants (CO, NO_2, NO_x, SO_2, $PM_{2.5}$, PM_{10}, O_3) was acquired from the Environmental Protection Department.

The relative risk (RR) of all-cause mortality between the extreme heat events and non-extreme heat events was estimated by adopting Poisson generalized additive regression models, adjusting for long-term trend, regular seasonal trend, day of the week, and daily concentration of air pollutants. Autocorrelations between covariates were removed by checking the residuals. Subgroup analysis was also conducted to explore the modifying effect of individual age and sex, which could be used to identify vulnerable populations.

Findings

During the study period, Hong Kong experienced 467 VHDs and 480 HNs, with 139, 75, and 253 of the VHDs observed as consecutive 1-2, 3, and >3 days of extreme heat events respectively. On the other hand, 125, 84, 271 of the HNs were identified as consecutive 1-2, 3, and >3 nights of extreme heat events respectively. A total of 424380 deaths were recorded, among which 236594 (55.8%) were males, and 66038 (15.5%), 51182 (12.1%), 100543 (23.7%), 206617 (48.7%) deaths in the four age groups of <60, 60-69, 70-79, and 80+ respectively.

Our results showed that the impact on mortality varied across the type, duration and timing of extreme heat events. Significant associations with a raised mortality risk were observed for a single VHD (RR=1.026, 95%CI: 1.012, 1.039) and a single HN (RR=1.024, 95%CI: 1.011, 1.037). Three consecutive VHDs showed a slightly stronger effect on mortality (RR=1.028, 95%CI: 1.013, 1.043) than three consecutive HNs (RR=1.023, 95%CI: 1.009, 1.038). More extreme hot nights between the consecutive VHDs significantly amplified the impact on mortality, with RR of 1.046 (95%CI: 1.027, 1.062) for 3D3N, and 1.035 (95%CI: 1.017, 1.053) for 2D2N. An extreme heat event occurring more than 3 days after the previous one, compared to ≤ 3 days after the previous one, was more likely to be significantly associated with a higher excess mortality for daytime (RR=1.033, 95%CI: 1.017, 1.056) and nighttime (RR=1.026, 95%CI: 1.009, 1.042) heat events. Females and individuals aged 80+ were observed

to be more significantly affected by all types, durations, and timings of the defined extreme heat events.

Interpretation

Our findings suggest that not only the duration but also the type and timing of the extreme heat events play important roles in heat-related mortality. Non-HNs showed resilience ability to the impacts caused by consecutive daytime extreme heat events. Longer time intervals between extreme heat events introduced higher mortality risk, potentially due to under-prepared adaptations for new coming events. During the extreme heat events, females and individuals aged 80+ are of potentially higher risk who warrant regular well-person checks.

This study highlights the need for better adaptations during extreme heat events at both individual and institutional levels. Through better understanding of the nature of extreme heat events and corresponding health risks, the heat-health warning system can be better informed and heat-related healthcare services can be more efficiently provided.

Keywords

Extreme heat event, hot weather, heat waves, mortality

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