Science of the Total Environment 575 (2017) 276–286

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Environmental ambient temperature and blood pressure in adults: A systematic review and meta-analysis

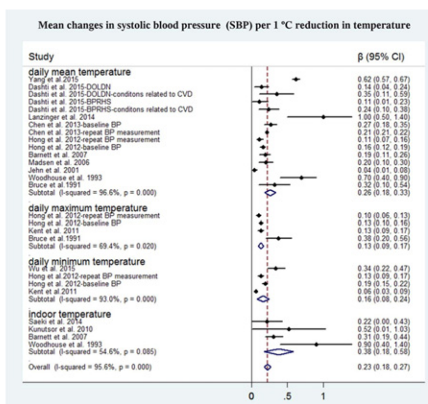
Qiong Wang [a,b], Changchang Li [a,b], Yanfang Guo [c], Adrian G. Barnett [d], Shilu Tong [d], Dung Phung [e], Cordia Chu [e], Keith Dear [f], Xuemei Wang [g,*], Cunrui Huang [a,b,e,**]

[a] *Department of Health Policy and Management, School of Public Health, Sun Yat-sen University, 74 Zhongshan 2nd Road, Guangzhou 510080, China*
[b] *Guangzhou Key Laboratory of Environmental Pollution and Health Risk Assessment, School of Public Health, Sun Yat-sen University, 74 Zhongshan 2nd Road, Guangzhou 510080, China*
[c] *Department of Chronic Disease Prevention, Bao'an Hospital for Chronic Disease Prevention and Treatment, 99 Wenwei Road, Shenzhen 518101, China*
[d] *School of Public Health and Institute of Health and Biomedical Innovation, Queensland University of Technology, 60 Musk Avenue, Brisbane, Queensland 4059, Australia*
[e] *Center for Environment and Population Health, School of Environment, Griffith University, 170 Kessels Road, Brisbane, Queensland 4111, Australia*
[f] *Global Health Research Center, Duke Kunshan University, Kunshan, Jiangsu 215316, China*
[g] *School of Atmospheric Sciences, Sun Yat-sen University, 135 Xingang Xi Road, Guangzhou 510275, China*

HIGHLIGHTS

- Lower ambient temperature would increase adults' blood pressure (BP).
- People with cardiovascular disease related conditions are more susceptible.
- Indoor temperature shows stronger effect on BP than outdoor temperature.
- Future research needs personal temperature exposure and ambulatory BP monitoring.
- Statistical methods should be improved for non-linear temperature-BP relationship.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 July 2016
Received in revised form 23 September 2016
Accepted 3 October 2016
Available online xxxx

Editor: D. Barcelo

ABSTRACT

Objective: Although many individual studies have examined the association between temperature and blood pressure (BP), they used different methods and also their results were somewhat inconsistent. The aims of this study are to quantitatively summarize previous studies and to systematically assess the methodological issues to make recommendations for future research.

Methods: We searched relevant empirical studies published before January 2016 concerning temperature and BP among adults using the MEDLINE, Embase and PubMed databases. Mean changes in systolic (SBP) and diastolic blood pressure (DBP) per 1 °C reduction in temperature were pooled using a random-effects meta-analysis.

Abbreviations: BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; PET, personal exposure temperature; ABP, ambulatory blood pressure; CVD, cardiovascular disease; CI, confidence interval; I2, statistic of inconsistency; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; NOS, Newcastle-Ottawa Scale; AHRQ, Agency for Healthcare Research and Quality; ARR, aldosterone renin ratio.

* Corresponding author.
** Correspondence to: C. Huang, Department of Health Policy and Management, School of Public Health, Sun Yat-sen University, 74 Zhongshan 2nd Road, Guangzhou 510080, China.
E-mail addresses: eeswxm@mail.sysu.edu.cn (X. Wang), huangcr@mail.sysu.edu.cn (C. Huang).

http://dx.doi.org/10.1016/j.scitotenv.2016.10.019

Keywords:
Meteorological factors
Cardiovascular disease
Mechanism
Meta-analysis
Methodology

Results: Of 23 studies included, 14 were used for meta-analysis. Consistent, statistically significant, inverse associations were observed between ambient temperature (mean, maximum, minimum outdoor temperature and indoor temperature) and BP. An 1 °C decrease in mean daily outdoor temperature was associated with an increase in SBP and DBP of 0.26 mm Hg (95% CI: 0.18–0.33) and 0.13 (95% CI: 0.11–0.16), respectively. The increase was greater in people with conditions related to cardiovascular disease. An 1 °C decrease in indoor temperature was associated with 0.38 mm Hg (0.18–0.58) increase in SBP, while the effects on DBP were not estimated due to limited studies. Among the previous studies on temperature-BP relationship, temperature and BP measurements are not accurate enough and statistical methods need to be improved.
Conclusions: Lower ambient temperatures seem to increase adults' BP and people with conditions related to cardiovascular disease are more susceptible to drops in temperature. Indoor temperature appeared to have a stronger effect on BP than outdoor temperature. To understand temperature-BP relationship well, a study combining repeated personal temperature exposure and ambulatory BP monitoring, applying improved statistical methods to examine potential non-linear relationship is warranted.

1. Introduction

Cardiovascular diseases (CVD) are the leading cause of death worldwide, with an estimated 17.5 million deaths in 2012, representing 31% of all global deaths (WHO, 2015) and will result in almost 23.6 million deaths by 2030 (Mendis et al., 2011). In many countries, CVD mortality is lower in summer and higher in winter (Schwartz et al., 2015; Wolf et al., 2009; Yang et al., 2015b). The association between ambient temperature and CVD mortality has been well described in numerous epidemiological studies (Analitis et al., 2008; Breitner et al., 2014; Claeys et al., 2016; Yang et al., 2012; Yang et al., 2015a; Yu et al., 2011; Zhang et al., 2014), showing V-, U- or J-shaped exposure-response curves. Understanding potential mechanisms which explain the strong association between temperature and cardiovascular events is of great importance for CVD prevention and treatment. Although the exact mechanisms are still debated, one likely mechanism is that changes in ambient temperature lead to changes in one or more cardiovascular risk factors (Schneider et al., 2008). Among these risk factors, blood pressure (BP) is an important intermediate marker of cardiovascular events (Ettehad et al., 2016; Gu et al., 2008; Mendis et al., 2011; Mensah et al., 2005), and elevation of blood pressure (BP) is thought to be the main risk factor for cardiovascular events (Jansen et al., 2001).

More than a dozen studies have examined the association between ambient temperature and BP (Alpérovitch et al., 2009; Brook et al., 2011b; Giorgini et al., 2015; Halonen et al., 2011; Hampel et al., 2011; Madsen and Nafstad, 2006; Wu et al., 2015; Yang et al., 2015b), most of which observed an inverse relationship although some studies did not find statistically significant associations (Brook et al., 2011b; Saeki et al., 2014). Among the studies with significant inverse association, the magnitude of temperature effects also varied, which may result from differences in study design, measurements of temperature and BP or demographic characteristics. Researchers have used different temperature measurements, including daily mean, maximum, and minimum temperature from weather stations, as well as indoor and personal exposure temperature (PET) to examine the effects on BP change (Chen et al., 2013; Dashti et al., 2016; Lanzinger et al., 2014b; Yang et al., 2015b). However, few studies have compared the effects of different temperature measurements (Barnett et al., 2007).

We also found no previous systematic review or meta-analysis on the association between environmental ambient temperature and blood pressure. In this study, we searched for epidemiological studies published in English, and used a meta-analysis to quantitatively evaluate the association between temperature and BP. Furthermore, we assessed the methodological issues among previous studies to identify knowledge gaps in this research field, and to make recommendations for future study.

2. Material and methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009).

2.1. Literature research

Relevant empirical studies examining the relationship between temperature and BP among adults were identified using the MEDLINE, Embase and PubMed databases. The search strategy is shown in Supplementary file. Studies published up to January 2016 (the date when the search was made) were considered. References in each identified paper were examined to check for papers missed in our electronic database searches.

2.2. Study eligibility

After removing duplicates, two researchers (QW and CL) independently screened titles and abstracts, and then assessed full records for eligibility. The following eligibility criteria were included in the final meta-analysis: (1) Longitudinal study with repeat BP measurement or cross-sectional study; (2) The subjects were adults aged over 18 years, because BP among children is quite different to that among adults; (3) The exposure measure was daily mean, maximum or minimum outdoor temperature, daily indoor temperature or personal-level exposure temperature, and the outcome was BP, including diastolic (DBP) and systolic blood pressure (SBP); (4) The reported results included the effect estimates associated with an increase or decrease of temperature, regression coefficients and corresponding standard error or 95% confidence intervals (CIs); (5) Where multiple publications came from the same study, we included the publication that considered the largest number of cases and/or that evaluated results based on the longest follow-up. Differences between reviewers were resolved by discussion.

The search procedure is shown as a PRISMA flowchart in Fig. 1.

2.3. Quality assessment and data extraction

The Newcastle-Ottawa Scale (NOS)-cohort study (Wells et al., 2013) was used to determine the quality of included longitudinal studies, and Cross-Sectional/Prevalence Study Quality Assessment Forms from the Agency for Healthcare Research and Quality (AHRQ) (Viswanathan et al., 2013) were used for cross-sectional studies. The quality assessment results are shown in Supplementary Table 1. All studies were included as we did not find clear evidence showing risk of bias.

For each eligible study, the following information was extracted into a standardized form: the first author's name, year of publication, study location, study period, study design, population size and features, age of subjects, temperature variables, blood pressure measurements, statistical method, covariates, and estimated BP change with temperature change.

Quality assessment and data extraction were conducted independently by two researchers (QW and CL), with differences resolved by discussion.