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Future temperature-related years of life lost projections for cardiovascular disease in Tianjin, China

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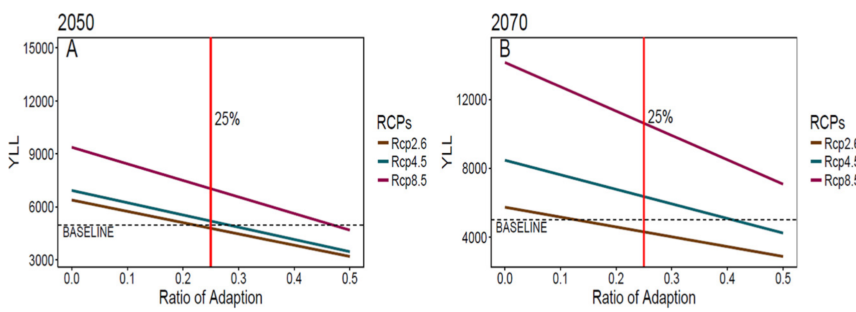
HIGHLIGHTS

- Monthly analyses of percent changes in YLL occurred from May to September.
- Warm adaptation could be fully offset the adverse effects under RCP2.6 in both 2050 and 2070.
- Strict emission control is needed to confront the future global warming.

GRAPHICAL ABSTRACT



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ABSTRACT

It is widely accepted that temperatures is associated with cardiovascular mortality, however, few studies have explored the effects of temperature on years of life lost (YLL) from cardiovascular mortality in China under future global warming scenarios. Therefore, there is an urgent need to obtain projections of YLL from cardiovascular diseases. Here we applied nineteen global-scale climate models (GCMs) and three Representative Concentration Pathway emission scenarios (RCPs) in the 2050s and 2070s for temperature-related YLL projection in Tianjin, China. We found the relationships between daily maximum temperatures with YLL from cardiovascular mortality were basically U-shaped. We observed increasing net annual YLL across a range of multiple models under different climate scenarios, suggesting that increasing heat-related YLL from cardiovascular mortality could offset decreasing cold-related YLL from cardiovascular mortality. The largest temperature-related YLL from cardiovascular mortality were observed under the RCP8.5 scenario and increased more rapidly in the 2070s versus the 2050s. Monthly analyses of percent changes in YLL from cardiovascular mortality showed that the largest percent increases occurred from May to September. If warm adaptation occurs, only the adverse effects under RCP2.6 could be fully offset in both 2050 and 2070. Our exploration provided further evidence for the potential health impacts of global warming and highlighted that government should develop environmental policies for future health risks.

1. Introduction

Climate variables affect human health by affecting the air that people breathe, the water they drink, the food they eat and the environment in which they live. The World Health Organization (WHO) predicts that high temperatures will become a growing public health concern because of climate change between 2030 and 2050, especially for those

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areas with weak health infrastructure mostly in developing countries (http://www.who.int/mediacentre/factsheets/fs266/en/). The fifth report of the Intergovernmental Panel on Climate Change (IPCC) stated that China's average annual temperature has significantly increased up to 0.5–0.8 °C in the last 100 years. In addition, it is estimated that the climate will continue to warm in the future (Zeng et al., 2008).

Many epidemiological studies have provided convincing evidence on the adverse effects of either high or low temperature. For example, in 2003, >70,000 people died in Europe. A total of 14,539 deaths directly related to the heat wave were observed over the period from August 1st to 20th, 2003 in France, including 3004 excess deaths from circulatory system diseases and 1365 for respiratory system diseases (Fouillet et al., 2006). Additional literature has shown that heat is an important cause of cardiovascular events (Cheng and Su, 2010; Halonen et al., 2011). Zhou et al. found that compared to non-cold spell days, the 2008 cold spell increased mortality by 43.8% with the greatest effects in southern and central China (Zhou et al., 2014). Analitis A, who studied the short-term effects of cold weather on mortality in 15 European cities, found that a 1 °C decrease in temperature was associated with a 1.35% increase in the daily number of total natural deaths and a 1.72%, 3.30% and 1.25% increase in cardiovascular, respiratory, and cerebrovascular deaths, respectively (Analitis et al., 2008). Liu F found that when the mean weekly temperature is below 6 °C, the incidence of acute coronary heart disease is higher than the morbidity at baseline and increases with the decrease of temperature in Beijing (Liu et al., 2005).

Some studies showed that adaptation could offset some of the adverse effects from higher temperature by shifting the minimum mortality temperature to a higher value (Astrom et al., 2016). Such a reduction in mortality can be achieved through adaptation strategies, such as improvement of prevention and early warning systems, systematic vaccination, improved health diet and better insulation of buildings (Christidis et al., 2010; Kettaneh et al., 2010). At the same time, it is possible that society loses some degree of acclimatization to cold conditions, as a result of the decrease in the frequency of cold waves, although the evidence base is limited (Ballester et al., 2011; McMichael and Lindgren, 2011).

In previous studies regarding the relationships between temperature and health outcomes, more attention was paid to excess deaths or mortality risk, which combined deaths occurring on the same day and weighted deaths for different age groups equally (Baccini et al., 2008; Le Tertre et al., 2006; McMichael et al., 2008; Medina-Ramon and Schwartz, 2007). Even those studies projecting health effects into the future chose deaths or mortality as outcome indicators (Benmarhnia et al., 2014; Guo et al., 2016; Li et al., 2016; Roldán et al., 2015; Tawatsupa et al., 2014). Zhang et al. projected the temperature-related mortality due to cardiovascular disease in Beijing, and found that the decrease in the number of cold-related deaths did not compensate for the increase in that of heat-related deaths, leading to a general increase in the number of temperature-related deaths due to CVD in Beijing (Zhang et al., 2018). However, this approach would likely have neglected differences in the life lost from different age groups (Yang et al., 2015). Therefore, YLL can make up for this deficiency, by taking into account the age at which deaths occur by giving greater weight to deaths at younger ages and it is mostly used to analyse the main cause of population life loss (Steenland and Armstrong, 2006). In recent years, some studies have focused on the association between climate change and YLL (Egondi et al., 2015; J et al., 2016; Yang et al., 2015; Z et al., 2015). Three relevant studies regarding temperature-related YLL were carried out in Australia and Europe (Baccini et al., 2013; Huang et al., 2012a; Huang et al., 2012b). However, only one focused on projected climate change on daily non-accidental mortality in Tianjin, China, simulating future daily temperatures by adding 1 to 4 °C to the observed daily temperature data at the climate baseline (Li et al., 2018).

In this study, we aimed to project future temperature-related YLL from cardiovascular mortality, with temperature projections using nineteen downscaled global climate models and three greenhouse gas emissions scenarios to estimate current and future seasonal patterns in the 2050s and 2070s in Tianjin, a metropolis in north China. YLL from cardiovascular mortality are additionally computed according to one of the adaptation scenarios, illustrating a hypothetical change in the vulnerability of the north China population as a result of future temperature rise.

2. Materials and methods

2.1. Study area

Tianjin covers an area of 11.917 thousand square kilometres. In 2016, its population reached 15.6212 million. This city belongs to the warm temperate semi-humid continental monsoon climate with four distinct seasons. In summer, it is hot, and the rainfall is concentrated. In winter, it is cold and dry with little snow.

2.2. Data collection

We acquired daily counts of cardiovascular disease mortality (International Classification of Disease (ICD)-10:I00-I99) from the Chinese Centers for Disease Control and Prevention (CDC) for a 6-year period centred around 2008 (2006–2011) in Tianjin (Yang et al., 2013). Information about date of death, gender and age groups were provided. Meteorological data, including daily mean temperature and relative humidity, were provided by the China Meteorological Data Sharing Service System. Max daily temperature was chosen as the exposure index. The daily average concentration of PM_{10} was from the Tianjin environmental monitoring centre.

2.3. YLL calculation

The YLL was calculated as previously described (Li et al., 2018). First, we matched each death by age and gender to the WHO life table for the same year (http://apps.who.int/gho/data/view.main.60340?lang=en) (Table S1). Then the sum of YLL for all deaths on that day was taken as the daily YLL.

2.4. Temperature projections

The representative concentration pathways (RCPs) proposed in the IPCC Fifth Assessment Report (Pachauri et al., 2014), were used to predict these factors describing four different 21st-century paths for GHG emissions, atmospheric concentrations, air pollutant emissions and land use. Three RCPs were selected, including a rigorous mitigation scenario (RCP2.6), an intermediate scenario (RCP4.5) and a scenario with very high GHG emissions (RCP8.5).

Because previous studies using different temperature measures suggested that no one temperature measure was superior to the others, they all have a similar predictive ability (Anderson and Bell, 2011; Barnett et al., 2010), we selected 19 GCMs in this study. Projected daily maximum temperature for two future periods (2041–2060, 2061–2080, hereafter referred to as "2050" and "2070") were established from nineteen global scale GCMs under the three above RCPs (http://www.worldclim.org/). Nineteen global climate models used in this study are introduced in Supplemental Table S2. We used the average daily maximum temperature of these 6 years as our baseline to reduce the influence of any unusual temperatures from one year. Then we added the monthly average difference between the baseline and the future climate from the models to each of the baseline daily maximum temperatures within the same month.

2.5. Statistical analysis

We applied a standard time-series regression to estimate the association between max daily temperature and YLL. We adopted a natural