Seasonal cold and circadian changes in blood pressure and physical activity in young and elderly people

James Goodwin, Vaughan R. Pearce, Rod S. Taylor1, Ken L. Q. Read2, Stephen J. Powers3

School of Postgraduate Medicine and Health Sciences, University of Exeter, Barrack Road, Exeter EX2 5DW, UK
1Health Services Research Unit, London School of Hygiene and Tropical Medicine, London, UK
2School of Mathematics, University of Exeter, Exeter, UK
3Long Ashton Research Station, Bristol, UK

Address correspondence to: J. Goodwin, Fax: (+44) 1392 435 357. Email: j_goodwin@exeter.ac.uk

Abstract

Aim: to test the hypothesis that there is no association between seasonal cold and the circadian responses of blood pressure, deep-body temperature and physical activity in healthy young and elderly men.

Methods: 25 healthy elderly (aged 70–82 years) and 21 young volunteers (aged 20–30 years) participated in a 3-year prospective cross-seasonal study.

Results: ambulatory day-time blood pressures in the older men were higher in the winter than in the summer and higher in both seasons than in the young people. The seasonally related differences were associated with lower outdoor and indoor temperatures, lower body temperature and higher activity levels in the elderly group in the winter. The older but not the younger group had higher blood pressure and levels of physical activity at certain times of the day in the winter compared with the summer.

Conclusion: time-of-day winter increases in blood pressure in older people may be related to increased activity as well as to levels of ambient temperature. Although it is generally advantageous for older people to be physically active in order to prevent circulatory disease, there may be a rationale for advising that they should avoid intense activity at certain times of the day, especially in the winter.

Keywords: ambulatory blood pressure, activity, circadian rhythm, elderly, seasonal cold

Introduction

Previous studies on normotensive elderly and young subjects have found little difference in diurnal blood pressure variation, but variations in circadian blood pressure are reported to be much diminished in elderly patients with arteriosclerotic vascular disease [1, 2]. There may be seasonal effects on the diurnal variation in blood pressure in the two age groups. This issue is important because some previous investigations have shown blood pressure to be higher in the winter than in the summer in elderly but not in young people [3–5]. Studies have also implied a possible causative role of increased blood pressure in the higher numbers of strokes and heart attacks in the winter [6, 7]. There is also evidence of a distinct circadian variation in the occurrence of acute cardiovascular illnesses, such as stroke and myocardial infarction [8–10].

Some authors have sought to explain the higher winter blood pressure in elderly people by attributing it to decreased physical fitness due to reduced physical activity in the winter [11]. Indeed, older people appear to have lower levels of (self-reported) physical activity in the winter [5], although reports which have measured activity levels objectively are infrequent [12, 13], as are studies of seasonal variation of the circadian rhythm of activity. In addition, lower deep-body temperatures have been associated with increases in blood pressure in elderly people in cold conditions, as has cold exposure of the face and hands [14, 15].

Daytime resting deep-body temperature has been shown to be the same in young and old people in thermoneutral conditions in previous circadian studies
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[1], but elderly people appear to be less able to defend their internal temperature or that of their extremities against a cold threat [1]. Therefore in this study we tested the hypothesis that there is no association between seasonal cold and the circadian responses of blood pressure, deep-body temperature and physical activity in healthy young and elderly men.

Methods

Subjects

The subjects were all healthy, medically screened volunteers: 21 young men (mean age 23.5, range 20–30 years) and 25 older men (mean age 73.6, range 70–82 years). Physical characteristics are shown in Table 1. Approval for the investigation was given by the ethics committee of the Royal Devon and Exeter Hospital and signed consent was obtained from each subject. One older subject withdrew for medical reasons during the study, reducing the final number in this group to 24.

Design

Two groups took part in the investigation, which was designed as a between-seasons cross-over study. We collected data from one subject group in the order winter–summer–winter and from the other group in the order summer–winter–summer. We defined winters as the period from 1 January to 31 March and summers from 1 July to 30 September. Each season was numbered consecutively—i.e. winter 1, winter 2, summer 1, summer 2. To prevent an order effect, we randomized young and old subjects to each cross-over group. We took measurements from each subject on 1 day (24 h) during each season, so that consecutive individual sampling took place over the 3 months of each season.

Measurements

Subjects reported at about the same time of day for instrumentation, not having exerted themselves before arrival, nor having exposed themselves unduly to cold air (in the winter) and having drunk liberally in order to provide a urine sample. We calculated body fat percentage from skinfold thicknesses [15]. Ambulatory systolic and diastolic blood pressure were measured using an automatic monitor (Accutrack II, Suntech, Raleigh, NC, USA), sampling every 15 min randomly over the 24-h period. We measured physical activity each minute using an accelerometer (Gaehwiler, Hombrechtkon, Switzerland). Urine temperature was measured throughout the 24-h period (several samples per subject per day) by the Uritemp method [17]. Subjects went about their normal activities of daily living during the measurement period.

Environmental temperatures were measured in the home by a portable ‘Squirrel’ logger (Grant Instruments, Cambridge, UK) in the living room by day and the bedroom by night. We obtained outdoor temperatures from the local meteorological station.

Statistical analysis

All data were tested for normality (Anderson–Darling test). The skew distribution of the raw activity data was brought to normality by a logarithmic transformation. Data were then analysed by parametric methods. Univariate statistical comparisons were made using two-sample t-tests for different age groups and paired t-tests for within-group data with a view to obtaining greater power. A pre-analysis α-level of 0.05 (two-tail) was set as a criterion of significance.

Results

Physical characteristics

The anthropometric data show some significant differences between the young and older men which persisted across all seasons of the study (Table 1). The elderly group were shorter (P≤0.01) and had a higher body fat content (P≤0.05) but were no different in body mass.

Table 1. Physical characteristics of young and elderly subjects in summer and winter, with levels of significance of difference between seasons

<table>
<thead>
<tr>
<th></th>
<th>Young (n=21)</th>
<th>Elderly (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean value ± SD</td>
<td>Mean value ± SD</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.781 ± 0.054</td>
<td>1.781 ± 0.054</td>
</tr>
<tr>
<td>Mass, kg</td>
<td>73.45 ± 9.91</td>
<td>74.84 ± 9.7</td>
</tr>
<tr>
<td>Body mass index</td>
<td>23.12 ± 2.51</td>
<td>23.57 ± 2.43</td>
</tr>
<tr>
<td>% body fat</td>
<td>18.63 ± 3.36</td>
<td>19.36 ± 3.88</td>
</tr>
</tbody>
</table>

aWinter versus summer; α = 0.05.

bSignificant difference (P≤0.05) between young and elderly.

NS, non-significant.
**Table 2. Day-time ambulatory blood pressure, activity and temperature data for young and elderly subjects in winter and summer and levels of significance of difference between age groups**

<table>
<thead>
<tr>
<th></th>
<th>Winter 1</th>
<th></th>
<th>Summer 1</th>
<th></th>
<th>Winter 2</th>
<th></th>
<th>Summer 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Elderly</td>
<td></td>
<td>Young</td>
<td>Elderly</td>
<td></td>
<td>Young</td>
<td>Elderly</td>
</tr>
<tr>
<td></td>
<td>(n=10)</td>
<td>(n=12)</td>
<td>P</td>
<td>(n=21)</td>
<td>(n=24)</td>
<td>P</td>
<td>(n=11)</td>
<td>(n=12)</td>
</tr>
<tr>
<td>Blood pressure, mmHg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>129 ± 9</td>
<td>145 ± 15</td>
<td>≤ 0.01</td>
<td>127 ± 9</td>
<td>136 ± 14</td>
<td>≤ 0.05</td>
<td>130 ± 9</td>
<td>139 ± 11</td>
</tr>
<tr>
<td>Diastolic</td>
<td>69 ± 4</td>
<td>78 ± 7</td>
<td>&lt; 0.01</td>
<td>73 ± 6</td>
<td>81 ± 9</td>
<td>&lt; 0.01</td>
<td>73 ± 9</td>
<td>76 ± 6</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine</td>
<td>36.66 ± 0.12</td>
<td>36.5 ± 0.14</td>
<td>NS</td>
<td>36.7 ± 0.11</td>
<td>36.7 ± 0.13</td>
<td>NS</td>
<td>36.7 ± 0.12</td>
<td>36.7 ± 0.10</td>
</tr>
<tr>
<td>Indoor³</td>
<td>17.4 ± 3.2</td>
<td>17.2 ± 0.7</td>
<td>NS</td>
<td>20.0 ± 1.5</td>
<td>18.3 ± 2.1</td>
<td>NS</td>
<td>22.0 ± 2.4</td>
<td>20.0 ± 1.7</td>
</tr>
<tr>
<td>Outdoor⁴</td>
<td>4.8 (−4.3 to 9.3)</td>
<td>14.9 (10.4 to 20.0)</td>
<td>NS</td>
<td>5.6 (−0.2 to 9.3)</td>
<td>16.3 (9.6 to 24.2)</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*α=0.05; NS, non-significant.

³Day-time living room temperature.

⁴24-h dry bulb temperature (range).

**Discussion**

Most previous studies have shown that older people have raised blood pressure in the winter compared with the summer even after age correction. These studies
discussed above were consistent with that finding. However, no seasonal differences in mean 24-h systolic and diastolic blood pressure were found. Further, the mean 24-h systolic and diastolic blood pressure was highest in the winter and lowest in the summer. The systolic and diastolic blood pressure in the elderly was consistently higher in the winter and lower in the summer than in the young group.

**Circadian rhythms**

The blood pressure data for both groups showed a typical circadian variation with a lower value in the daytime than in the nocturnal period. The systolic and diastolic blood pressure in the elderly was consistently higher in the winter and lower in the summer than in the young group.

**Seasonal cold and circadian changes in blood pressure and temperature**

Both systolic and diastolic blood pressure were significantly higher in the winter than in the summer. The mean 24-h systolic and diastolic blood pressure in the winter was significantly higher in all sessions (P<0.05; Table 2). Further, the mean temperature data showed no significant difference between the mean temperature in the winter and summer. The mean temperature in the winter was significantly lower in all sessions compared with that in the summer. The mean temperature in the winter was significantly lower in the elderly group compared with that in the young group.
Figure 1. Circadian rhythms of systolic blood pressure and activity in a elderly men (n=24) and b young men (n=21) in summer 1 and winter 2. Level of significance of seasonal difference for older men: P<0.05; ▲ point of significant difference.

are consistent with the data presented here which are highly representative ambulatory data and which may be construed as being largely free of ‘one-off’ situational effects, such as white-coat hypertension [19, 20].

The nocturnal data are particularly important. They show that there was not a generalized winter elevation of blood pressure in healthy, aged individuals over the whole of the 24-h period; rather, winter differences were restricted to the waking hours. This suggests that the raised winter pressures in the older group may have been related to waking activity. Whilst it is inappropriate to assert causality, it is conceivable that there were pressor-inducing interactions between exposure to cold and activity levels in the elderly group. This requires further research.

In both groups, changes in the circadian rhythm of blood pressure were paralleled by changes in the level of physical activity, seen particularly in the early morning. Whereas blood pressure (and heart rate) exhibit a marked circadian variation linked to the individual rest activity pattern [21, 22], the seasonal differences in older men’s blood pressure indicated in this study do not appear to have been previously reported.

The circadian variation of acute cardiovascular illness has been associated with concurrent elevations of blood pressure, particularly during the morning and early evening [9, 10]. Given the findings of this study, it may be that elderly people are at potentially greater risk with significantly higher morning blood pressure in the winter compared with the summer. Other evidence has shown that there is a strong association between ‘external triggers’ and the onset of sudden cardiac death, beyond that which is due to chance alone [23, 24]. Physical exertion is one of the most potent ‘triggers’; electrocardiogram data reveal an increased occurrence of transient ischaemic episodes and increased myocardial demand during the morning onset of activity [25]. Physical activity measures are shown here to be higher in the morning in winter than in summer, in the older group but not in the young group. Physical activity generally, and a high level of aerobic fitness, are beneficial to health [26], lowering resting blood pressure and notably reducing the risk of mortality from cardiovascular disease.

Interestingly, in this study, at certain times of the day in the winter the elderly men had significant increases in blood pressure, which coincided with raised levels of activity. The average risk of thrombotic events is apparently lower in habitually active than in sedentary men, but the rate of sudden death during vigorous activity in the former group is higher than the average
Seasonal cold and circadian changes in blood pressure

![Graph](image)

Figure 2. Circadian rhythms of deep-body temperature in a young \((n=21)\) and b elderly men \((n=24)\), in summer 1 (—) and winter 2 (——).

rate in the latter [27]. Although it is advantageous for older people to be physically active in order to prevent circulatory disease, there may be a rationale for advising that they should avoid intense activity at certain times of the day—especially in the winter—and should moderate their unprotected outdoor excursions into the cold.

Hitherto, most studies of seasonal differences in blood pressure have ascribed a central role to the effects of cold, acting primarily through the sympathetic nervous system [3, 7, 18, 28]. There are also some reports that the level of salt intake and body weight gain during winter correlate with blood pressure elevation [5, 32–34]. The summer data collected here corroborate previous reports which indicate that in the thermoneutral environment, there is no apparent age-related difference in the circadian deep-body temperature [1]. However, the winter fall in body temperature we observed in this study is most probably due to age-related changes in the thermoregulatory system which render older people less able to defend themselves against a cold threat [29].

Indoor and outdoor temperatures were considerably lower in the winter than in the summer, and we have previously shown that these elderly men made no substantial changes to their excursional behaviour between winter and summer [30]. There is additional evidence [7, 31] to suggest that even brief exposure to outdoor (or indoor) winter cold can evoke pressor responses. After prolonged exposure, reduced core temperatures have been strongly associated with raised systolic and diastolic pressures [14], at the levels of winter blood pressure measured in the elderly men in this study.

The implications for the wider elderly population who may be at greater risk of arterial disease are less clear. Whether the cold pressor effect can be seen in elderly hypertensives, for example, is not well studied. There are some limited ambulatory data to show that winter blood pressure in elderly hypertensives is higher than in the summer [35] and that their orthostatic reflexes are less pronounced in the winter [36]. Similarly, there is a dearth of objective data on the activity levels of higher risk groups. These issues require further research to establish whether the tentative conclusions reached in this study may be applied to the elderly population at large.

Key points
- In a group of healthy elderly men, but not in a younger group, ambulatory blood pressure was higher at certain times of the day in the winter than in the summer.
- The winter circadian elevations of blood pressure were coincident with increases in level of activity.
- While body temperature in the elderly group was significantly lower in the winter than in the summer, there was no difference between the two age groups in the summer.
- Reduced body temperature due to cold stress experienced by this group of elderly people may play a role in the winter elevation of blood pressure.
- Although it is advantageous for older people to be physically active in order to prevent circulatory disease, there may be a rationale for advising that they should avoid intense activity at certain times of the day, especially in the winter, and that they should moderate their unprotected excursions into the cold.

Acknowledgements

The authors wish to thank Suntech, Raleigh, NC, USA for their technical support during this study. This
research was supported by generous grants from the Northcott Medical Foundation, Devon, UK, and the University of Exeter, UK.

References


Received 15 June 2000; accepted in revised form 5 March 2001