International Journal of Hygiene and Environmental Health 217 (2014) 775–784

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

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

Short-term effects of air temperature on blood pressure and pulse pressure in potentially susceptible individuals

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ARTICLE INFO

Article history:
Received 17 December 2013
Received in revised form 15 April 2014
Accepted 18 April 2014

Keywords:
Blood pressure
Epidemiology
Personal measurements
Pulse pressure
Temperature

ABSTRACT

Background: Only few epidemiological studies have investigated the association between air temperature and blood pressure (BP) or pulse pressure (PP), with inconsistent findings. We examined whether short-term changes in air temperature were associated with changes in BP or PP in three different populations.
Methods: Between March 2007 and December 2008, 371 systolic and diastolic BP measurements were collected in 30 individuals with type-2 diabetes mellitus (T2D), 30 persons with impaired glucose tolerance and 42 healthy individuals without a metabolic disorder from Augsburg, Germany. Hourly means of ambient meteorological data were obtained from a fixed measurement station. Personal temperature measurements were conducted using data loggers. Temperature effects were evaluated using additive mixed models adjusting for time trend and relative humidity.
Results: Decreases in air temperature were associated with an increase in systolic BP, diastolic BP and PP in individuals with T2D. For example, a 1 °C decrease in ambient temperature was associated with an immediate increase in systolic BP of 1.0 mmHg (95%-confidence interval: [0.5;1.4] mmHg). Effects of personally measured air temperature were similar. Temperature effects were modified by age, body mass index, gender, antihypertensive medication and whereabouts, such as being indoors.
Conclusions: We observed associations between decreases in air temperature and increases in BP as well as PP in persons with T2D indicating that these people might be potentially more susceptible to changes in air temperature. Our findings may provide a hypothesis for a mechanism between air temperature decreases and short-term increases of cardiovascular events.

Introduction

Cardiovascular diseases are known to be the leading cause of death in the world. The number of people who will die from cardiovascular diseases by 2030 is anticipated to be almost 23.6 million (Mendis et al., 2011). Studies have shown that even short-term changes in air temperature are associated with cardiovascular events (Brook et al., 2011). Associations have often been reported to be U-shaped showing an increased risk of cardiovascular events at higher as well as lower temperatures (Brook et al., 2011; McMichael et al., 2008). In a European study Analitis et al. (2008) observed a statistically significant short-term increase in cardiovascular mortality of 1.72% in association with a 1 °C decrease in the 15-day average temperature. Moreover, researchers detected a short-term increased risk of myocardial infarctions at higher and lower temperatures (Bhaskaran et al., 2009; Wolf et al., 2009). Finding the underlying biological mechanisms which explain the relationship between air temperature and acute cardiovascular effects remains a major challenge. One possible mechanism could be that short-term increases and decreases in temperature lead to changes in the autonomic function, which may result in changes in blood pressure (BP) (Hanna, 1999). Elevated BP is an established risk factor for coronary heart disease and stroke (MacMahon et al., 1990). Furthermore, it is an important intermediate marker of cardiovascular health (Mendis et al., 2011). Several studies have so far observed an inverse association between air temperature and BP showing an increase in BP with a decrease in air temperature (Alperovitch et al., 2009; Brook et al., 2011; Halonen et al., 2010; Hampel et al.,

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http://dx.doi.org/10.1016/j.ijheh.2014.04.002
1438-4639/

2011; Madsen and Nafstad, 2006). Halonen et al. (2010) reported that a 5 °C decrease in apparent temperature led to a 0.78%(95%-confidence interval (CI): [0.17%;1.39%]) increase in systolic BP (SBP) and to a 0.94%[0.36%;1.52%] increase in diastolic BP (DBP) with a lag of five days in elderly men. Hampel et al. (2011) observed for a 10 °C decrease in air temperature an immediate increase in SBP by 0.5%[0.1%;1.0%] among pregnant woman. However, some studies have also reported no associations (Alperovitch et al., 2009; Halonen et al., 2010; Hampel et al., 2011).

It has also been shown that pulse pressure (PP) is linked to changes in temperature (Adamopoulos et al., 2010; Brook et al., 2011). PP is defined as the difference between SBP and DBP and is a marker of arterial stiffness (Franklin et al., 1999; O'Rourke and Frohlich, 1999). It is important to consider PP as an independent predictor for cardiovascular events due to the age-related changes in BP and PP (Franklin et al., 1997, 1999; O'Rourke and Frohlich, 1999), especially in middle-aged and elderly individuals (Franklin et al., 1999). Adamopoulos et al. (2010) detected a relation between mean daily temperature and PP; consequently, cardiovascular events associated with changes in air temperature could also be triggered by changes in PP.

Individuals with chronic conditions like diabetes mellitus have been reported to be at greater risk of cardiovascular events (Lüscher et al., 2003; Oakley and Emond, 2011). Moreover, it is assumed that people with diabetes mellitus are especially susceptible to changes in air temperature (Hoffmann et al., 2011; Schwartz, 2005). Schwartz (2005) pointed out that diabetic individuals are more sensitive to temperature extremes than other individuals. Accordingly, the objective of our analyses was to investigate short-term effects of ambient as well as personally measured air temperature on BP and PP in individuals with type-2 diabetes mellitus (T2D), individuals with impaired glucose tolerance (IGT), a pre-diabetic state, and in apparently healthy individuals. Based on the above mentioned studies we expected an increase in BP and PP in association with a decrease in air temperature.

Methods

Study design and study population

As part of the University of Rochester Particulate Matter Center investigations, a prospective panel study was conducted in Augsburg, Germany, between March 19th 2007 and December 17th 2008. The primary objectives were to examine the effects of ambient fine and ultrafine particles on acute phase reaction in the blood, pro-thrombotic states of the blood, endothelial function of small arteries, cardiac rhythm and BP. The study consisted of three different subgroups: (1) individuals with T2D, (2) individuals with IGT indicating an enhanced risk of T2D yet without medication and (3) apparently healthy participants with a potential genetic susceptibility on the detoxification or inflammation pathways but without a metabolic disorder. Individuals were recruited from the KORA (Cooperative Health Research in the Region of Augsburg) cohort between 2006 and 2008 (Holle et al., 2005). T2D was diagnosed by a physician, by typical medication use, or by an oral glucose tolerance test (OGTT) with a fasting glucose level > 125 mg/dl or a 2 h OGTT glucose level ≥200 mg/dl. IGT was specified as 2 h OGTT glucose levels ≥140 mg/dl but <200 mg/dl. Information on demographics, medication, health and smoking status was assessed using questionnaires. Persons with the following characteristics were excluded from the study: (1) smoking during the last 12 months, (2) anticoagulant intake, (3) a myocardial infarction and/or interventional procedure (balloon dilatation, bypass surgery) during the last six months before the start of the study, (4) atrial fibrillation and (5) chronic inflammatory disease, such as Crohn's disease.

All study participants gave written informed consent. The study protocol was approved by the Ethics Commission of the Bavarian Chamber of Physicians ("Bayerische Landesärztekammer").

Clinical measurements

Individuals were invited to participate in up to four repeated visits, scheduled every four to six weeks. Visits were scheduled on the same weekday and approximately the same time of the day for each participant. BP measurements took place in the early afternoon directly after the interview and in the same room as the interview. The participant was in a seated position throughout the interview. SBP and DBP were assessed once in each visit using a digital BP monitor (HEM 705 CP, OMRON HEALTHCARE GmbH). BP was measured on the right arm while the participant was in a seated position. Only participants with at least two valid BP measurements were included in the analyses. In some cases, only one BP measurement was available due to refusal of additional measurements or illness of the respective persons. PP was calculated as the difference between SBP and DBP.

Ambient meteorological and air pollution measurements

Ambient meteorological and air pollution data were measured at a fixed monitoring site in the urban background on an hourly basis throughout the whole study period. Data on air temperature, relative humidity, barometric pressure, as well as mass and number concentrations of particulate air pollution were provided by the measurement station (Pitz et al., 2008). Hourly means of ozone were provided by a monitoring site operated by the Bavarian Environment Agency (Bayerisches Landesamt für Umwelt). For ozone concentrations, we calculated maximum 8-hour moving averages. If at least two-thirds of the hourly measurements were available, individual 24-hour averages of meteorological variables and air pollutants were calculated before each visit. Hence, we calculated 24-hour averages of meteorological variables and air pollutants directly preceding the BP measurements (lag 0). Averages of 24–47 hours (lag 1), 48–71 hours (lag 2), 72–95 hours (lag 3), 96–119 hours (lag 4) before the BP measurement and a 5-day average (lag 04) were also calculated and taken into consideration. In addition to the 24-hour averages, we calculated 6-hour averages directly preceding the visits.

Personal air temperature measurements and activity diary

The participants were equipped with a personal temperature measurement device (Tinytag II data logger [Gemini, part number: 9904-0015]). Personal measurements were conducted during the four to six hours before the BP measurement. Hence, about five hours of personal temperature measurements were available for each visit. To get information on the whereabouts before the visits, the participants were asked to fill in an activity diary. Accordingly, information on the percentage of time spent indoors or outdoors while carrying the data logger was provided by the activity diary.

Statistical analyses

Demographics, smoking habits, disease status, medication, whereabouts and season were compared between participants with T2D, IGT and healthy individuals. Analysis of variance (ANOVA) was used for continuous variables and chi-squared test for categorical variables, respectively. Fisher's exact test was used in case the number of observations in a category was smaller than five. Furthermore, we calculated mixed models with a random participant effect including dummy variables for the group effect in order to compare SBP, DBP and PP values between the three