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Toward meta-analysis of impacts of heat and cold waves on mortality in Russian North

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A B S T R A C T

Russian North experiences greater warming trends than other regions of the country. Absence of large cities in this region makes direct epidemiological studies difficult, and new methods are being developed. This study proposes a framework for a meta-analysis of health impacts of heat waves and cold spells, using four selected cities with populations between 100,000 and 350,000 as project sites. Heat waves and cold spells were identified during 1999–2007. Statistical analysis of mortality from all non-traumatic, cardiovascular, respiratory and all external causes among age groups 30–64 and ⩾65 allowed to obtain site-specific and then pooled estimates of relative increases in mortality separately for heat and cold waves. The evidence of impacts of cold on mortality was more robust than the same for heat. Greater increases in mortality were observed during long cold waves than during short ones; however, the opposite was true for heat waves. Age group ⩾65 was more vulnerable to cold than age group 30–64. Nearly all increase in non-traumatic mortality during cold waves was attributed to cardiovascular causes. External causes also showed significant increase during heat. The proposed methodology gives statistically significant results in cities with populations greater than approximately 100,000.

1. Introduction

Recent studies of potential health effects of climate change renewed interest in assessment of health effects of extreme temperature events all over the world, because it is very likely that global climate change will generate more heat waves (Peng et al., 2011; Shaposhnikov et al., 2011). The importance of circumpolar areas in such studies has been emphasized because these areas are experiencing more pronounced changes of near-surface temperatures than the average changes in the North Hemisphere. For example, annual average temperatures in Central Siberia increased by 1–3 °C over the last 50 years (Federal Service for Hydrometeorology and Environmental Monitoring, 2008), while the average global surface temperature increased by 0.65 °C during the same period (Solomon et al., 2007). Climate simulations performed in Russian Main Geophysical Observatory confirmed that climate change would lead to longer heat waves and shorter cold waves (Shaposhnikov et al., 2011).

Abbreviations: IHD, ischemic heart disease; CVD, cerebrovascular diseases; RD, respiratory diseases; RR, relative risk; H_0, null hypothesis; df, degrees of freedom.

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The observed increases in total mortality during heat waves may reach 60–85% (McGeehin and Mirabelli, 2001; Johnson et al., 2005; Poumadère et al., 2003). However, catastrophic heat waves happen rarely, and average heat wave effects are much smaller. For example, an average increase in total mortality on heat wave days compared to non-heat wave days for all waves with duration $\geqslant 2$ days ranged from 1.8% in US South to 6.8% in US Northeast (Anderson and Bell, 2011). The documented impacts of cold spells on non-accidental mortality are generally 10–15% (Huynen et al., 2001; Revich and Shaposhnikov, 2008).

While health impacts of extreme temperature events, including relative increases in mortality, have been well documented for major cities, usually with population over one million, studies of small populations present considerable statistical difficulties, because daily number of health outcomes are too small. The relationship between population size and the significance of the heat effect estimate can the illustrated by the following example: an Italian study (Conti et al., 2003) attempted to detect the differences in mortality rates in age group $\geqslant 75$ between the summers of 2002 and 2003 (the latter was unusually hot in Europe) in all 21 regional capitals with populations ranging from 40,000 to 2,547,000. Only 10 out of 21 tests showed significant increases in mortality rates; these 10 were the largest cities. The smallest city where the test was significant was Bari (317,000 people); and the largest city where the test was not significant was Florence (356,000 people). For a US nationwide study of heat waves, the authors selected only communities with $\geqslant 200{,}000$ inhabitants (Hajat et al., 2006). The same minimum population threshold was used in a Chinese study of cold spells "in order to ensure enough death counts" (Zhou et al., 2014). Given that sensitivity of statistical criteria used for hypothesis testing crucially depends upon the average number of daily outcomes, direct statistical evidence of health risks posed by temperature waves in small towns with <200,000 inhabitants is generally scarce.

Russian labor legislation established the list of "Far Northern" regions, defined on the basis of harsh climatic conditions. Total population of these regions is 10.6 million (Federal Statistical Service, 2011), of which 2.5 million live in the Arctic Circle (Ministry of Regional Development of the Russian Federation, 2010), where the largest city (Murmansk) has the population of 350,000. Although the exposed population is large, the absence of big cities in Russian North poses specific challenges for assessments of health impacts of temperature waves (Shaposhnikov et al., 2011; Revich and Shaposhnikov, 2010). In this study, we attempted to gain more information about the potential health effects pooling together site-specific estimates of mortality risks obtained at four different locations near the Arctic Circle, in circumpolar regions, as defined in Arbour et al. (2010). In particular, the following questions were addressed: Are heat waves more hazardous than cold spells, if symmetrical definitions are applied to both types of these weather events? Are long temperature waves more devastating than short waves? (The distinction between short and long temperature waves might be particularly important in future studies of climate and health projections.) Which causes of death mainly explain increases in total mortality during such events? What are the inputs of accidental and non-accidental causes? Are there any significant age-specific differences? And, finally, what is the minimum size of population which can be studied with the methods developed in this paper?

2. Methods

2.1. Study locations and data

This study consisted of two successive steps: first, site-specific estimates of relative increases of mortality during temperature waves were obtained at the four selected cities of Russian North. Then, the pooled risk estimates were calculated and several hypotheses were tested using these estimates. Table 1 lists the project sites sorted by population size. During the selection of project sites, the authors took in account the size of urban populations, their ethnic composition and massive migrations. Some cities were excluded at this step, e.g., Norilsk, because of dramatic changes in the population size during the study period (1999–2007). Some of selected cities also showed considerable declines in their populations between the beginning and the end of study period: e.g., −14% in Murmansk and −22% in Magadan, which were taken in account during statistical analysis. Although only one of the four cities (Murmansk) is situated above the Northern Polar Circle, the climate there is actually milder than in the other cities included in the study.

A database of daily death counts was obtained from Russian State Statistical Service; each death record contained cause of death coded in ICD-10 format and age at death. This database was used to construct daily time series for ten indicators of

Table 1
Geographic location, climate and population of four cities included in the study.

City	Geographic coordinates	Mean temperature (°C)		Temperature thresholds[a] (°C)		Population, thousand	
		January	July	Cold	Heat	Beginning of study period	End of study period
Archangelsk	65°N; 40°E	−13	+15	−23.8	+21.0	369	355
Murmansk	69°N; 33°E	−11	+13	−18.4	+17.3	364	318
Yakutsk	62°N; 130°E	−40	+19	−43.0	+22.8	204	246
Magadan	60°N; 151°E	−26	+13	−22.4	+13.9	122	100

[a] Cold and heat thresholds were set at the 3rd and 97th percentiles of distribution of daily mean temperatures during the study period.