Physiology & Behavior 149 (2015) 203–211

Contents lists available at ScienceDirect

Physiology & Behavior

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

Daytime variation in ambient temperature affects skin temperatures and blood pressure: Ambulatory winter/summer comparison in healthy young women

Antonio Martinez-Nicolas [a], Martin Meyer [b], Stefan Hunkler [b], Juan Antonio Madrid [a], Maria Angeles Rol [a], Andrea H. Meyer [c], Andy Schötzau [d], Selim Orgül [d], Kurt Kräuchi [b,*]

[a] Chronobiology Laboratory, Department of Physiology, Faculty of Biology, University of Murcia, 30100 Murcia, Spain
[b] Thermophysiological Chronobiology, Centre for Chronobiology, Psychiatric Hospital of the University of Basel, Switzerland
[c] Department of Psychology, Division of Clinical Psychology and Epidemiology, University of Basel, Switzerland
[d] Department of Ophthalmology, University of Basel, Switzerland

HIGHLIGHTS

- Ambient temperature changes induce alterations in distal skin temperature.
- Short-term changes in distal skin temperature and blood pressure are associated.
- Seasonal changes in distal skin temperature and blood pressure are not correlated.

ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form 8 June 2015
Accepted 9 June 2015
Available online 11 June 2015

Keywords:
Ambulatory blood pressure monitoring
Distal skin temperature
Proximal skin temperature
Personal-level environmental temperature
Path analysis
Outdoor exposure

ABSTRACT

It is widely accepted that cold exposure increases peripheral vascular resistance and arterial blood pressure (BP) and, hence, increases cardiovascular risk primarily in the elderly. However, there is a lack of concomitantly longitudinal recordings at personal level of environmental temperature (PET) and cardiophysiological variables together with skin temperatures (STs, the "interface-variable" between the body core and ambient temperature). To investigate the intra-individual temporal relationships between PET, STs and BP 60 healthy young women (52 completed the entire study) were prospectively studied in a winter/summer design for 26 h under real life conditions. The main hypothesis was tested whether distal ST (T_{dist}) mediates the effect of PET-changes on mean arterial BP (MAP).

Diurnal profiles of cardiophysiological variables (including BP), STs and PET were ambulatory recorded. Daytime variations between 0930 and 2030 h were analyzed in detail by intra-individual longitudinal path analysis. Additionally, time segments before, during and after outdoor exposure were separately analyzed.

In both seasons short-term variations in PET were positively associated with short-term changes in T_{dist} (not proximal ST, T_{prox}) and negatively with those in MAP. However, long-term seasonal differences in daytime mean levels were observed in STs but not in BP leading to non-significant inter-individual correlation between STs and BP. Additionally, higher individual body mass index (BMI) was significantly associated with lower daytime mean levels of T_{prox} and higher MAP suggesting T_{prox} as potential mediator variable for the association of BMI with MAP.

In healthy young women the thermoregulatory and BP-regulatory systems are closely linked with respect to short-term, but not long-term changes in PET. One hypothetical explanation could serve recent findings that thermogenesis in brown adipose tissue is activated in a cool environment, which could be responsible for the counter-regulation of cold induced increase of BP in winter leading to no seasonal differences in MAP.

Our findings suggest that the assessment of diurnal patterns of STs and PET, in addition to the conventional ambulatory BP monitoring, might improve individual cardiovascular risk prediction.

Abbreviations: T_{dist}, distal skin temperature; T_{prox}, proximal skin temperature; PET, personal-level of environmental temperature; ST, skin temperature; BP, blood pressure; DBP, distal blood pressure; MAP, mean arterial blood pressure; SBP, systolic blood pressure; BAT, brown adipose tissue; SOL, sleep onset latency.

* Corresponding author at: Thermophysiological Chronobiology, Centre for Chronobiology, Psychiatric Hospitals of the University of Basel, Wilhelm Klein Strasse 27, 4012 Basel, Switzerland.

E-mail address: kurt.kraeuchi@upkbs.ch (K. Kräuchi).

http://dx.doi.org/10.1016/j.physbeh.2015.06.014
0031-9384/

1. Introduction

There is a higher mortality and incidence of vascular diseases including e.g. stroke, coronary ischemic events and heart failure in the general population (most pronounced in elderly) during winter than in other seasons [1–5]. The underlying mechanisms are not fully understood, however adverse effects of thermoregulatory adjustments seem to play an important role. For example, physiological, observational and epidemiological research has shown that cold exposure leads to cutaneous vasoconstriction with subsequent centralization of blood, increased cardiac preload, a rise in blood pressure (BP) and hemoconcentration [3,5,6].

The thermophysiological core/shell model developed by Aschoff [7] provides a possible explanation for the findings described above. In a cool environment the shell is large (relatively cool) and protects the core body against a rapid cooling (centralization of blood). In a warm environment, as well as during sleep, the shell is small (relatively warm) and the body loses its two-compartment system and is prone to cool [8]. Distal skin regions (e.g. hands, feet; belonging to the shell) are particularly suitable to lose body heat thanks to their physiological (abundant arteriovenous anastomoses) and physical (high surface to volume ratio) properties. Diverse controlled physiological and pharmacological laboratory studies have shown that changed distal skin temperature (T_{dist}) in relation to proximal skin temperature (T_{prox}) is associated with changes in core body temperature and body heat loss [7,9–12]. Furthermore, the difference between T_{dist} and T_{prox} has been validated as a measure for distal skin blood flow by plethysmographic and laser-Doppler-flowmetry methods [13–15], e.g. with lowered environmental temperature distal skin regions exhibit larger reduction in skin temperature (ST) and skin blood flow than proximal sites indicating redistribution of shell blood to the core [13,15]. Using wireless ST probes [16] T_{dist} and T_{prox} measurements easily provide information about the thermophysiological state of the human body also under ambulatory conditions, i.e. lower T_{dist} in relation to T_{prox} is indicative of a larger shell [8].

The relationship between ambient temperature and BP has mostly been studied in a cross-sectional design, however, for more accurate and reliable information longitudinal studies are needed [4]. In spite of the convincing amount of evidence for the influence of cold ambient temperature on BP it is amazing that in most studies BP measurements were compared only with outdoor environmental air temperature data provided by meteorological institutes. This shortcoming can be easily improved by direct personal-level environmental temperature recording (PET) [4,17,18]. Because of the obvious relationship that PET affects the body's physiology via the skin, it is a logical step to include also ST (the “interface-variable” between body core and ambient temperature) measurements with respect to ambient temperature induced changes in BP. Including ST measurements can further improve the understanding about mechanisms how changes in PET are transformed to changes in BP.

In a recent study under structured ambulatory conditions it could be shown that mean arterial BP exhibits an inverse 24 h pattern to STs most pronounced in distal skin regions in relation to proximal skin regions [19,20]. Unfortunately, no direct measurements of PET were recorded preventing detailed analyses and interpretation with respect to temporal changes in PET and its association with STs and BP.

The main objective of this prospective ambulatory study with healthy young women was to test the hypothesis whether the temporal association between PET and BP is mediated via T_{dist}, and whether this relationship is different in winter and summer. Healthy young women were chosen, first, because they are particularly sensitive to cool environment [21,22] and second, it could be expected that in the same subject acute outdoor effects can be found in BP, but not long-term seasonal effects [2,4]. Using a multivariate approach including diverse variables, e.g. PET, T_{dist} and BP, the comparison of intra-individual difference between acute and long-term effects could disclose possible mechanisms to explain why seasonal differences in BP are not present in younger subjects. In a first step potential seasonal differences in diurnal patterns of the measured variables and their interrelationships were analyzed. This approach includes day–night comparisons allowing one to specify whether environmental influences on STs and BP are dependent on time of day. In a further step daytime variation in the variables between 0930 and 2030 h were compared within subjects followed by a detailed analysis of outdoor effects. Furthermore, the present study should serve as database to compare future subject groups including e.g. men and elderly.

2. Methods

2.1. Study population and design

The study, including all experimental procedures and the informed consent form, has been approved by the local ethics committee (Ethikkommission beider Basel). Before admission to the study, each subject signed an informed consent form and was explicitly informed that she could stop the study at any time. However, none complained about the study and all subjects who did not complete the study did so for scheduling reasons.

Sixty healthy female residents (age: 25.0 ± 0.6) of the city of Basel (Switzerland) including rural agglomeration fulfilled the defined exclusion/inclusion criteria (Table 1) and were studied in a winter vs. summer design during 26 h. In order to obtain a study sample comprising a high variance with respect to STs women with (N = 32) and without (N = 28) thermal discomfort with cold extremities were selected [19].

Subjects were recruited via an announcement in an internet platform of the University of Basel informing potential volunteers about the opportunity to participate in a scientific research project. The screening questionnaire including the inclusion/exclusion criteria questions of Table 1 was sent to 394 potential study subjects, 194 sent the questionnaire back. Of the sixty study subjects, 39 women started in winter (02/12/11–09/03/12) and finished in summer (04/06/12–12/09/12), and 21 women started in summer (04/06/12–12/09/12) and finished in winter (04/12/12–14/03/13). Fifty-two subjects completed the entire study, six dropped out after winter 2011/2012 and two after summer 2012.

In order to get a more homogenous group of women with respect to female sex hormones, women without contraceptives and with regular menstrual cycle were studied during their luteal phase. This phase was defined as the interval between day 14 and the end of the menstrual cycle. 25 women with and 35 without taking contraceptives were studied. All subjects were asked to maintain their normal daily activities and sleep wake schedules, however, without sporting activities and not taking a shower or a bath.

Table 1
Exclusion criteria.

Exclusion criteria are defined as follows
• Age < 20 and >35 yr • Body mass index (BMI) < 18 kg/m^2 and >28 kg/m^2. • Acute or chronic mental or physical disease. • Nickel or other skin allergies. • Medication in the last month, except contraceptives. • Irregular menstrual cycle (>±2 days). • Shiftwork within 3 months or transmeridian travel within 1 month before the study begin. • Pregnancy (pregnancy test was performed before study begin). • Smoking, not abstinent at least for 3 months. • Drug consumption. • Excessive caffeine (≥5 cups/day) or alcohol consumption (>1 glass unit/day). • Excessive sporting activities (>3 days per week). • Not to experience thermal discomfort with cold extremities or not to be a control subject usually perceiving during winter according to [24].