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Heat and health in Antwerp under climate change: Projected impacts and implications for prevention

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A R T I C L E I N F O

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A B S T R A C T

Background: Excessive summer heat is a serious environmental health problem in several European cities. Heat-related mortality and morbidity is likely to increase under climate change scenarios without adequate prevention based on locally relevant evidence.

Methods: We modelled the urban climate of Antwerp for the summer season during the period 1986–2015, and projected summer daily temperatures for two periods, one in the near (2026–2045) and one in the far future (2081–2100), under the Representative Concentration Pathway (RCP) 8.5. We then analysed the relationship between temperature and mortality, as well as with hospital admissions for the period 2009–2013, and estimated the projected mortality in the near future and far future periods under changing climate and population, assuming alternatively no acclimatization and acclimatization based on a constant threshold percentile temperature.

Results: During the sample period 2009–2013 we observed an increase in daily mortality from a maximum daily temperature of 26 °C, or the 89th percentile of the maximum daily temperature series. The annual average heat-related mortality in this period was 13.4 persons (95% CI: 3.8–23.4). No effect of heat was observed in the case of hospital admissions due to cardiorespiratory causes. Under a no acclimatization scenario, annual average heat-related mortality is multiplied by a factor of 1.7 in the near future (24.1 deaths/year CI 95%: 6.78–41.94) and by a factor of 4.5 in the far future (60.38 deaths/year CI 95%: 17.00–105.11). Under a heat acclimatization scenario, mortality does not increase significantly in the near or in the far future.

Conclusion: These results highlight the importance of a long-term perspective in the public health prevention of heat exposure, particularly in the context of a changing climate, and the calibration of existing prevention activities in light of locally relevant evidence.

1. Background

The epidemiologic evidence on the association between heat and health impacts is clear and well established in major cities of western Europe (Analitis et al., 2014; D'Ippoliti et al., 2010; Leone et al., 2013; Michelozzi et al., 2009), especially concerning the relationship between high temperatures and mortality, and several of the risk factors in the relevant causal pathways (Bouchama et al., 2007; Kovats and Hajat, 2008). Baccini et al. studied the relationship between daily maximum apparent temperatures and mortality in 15 European cities, finding

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various degrees of increase in mortality in Mediterranean cities and north-continental cities, respectively, for every 1 °C increase in maximum apparent temperature above a city-specific threshold (Baccini et al., 2008). An additional study, conducted across 12 European cities, found a positive association between temperature and hospital admissions for respiratory disorders (Michelozzi et al., 2009). Subsequent studies have confirmed similar findings.

Heat-related health effects are likely to exacerbate in these urban settings under climate change, with projected rising temperatures, an increase in frequency and intensity of heat waves in the European Region (IPCC, 2013) and an intensification of the urban heat island effect (Founda and Santamouris, 2017; Wouters et al., 2017). In the absence of adaptation, an increase in heat-related adverse health effects may follow (Ciscar et al., 2014; Hajat et al., 2014; Petkova et al., 2014). Notwithstanding the increase in the available evidence, there are several major urban agglomerations in Europe for which no study has been published on the local links between heat and health. This hampers the ability to plan and implement adequate prevention, and evidence-based health adaptation to climate change.

Heat-related mortality has been described in Belgium from the early 1990s (Sartor et al., 1995, 1997), and thereafter very strong impacts have been confirmed in 2003 (Sartor, 2004) and 2006 (Maes et al., 2007). In this paper, we examine retrospectively the association between temperature and mortality, and selected non-fatal outcomes, in the city of Antwerp, in Belgium, in the period 2009 to 2013. Thereafter, we estimate the changes in heat-related mortality under likely climate change and population scenarios in two future time periods (2026–2045 and 2081–2100), in the absence of adequate adaptation, and discuss policy implications in the context of current prevention and adaptation efforts in Belgium.

2. Methods

2.1. Current and future Antwerp urban climate assessment

The retrospective meteorological data series is based on temperatures derived by UrbClim, an urban climate model designed to model the urban influence on large-scale meteorological conditions at a resolution of a few hundred of metres (De Ridder et al., 2015; Lauwaet et al., 2015). The model solves a set of simplified prognostic flow equations for the atmospheric boundary layer and contains detailed urban surface physics, taking into account the reduced vegetation and increased soil sealing in the city centre. The synoptic (large-scale) atmospheric boundary conditions are taken from the global ERA-Interim reanalysis data set of the European Centre for Medium-Range Weather Forecasts (ECMWF) (Dee et al., 2011). Local terrain and surface data are based on open-source datasets, such as the Corine land cover and the European Environment Agency soil sealing data set for Europe. The model has previously been validated with several validation campaigns, among which one has focussed on the agglomeration of Antwerp (De Ridder et al., 2015; Garcia-Diez et al., 2016; Laaidi et al., 2011). Using the UrbClim model, daily urban climate data has been composed for all summer periods (May–September) for a climate reference period (1986–2015). The model provides gridded hourly data with a 250 m resolution for the entire urban agglomeration of Antwerp, which occupies a domain of approximately 20 by 20 km. This raw output is subsequently converted to daily minimal, mean and maximal temperature values, and for each of the 22 municipalities within the agglomeration, the (spatial) mean over the municipality is computed.

Future climate data has been compiled using a statistical method, as described in detail in (Lauwaet et al., 2015). We have composed projected summer daily minimal, maximal and mean temperatures for two periods, one in the near (2026–2045) and one in the far future (2081–2100), by rescaling reference temperatures (1986–2015) according to the monthly temperature changes observed in an ensemble of global climate models (GCMs). For the study at hand, the temperature rescaling functions are based on the output of a set of GCMs contained in the archives of the Coupled Model Intercomparison Project (CMIP5) archive of the Intergovernmental Panel on Climate Change (IPCC, 2013). Based on data requirements and availability, eleven GCMs have been selected, which have to form a representative set of the GCMs contained in the entire CMIP5 archive (Lauwaet et al., 2015). Due to the large computational demand of the study, only one climate scenario has been used. In its most recent assessment report (AR5), the IPCC has identified four pathways (Representative Concentration Pathways, RCPs) (IPCC, 2013), ranging from strong (RCP2.6) to weak mitigation (RCP8.5). To provide a range for the negative effects of climate change on human health, we have focused on the RCP8.5 scenario. Although this is the IPCC-scenario with the largest warming potential, global emission trends still track along the lines of this scenario (Peters et al., 2012).

2.2. Health impact assessment

The geographical area under study comprises the municipality of Antwerp (Belgium) for which the daily mortality series (all non-accidental causes, ICD-10 codes: A00-R99) was collected for the period 2009–2013. Initially, mortality data were collected for the 22 municipalities that can be loosely defined as the greater Antwerp area. However, for these surrounding municipalities, both separately and in aggregate, the mortality count was too low to find statistical associations. Therefore, the analysis included only temperature and health outcome data for the city (municipality) of Antwerp for the years 2009 to 2013, for which data were provided by the Flemish Agency of Public Health. In addition, the daily series of emergency admissions due to cardiorespiratory causes (ICD-10 codes: I00-I99 and J00-J99) were collected for the same period. Population data for the city of Antwerp were obtained from Statistics Belgium for the period 1986–2015. Projections for the periods 2026–2045 and 2081–2100 were based on the United Nations World Population Prospects (WPP) forecasts for Belgium (UNDESA, 2013). Taking as reference the population data for the city of Antwerp in the year 2015 (516.009 inhabitants), we calculated the proportion it represented from the total national population. Thereafter, that proportion was assumed constant, whereby the population of Antwerp would behave like that of Belgium. The specific WPP scenario chosen was the “medium variant” (UNDESA, 2008).

2.2.1. Determination of heatwave threshold temperature

As the dependent variable, we used data on daily mortality due to natural causes in the summer months in Antwerp from 1st January 2009 to 31st December 2013. As the independent variable, we used data on the daily maximum and minimum temperatures in this city across the same period. Instead of using daily mortality data, we chose to work with mortality residuals, thereby eliminating trend and seasonalities from the mortality series, leaving anomalies in mortality to be related to temperature. The residuals were obtained by means of univariate autoregressive integrated moving average (ARIMA) modelling (Box et al., 1994). The advantage of working with residuals as opposed to daily mortality is that, once modelled, residuals display neither trends nor periodicities (both of which are inherent in daily mortality), with the result that any associations found will show a genuine temperature–mortality relationship from a statistical standpoint (with significance cut-off $p < 0.05$). We proceeded to plot the following on a scatter plot diagram: the mean value of the mortality series residuals on the same day (vertical axis); the maximum daily temperatures at 2 °C intervals (horizontal axis), and their corresponding 95% confidence intervals (CIs). When these mortality residuals are showed in a scatter plot with the maximum temperature data, the deviations detected correspond to real mortality anomalies. The temperature from which the mortality residuals increased significantly vis-à-vis the mean would thus be the threshold temperature.