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## Drivers of the time-varying heat-cold-mortality association in Spain

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**Background:** A number of studies have reported reductions in mortality risk due to heat and cold over time. However, questions remain about the drivers of these adaptation processes to ambient temperatures. We aimed to analyse the demographic and socioeconomic drivers of the downward trends in vulnerability to heat- and cold-related mortality observed in Spain during recent decades (1980-2018).

**Methods:** We collected data on all-cause mortality, temperature and relevant contextual indicators for 48 provinces in mainland Spain and the Balearic Islands between Jan 1, 1980, and Dec 31, 2018. Fourteen contextual indicators were analysed representing ageing, isolation, urbanicity, heating, air conditioning (AC), house antiquity and ownership, education, life expectancy, macroeconomics, socioeconomic, and health investment. The statistical analysis was separately performed for the range of months mostly causing heat- (June-September) and cold- (October-May) related mortality. We first applied a quasi-Poisson generalised linear regression in combination with distributed lag non-linear models (DLNM) to estimate province-specific temperature-mortality associations for different periods, and then we fitted univariable and multivariable multilevel spatiotemporal meta-regression models to evaluate the effect modification of the contextual characteristics on heat- and cold-related mortality risks over time.

**Findings:** The average annual mean temperature has risen at an average rate of 0.36°C per decade in Spain over 1980-2012, although the increase in temperature has been more pronounced in summer (0.40°C per decade in June-September) than during the rest of the year (0.33°C per decade). This warming has been observed, however, in parallel with a progressive reduction in the mortality risk associated to both hot and cold temperatures. We found independent associations for AC with heat-related mortality, and heating with cold-related mortality. AC was responsible for about 28.6% (31.5%) of the decrease in deaths due to heat (extreme heat) between 1989-1993 and 2009-2013, and heating for about 38.3% (50.8%) of the reductions in deaths due to cold (extreme cold) temperatures. Ageing (ie, proportion of population over 64 years) attenuated the decrease in cold-related mortality.

**Conclusion:** AC and heating are effective societal adaptive measures to heat and cold temperatures. This evidence holds important implications for climate change health adaptation policies, and for the projections of climate change impacts on human health.

