Projecting future temperature-related mortality in Hong Kong under climate change scenarios: abridged secondary publication

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KEY MESSAGES

1. Age-standardised mortality rate (ASMR) was estimated to increase generally secondary to hot weather and decrease generally secondary to cold weather. The net change was estimated to be positive and increase during the entire century.
2. The increase in ASMR secondary to increasing heat and the decrease in ASMR secondary to decreasing cold among the population aged ≥75 years were both estimated to be higher than those among the younger population.

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Introduction

Climate change has brought about increases in mean annual temperatures, increases in the frequencies of hot days, and decreases in the frequencies of cold days worldwide. Mortality, particularly cardiovascular and respiratory mortality, is higher during periods of hot and cold weather,[1] but the nature of associations varies considerably among locales, owing to differences in climate and socioeconomic levels.

As increases in mean temperatures are expected to continue, these increases might affect population health outcomes including mortality. The increasing number of hot days is expected to increase heat-related mortality, whereas the decreasing number of cold days is expected to decrease cold-related mortality.[2] Therefore, if increases in heat-related mortality exceed decreases in cold-related mortality, the net impact of a long-term rise in mean temperatures could be increased mortality. If both the mean and variance of temperature increase, then both hot- and cold-related mortality could increase.[2]

Most studies use short-term exposure (temperature) – response (mortality) curves estimated from daily time-series studies. Discrepant results have been reported in various locations with different climatic, demographic, and socioeconomic conditions.[3] We aim to project future changes in temperature-related mortality secondary to climate change in Hong Kong.

Methods

Mortality data in Hong Kong from 1976 to 2018 were obtained from the Hong Kong Census and Statistics Department. Data on mean daily temperature, relative humidity, wind speed, and solar radiation were obtained from the Hong Kong Observatory, as were projections of daily temperature distributions for the years 2030-2039, 2050-2059, and 2090-2099. Daily pollutant levels (particulate matters <2.5 microns and <10 microns in diameter, ozone, and nitrogen dioxide) were obtained from the Hong Kong Environmental Protection Department. Deaths from external causes and cancer were excluded from analyses. The general circulation models with the minimum, 25th, 50th, and 75th percentiles, and maximum of the average annual mean temperatures during 2080 to 2099 across multiple general circulation models were chosen for the projection of future mortality. The final results were reported using the average of the five chosen general circulation models.

The mortality, meteorological, and pollutant data were used to update our previous work on long-term (annual) associations between hot and cold 'degree-days' and mortality.[4] Analyses were stratified by age groups (>75 vs ≤75 years). Annual frequency and severity of hot and cold weather were summarised using a degree-days approach, with annual hot degree-days (DDHOT) being defined as the sum of degree-days above the hot threshold, and annual cold degree-days (DDCOLD) as the sum of degree days below the cold threshold. For example, given a hot threshold of 28°C and a cold threshold of 25°C, a day with temperature of 29.8°C contributes 1.8°C to the annual DDHOT, whereas a day with temperature of 21.8°C contributes 3.2°C to the annual DDCOLD.

The projected distributions of daily temperatures were used to estimate the mean annual DDHOT and DDCOLD for each decade under consideration. Together with the association estimated by the previous models, these projected temperatures were plugged into the estimated annual model to obtain projected future age-standardised mortality rates (ASMR). The baseline period was chosen as 2014 to 2018. Our annual generalised additive model is presented as: LN (ASMR) = β0 + βH × DDHOT + βC × DDCOLD + s(year of study, maximum degrees of freedom for the smooth term for trend = 8) + ε, where βH and βC are parameters describing the association between DDHOT/DDCOLD and ASMR. Estimated percentage changes in ASMR associated with particular changes in the distribution of hot (cold) degree days—Δ DDHOT(COLD)—were calculated from the relative risks from the generalised additive model as percentage change = (relative risk – 1) × 100, where relative risk = exp(βH × Δ DDHOT(COLD). Projections were expressed in terms of changes in ASMR rather than number of deaths. All analyses were conducted using the R statistical software 4.0.

Results

Between 1976 and 2018 in Hong Kong, 918 586 non-accidental and non-cancer deaths were recorded. Among which, 550 298 (59.9%) were deaths among those aged ≥75 years. The hot and cold threshold was 29.6°C and 26.4°C, chosen from May to April and November to October models that minimised the generalised cross-validation score, respectively.

ASMR was estimated to increase (attributable to excess hot days) and decrease (attributable to excess cold days), and the net change was estimated to be positive and increase, particularly after 2050 (Fig 1 and Table). There was no significant difference between representative concentration pathway (RCP) 4.5 and RCP6.0 projections, although net changes under RCP4.5 were estimated to be higher than those under RCP6.0, except for 2090 to 2099. The increase in ASMR in both hot and net effect under RCP8.5 was remarkably steep, with the net change from 0.12% in 2030s to 89.25% in 2090s.

Age was estimated to be a significant effect modifier (Fig 2). Under RCP2.6, 4.5, and 6.0, the increases in ASMR secondary to the increase of hot weather among those aged ≥75 years were estimated to be over two-fold relative to those aged ≤74 years (eg, 12.48% and 25.66% increase under RCP4.5, 15.24% and 31.35% increase under RCP6.0, and 67.42% and 174.64% increase under RCP8.5 in 2090s for those aged ≤74 and ≥75 years, respectively). In addition, larger decreases in ASMR secondary to the decrease of cold weather were estimated among those aged ≥75 years.

Discussion

Under the RCP4.5, 6.0, and 8.5 scenarios, ASMR was estimated to increase generally secondary to hot weather and decrease generally secondary to cold weather, and the net change was estimated to be positive and increase during the entire century. In addition, the increase in ASMR secondary to increasing heat and the decrease in ASMR secondary to decreasing cold among the population aged ≥75 years were both estimated to be higher than those among the younger population.

Projections on future deaths based on temperatures from climate models vary considerably

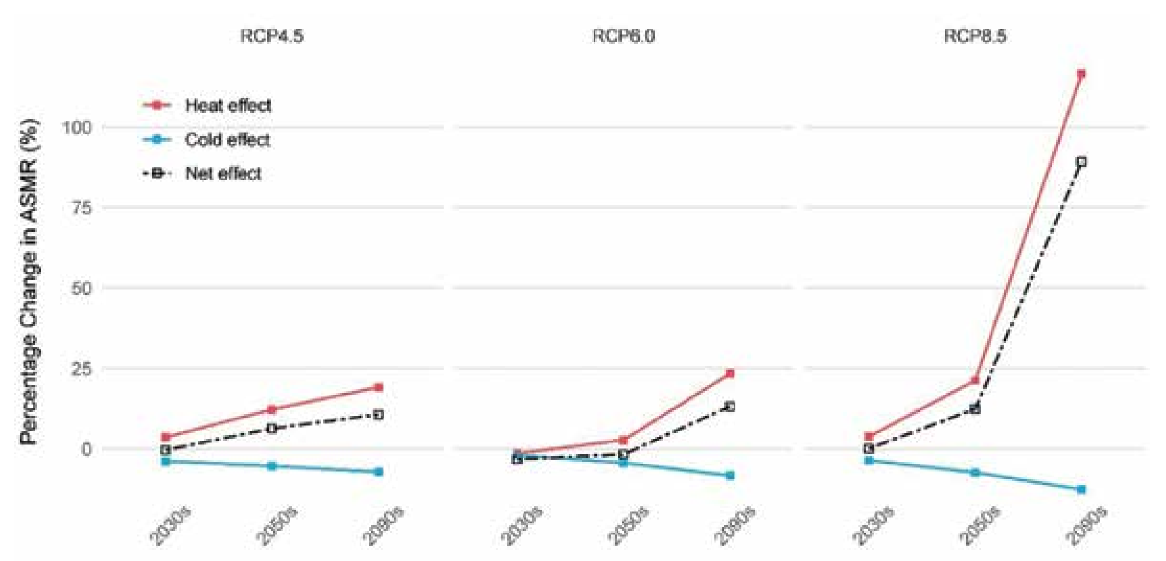

FIG 1. Average percentage changes in age-standardised mortality rate (ASMR) in Hong Kong during 2030s, 2050s, and 2090s under three climate change scenarios: representative concentration pathway (RCP) of 4.5, 6.0, and 8.5

TABLE. Projected percentage changes in age-standardised mortality rates in 2030s, 2050s, and 2090s in Hong Kong

Representative concentration pathway	% changes in age-standardised mortality rate								
	Lower bound of 95% CI			Mean			Upper bound of 95% CI		
	Hot degree-days	Cold degree-days	Net	Hot degree-days	Cold degree-days	Net	Hot degree-days	Cold degree-days	Net
4.5									
2030s	0.21	-2.10	-1.89	3.62	-3.78	-0.29	7.70	-5.41	1.87
2050s	0.72	-2.94	-2.24	12.28	-5.27	6.36	26.27	-7.52	16.78
2090s	1.08	-3.98	-2.95	19.18	-7.12	10.69	43.29	-10.14	28.77
6.0									
2030s	-0.09	-1.05	-1.15	-1.33	-1.91	-3.21	-2.36	-2.75	-5.04
2050s	0.16	-2.39	-2.23	2.78	-4.30	-1.64	5.98	-6.18	-0.57
2090s	1.32	-4.61	-3.36	23.42	-8.25	13.24	52.91	-11.73	34.96
8.5									
2030s	0.23	-1.97	-1.75	3.81	-3.55	0.12	8.08	-5.09	2.57
2050s	1.20	-4.08	-2.94	21.30	-7.30	12.44	48.13	-10.38	32.75
2090s	4.77	-7.12	-2.69	116.49	-12.58	89.25	399.28	-17.70	310.89

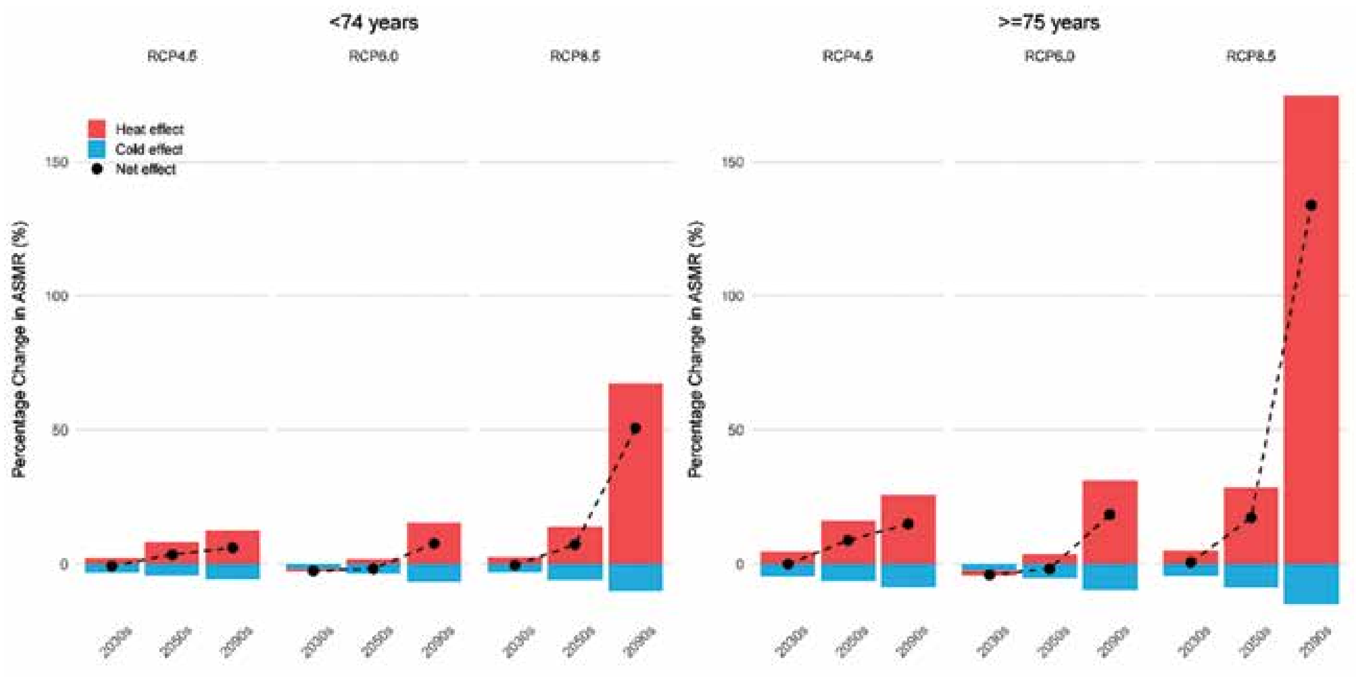

Fig 2. Average percentage changes in age-standardised mortality rate (ASMR) by age group in Hong Kong during 2030s, 2050s, and 2090s under three climate change scenarios: representative concentration pathway (RCP) of 4.5, 6.0, and 8.5

among locations.[3] Our results were in line with previous studies from other locations,[5] showing that the decrease in mortality secondary to decrease in cold temperatures in the future might not offset the increase in mortality secondary to increase in hot temperatures. We also found a negative net effect for all scenarios, but it was only reported for the lower bound of 95% confidence intervals of the estimated effects of the main model. In addition, the increasing trend by year and by climate change scenario was also partially supported by a global study on mortality projection, particularly in Southeast Asia,[3] where the climate is more similar to Hong Kong than to East Asia.

In a prediction study in the UK, older people aged ≥75 years are more sensitive to the future climate change.[5] However, even with the elevating temperatures in the coming decades in the 21st century, the impact of cold temperatures is estimated to outweigh the impact of hot temperatures.[5] Similarly, our study found that the increase in heat-attributed mortality rate secondary to increase in high temperatures could not be offset by the decrease in cold-attributed mortality rate secondary to decrease in low temperatures.

The current study has limitations. We used the annual data to project the future mortality secondary to climate change. Therefore, shift of seasonal pattern secondary to short-term climatological change could not be captured by our study. In addition, only 42 years were used for historical analysis and thus the sample size might not be sufficient for non-biased effect estimation. Furthermore, two important sources of uncertainty in estimates of future mortality were not accounted: adaptation assessment and potential demographic change. The integration of potential adaptation evaluation with long-term exposure-response association is required in future studies. Population change was not taken into consideration; future age structure was an essential factor influencing ASMR.

Conclusion

In the coming decades in Hong Kong, the ASMR was estimated to increase under medium and high emission scenarios secondary to climate change. Better urban planning strategy and public awareness should be promoted for the effective mitigation of future climate change.

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Disclosure

The results of this research have been previously published in:

1. Wang P, Tong HW, Lee TC, Goggins WB. Projecting future temperature-related mortality using annual time series data: an example from Hong Kong. Environ Res 2022;212:113351.

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