Original Article

Factors affecting seasonal changes in blood pressure in North India: A population based four-seasons study

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1. Introduction

Weather considerably influences cardiovascular health. It is a well-known phenomenon that cardiovascular morbidity and mortality increases during winter.\(^1\) This observation is attributed to multiple physiological changes that occur during winter, such as increased sympathetic activity, alteration in the coagulation profile, endothelial dysfunction, and increased blood pressure (BP).\(^2,3\)

Of various weather parameters such as temperature, relative humidity, frost, and sunshine, outdoor temperature is the most important determinant of BP fluctuation and is inversely correlated with BP.\(^4\) Studies have shown that BP increases with decrease in temperature.\(^4,12\) The climatic conditions in tropical areas are considerably different from those in temperate areas, with extremely hot summers and near zero temperatures during winters, resulting in an unusually large seasonal variation in temperature. In addition to geographical location, many other factors affect the strength of the association between temperature and BP in low-middle income countries such as India. A considerable proportion of the population consists of manual laborers and farmers who work in natural outdoor conditions. Housing conditions (lack of central heating) and other known risk factors of hypertension (obesity, age and social stress) are different as compared to western countries, which can modify the effect of season on BP.\(^5\)

Despite being one of the most populous areas of the world, no adequately powered community-based study has been conducted in Asia in out-of-clinic settings, evaluating the effect of
temperature variation on BP within same subjects in general population. Thus, we conducted a community-based longitudinal study involving subjects from both rural and urban areas. The aim of this study is to determine within-subject fluctuation in BP in out-of-clinic settings in native surroundings (either home or workplace) for evaluating the effect of change in season and outdoor temperature on BP.

Recently, it was also reported that seasonal variations are more marked in rural areas. Since two-third population of India resides in villages, the current analysis was done to see rural urban difference and other factors affecting seasonal variation in BP.

2. Material and methods

This was a community based prospective longitudinal study conducted in rural and urban areas of Ludhiana, Punjab. The state of Punjab is located in the north west of India. The latitude and longitude of Ludhiana city are 30°55′N and 75°54′E which is shown in Fig. 1. Rural areas included six villages (Jaghera, Jhammat, Lehra, Sahara Majra, Pohir and Rurka) of field practice areas of Rural health training center of Department of Community Medicine, Dayanand Medical College & Hospital, Ludhiana. All the villages are located within 20–40 kms geographical distance from the urban area. Majority of the population in rural area belonged to farming community. Population in urban areas comprised of manual laborers in factories, officers, teachers and technical staff in agricultural university and school. Study population consisted of both the sexes with age group of 18 years and above.

Enrollment of the subjects was started in summer season. The same subjects were followed for 4 seasons: summer season (May, June), Post-monsoon season (September, October) and Winter season (December, January) and Spring (March, April). These months were chosen based on observed temperature variation in different months in north India as per the Indian Meteorological Department (IMD). Coldest months are December and January. The severe cold wave conditions abate as temperature starts declining during February. March and April represent a transition period from extreme cold weather to hot weather. May and June are the hottest months of the year. Temperature starts falling during post monsoon season. Hence, September and October are the months when transition to winter season starts occurring.

The demographic characteristics of subject viz. age, gender, education were recorded on a predesigned performa. Occupation based physical activity, smoking and alcohol consumption were also noted.

BP was recorded using standard protocol by the three experienced and trained nurses using sphygmanometer. BP was recorded indoor in the native surroundings either home or work place between 9 am to 2 pm. It was assured that subjects were sitting in a comfortable setting with no consumption of caffeine in preceding one hour or smoking in preceding 15 min. BP devices were regularly calibrated. BP was recorded twice in right arm, in the sitting position. An average of two readings (recorded 5 min apart) was used for analysis. After the BP measurement, weight, height and waist hip ratio was measured during each season. Obesity was defined as body mass index ≥ 25 kg/m² as per the consensus statement of Asian classification.

A preliminary report of this study was published earlier. Now, we are reporting the sub group analysis of the total subjects who had completed follow up of four seasons as defined above. A total of 978 eligible subjects were included in the current analysis.

All the subjects were informed regarding the procedures and objectives after the study. A written informed consent was
obtained. The study was approved by institutional ethics
committee.

3. Meteorological data

Data about temperature was provided by local agency of
National Weather Service, PAU, Ludhiana. Mean temperature
degree Celsius \pm standard deviation recorded in summer, post
monsoon, winter and spring seasons were 30.93 \pm 3.82,
26.94 \pm 2.32, 11.36 \pm 1.97 and 26.91 \pm 2.18, respectively.

4. Statistical analysis

The data was analyzed by statistical software SPSS version 20.
Data was expressed as mean \pm standard deviation for quantitative
variables and as frequency (\%) for qualitative variables. Chi-square/
Fisher’s exact test was applied to compare the patient’s character-
istics between the rural and urban areas. Because the same
subjects were studied across the four seasons, two-factors
repeated measures ANOVA was applied (BP was dependent
variable and season and area were two factors). Pairwise multiple
comparisons among the four seasons was done and p-value
adjusted according to Bonferroni correction. The linear mixed
model was applied to compare the seasonal effect after adjusting
other patient characteristics like age, sex, education, temp,
occupation, alcohol, and smoking. The interaction between the
season and other variables (age, gender, occupation, obesity and
area) was also included in the model. Non-significant interactions
were excluded from the final model. The Akaike Information
Criterion (AIC) was applied to find the suitable covariance
structure among the seasonal groups.

Correlation between temperature and BP was calculated by
Pearson’s correlation coefficient. The p < 0.05 was taken as a level
of statistical significance.

The sample size was determined using the paired design of t-
test and expecting summer season has different BP compared to
other seasons. The standard deviation of difference of systolic BP is
around 15 mmHg between summer and other seasons. To detect a
difference of 4 mmHg as clinical important difference with 90% power
and 1% level of significance a sample size of 212 subjects was
required. Adding the 1.8 design effect due to clustering in subject’s
area and 15% follow loss, thus 450 subjects was required.
Considering, the similar differences between rural and urban
subjects for systolic BP change, we selected at least 450 subjects
from each of the region.

5. Results

A total of 1600 subjects were enrolled in the study. 978 subjects
were eligible for current analysis with 457 subjects in rural and 521
subjects in urban areas. Table 1 shows socio-demographic
characteristics of study subjects, both rural and urban areas.
Proportion of males was 51.3%. Mean age of study population
was 42.52 \pm 14.48 years. Mean age in rural was significantly higher
than urban subjects (47.21 \pm 17.0 vs 38.40 \pm 10.21 years, p < 0.001).
Other socio-demographic characteristics such as gender, educa-
tion, occupation, socio economic status, alcohol consumption
and smoking were also significantly different between rural and urban
population. Obesity prevalence was 48.35% in rural and 51.82% in
urban areas (p < 0.28).

Prevalence of hypertension (systolic BP/diastolic BP \geq 140/
90 mmHg) was 10.12% during summer season which more than
doubled (23.72%) during winter season. Prevalence of hyperten-
sion during spring and Post monsoon was 20.96% and 13.80%,
respectively.

Systolic BP across four seasons was significantly different
(p < 0.001) (Table 2). Minimum systolic BP (mmHg) was recorded
in summer season (122.27 \pm 17.30) and maximum systolic BP was
seen in winter season (131.28 \pm 20.24) (Fig. 2). Mean difference
between winter and summer was 9.01 (95% CI: 7.74–10.28,
p < 0.001). The difference of BP was seen among all the seasons
except spring and post monsoon. Systolic BP in spring season and
post monsoon seasons were 127.28 \pm 19.60 and 126.97 \pm 16.28,
respectively. The diastolic BP was also significantly different during
four seasons (Table 2). Diastolic BP (mm Hg) was minimum during
summer season (77.63 \pm 10.87) (Fig. 1). During winter season,
diastolic BP was significantly increased as compared to summer
season with a mean difference of 5.61 (95% CI: 4.75–6.47, p < 0.001).
This difference and trend of BP, both systolic BP and diastolic BP,
was maintained even after adjusting for other variables such as
age, sex, education, occupation, socioeconomic status, alcohol and
smoking as shown by linear mixed model (p < 0.001), the compound
symmetry covariance structure had minimum AIC
(Tables 3 and 4).

Both systolic BP and diastolic BP show a negative correlation
with temperature (r = -0.169, p = 0.038 and r = -0.065; p < 0.001
for systolic BP and diastolic BP respectively) (Fig. 3). The overall

Table 1

| Socio-demographic characteristics of study population. | VARIABLE | CATEGORY | RURAL n = 457 | URBAN n = 521 | TOTAL n = 978 | P value |
|-------------------------------------------------------|----------|----------|--------------|--------------|--------------|---------|
| Age(years)                                            | Male     | 472.1 \pm 17.0 | 38.40 \pm 10.21 | 42.52 \pm 14.48 | <0.001 |
|                                                      | Female   | 508(34.6)   | 344(66.0)   | 502(51.3) | <0.001 |
| Obesity                                               | Yes      | 221(48.35) | 270(51.82) | 491(50.20) | 0.280 |
|                                                      | No       | 55(5.6)    | 51(5.6)    | 106(10.9) | <0.001 |
| Education                                             | Primary  | 84(18.4)   | 12(2.3)     | 96(9.8)   | <0.001 |
|                                                      | Middle   | 55(12.0)   | 25(4.8)     | 80(8.2)   |
|                                                      | Senior Secondary | 177(34.0) | 38(73.9) | 419(42.8) |
|                                                      | Graduate & above | 177(34.0) | 38(73.9) | 419(42.8) |
|                                                      | Illiterate | 147(32.2) | 12(2.3)     | 159(16.3) |
| Occupation                                            | Heavy workers | 81(17.7)   | 1(0.2)      | 82(8.4)   | <0.001 |
|                                                      | Moderate workers | 298(65.2) | 21(4.0)     | 319(32.6) |
|                                                      | Light workers | 78(17.1)  | 49(95.8)    | 577(59.0) |
|                                                      | Lower     | 193(42.2)  | 73(14.0)    | 266(27.2) |
|                                                      | Lower Middle | 211(46.2) | 155(29.8)   | 366(37.4) |
|                                                      | Middle    | 0(0.0)     | 105(20.2)   | 105(10.7) |
|                                                      | Upper     | 17(3.7)    | 21(4.0)     | 38(3.9)   |
|                                                      | Upper Middle | 36(7.9)   | 167(32.1)   | 203(20.8) |
| Alcohol consumption                                   | Yes      | 50(10.9)   | 105(20.2)   | 155(15.8) | <0.001 |
|                                                      | No       | 7(1.5)     | 48(9.2)     | 55(5.6)   | <0.001 |


Table 2
Comparison of BP (mmHg) across the four seasons.

| Season       | SBP Mean ± SD | p-value | DBP Mean ± SD | p-value |
|--------------|---------------|---------|---------------|---------|
| Spring       | 127.28 ± 19.60 | $f = 103.0$ $p < 0.001$ | 83.51 ± 11.31 | $f = 149.86$ $p < 0.001$ |
| Post monsoon | 126.97 ± 16.28 |            | 81.87 ± 10.87 |         |
| Winter       | 131.28 ± 20.24 |            | 83.24 ± 11.35 |         |
| Summer       | 122.27 ± 17.30 |            | 77.63 ± 10.87 |         |

Fig. 2. The mean systolic BP and diastolic BP across the four seasons of Total study population.

Table 3
Effect of each factor/variable on systolic BP (Linear Mixed Model).

| Variable         | Category         | Estimate(SE) | 95% CI       | p-value | Overall p-value |
|------------------|------------------|--------------|--------------|---------|----------------|
| Season           | Spring           | 3.27(1.89)   | -0.43 to 6.99 | 0.083   | F = 23.80 $p < 0.001$ |
|                  | Post monsoon     | 2.29(1.93)   | -1.5 to 6.08  | 0.236   |               |
|                  | Winter           | 15.81(2.70)  | 10.51–21.10   | <0.001  |               |
|                  | Summer Reference | Reference    |              |         |               |
| Gender           | Female           | -6.82(1.14)  | -9.07 to -4.58 | <0.001  | F = 35.71; $p < 0.001$ |
| Area             | Rural            | 6.84(1.65)   | 3.60 to 10.08 | <0.001  | F = 46.0; $p < 0.001$ |
| Age (years)      | 18–40            | -15.0(1.88)  | -18.69 to -11.30 | <0.001  | F = 68.86; $p < 0.001$ |
|                  | 40–60            | -6.83(1.88)  | -10.51 to -3.13 | <0.001  |               |
| BMI              | Per unit         | 0.11(0.10)   | -0.09 to 0.30  | 0.270   | F = 0.122; $p = 0.270$ |
| Spring “area”    | Obesity          | 6.06(0.95)   | 4.20 to 7.98   | <0.001  | F = 67.22; $p < 0.001$ |
| Post monsoon “area” | Rural        | 6.58(1.08)   | 4.45 to 8.71   | <0.001  | F = 17.80; $p < 0.001$ |
| Winter “area”    | Rural            | 1.97(1.18)   | -0.34 to 4.28  | 0.095   |               |
| Spring “BMI”     | Rural            | 2.59(1.09)   | 0.45 to 4.72   | 0.018   |               |
| Post monsoon “BMI” | Obesity   | 0.36(1.03)   | -1.67 to 2.39  | 0.727   | F = 3.113; $p = 0.025$ |
| Winter “BMI”     | Obesity         | -2.09(1.03)  | -4.11 to -0.7  | 0.043   |               |
| Spring “Age”     | 18–40           | -1.0(1.71)   | -4.37 to 2.33  | 0.551   | F = 8.754; $p < 0.001$ |
| Post monsoon “Age” | 18–40        | 4.38(1.70)   | 0.83 to 7.53   | 0.014   |               |
| Winter “Age”     | 18–40           | -7.82(1.71)  | -11.17 to -4.47| <0.001  |               |
| Post monsoon “Age” | 40–60       | -1.10(1.77)  | -4.58 to 2.36  | 0.530   |               |
| Winter “Age”     | 40–60           | 2.22(1.77)   | -1.25 to 5.68  | 0.210   |               |

Variables whose effects were non-significant (education, occupation, socio economic status, alcohol and smoking) are not shown in the table.

* Shows interaction between season and other variables (area, body mass index (BMI), age). Interaction of season with gender and occupation was non-significant (not shown in the table).
Table 4

| Variable          | Category | Estimate(SE) | 95% CI          | p-value | Overall p-value |
|-------------------|----------|--------------|-----------------|---------|----------------|
| Season            | Spring   | 4.02(1.18)   | 1.70 to 6.34    | 0.001   |                |
|                   | Post monsoon | 4.26(2.12) | 1.88 to 6.63    | <0.001  |                |
|                   | Winter   | 7.38(1.72)   | 4.00 to 10.76   | <0.001  |                |
| Gender            | Female   | -4.94(0.71)  | -6.33 to -3.54  | <0.001  | F=64.94 P < 0.001 |
| Socio Economic status | Lower  | -1.99(0.84)  | -3.64 to -0.34  | 0.018   |                |
|                   | Lower Middle | 0.10(0.75) | -1.36 to 1.57   | 0.890   |                |
|                   | Middle   | 0.09(0.94)   | -1.75 to 1.92   | 0.926   |                |
|                   | Upper    | -0.31(1.40)  | -3.26 to 2.29   | 0.713   |                |
| Area              | Rural    | 3.48(1.04)   | 1.45 to 5.52    | <0.001  | F=46.0; P < 0.001 |
|                   | Age (years) | 18–40 | -3.50(1.19)     | -5.84 to -1.17 | <0.001 | F=18.71; P < 0.001 |
|                   |          | 40–60 | -0.38(1.19)     | -2.71 to 1.95 | 0.747 |                |
|                   |          | 60+  | Reference       |       |                |
| Temp              | Per unit | 0.03(0.06)   | -0.09 to 0.15   | 0.659   | F=0.195; p < 0.659 |
| BMI               | Obesity  | 4.51(0.45)   | 3.63 to 5.39    | <0.001  | F=100.81 P < 0.001 |
|                   | Rural    | 7.53(1.02)   | 5.52 to 9.53    | <0.001  | F=13.48; P < 0.001 |
|                   | Rural    | 3.84(1.01)   | 1.86 to 5.81    | <0.001  |                |
|                   | Rural    | 5.20(1.02)   | 3.20 to 7.20    | <0.001  |                |
|                   | 18–40    | 0.44(1.11)   | -1.74 to 2.62   | 0.691   | F=2.311; P=0.031 |
|                   | 18–40    | 0.07(1.11)   | 0.83 to 7.53    | 0.896   |                |
|                   | 18–40    | -2.79(1.11)  | -4.97 to -0.61  | 0.012   |                |
|                   | 18–40    | -0.12(1.15)  | -2.37 to 2.14   | 0.919   |                |
|                   | 18–40    | -0.15(1.15)  | -2.40 to 2.10   | 0.896   |                |
|                   | 18–40    | -1.61(1.15)  | -3.87 to 0.64   | <0.001  |                |

Variables whose effects was non-significant (education, occupation, alcohol and smoking) are not shown in the table.

* Shows interaction between season and other variables (area, age). Interaction of season with gender, occupation & body mass index (BMI) was non-significant (not shown in the table).

Fig. 3. Showing the correlation between temperature and BP.

correlation is small but statistically significant due to large sample size. However, temperature was not found to be an independent predictor of both systolic BP and diastolic BP as shown in LMM (p = not significant).

5.1. Subgroup analysis

Subgroup analysis was done for the variables which showed significant interaction with the season in LMM (Tables 5 and 6). Seasonal variations in BP were more marked in rural areas as compared to urban subjects. The difference of winter and summer SBP in rural areas was 14.1 while this difference was 11.5 in urban areas. The difference is seen in all the seasons and the magnitude varies according to the season. Similarly, the difference of winter and summer diastolic BP was higher in rural areas (7.63) as compared to urban areas (5.91).

The difference between summer and winter systolic BP increased with age with 9.7 mmHg difference at age 18–40 years and 17.5 mmHg at age >60 years. Diastolic BP also showed the similar trend. Diastolic BP difference was 5.45 in age group 18–40 years and 8.24 in age group >60 years.

Seasonal variation of systolic BP was slightly higher in obese subjects. The difference of winter and summer systolic BP in obese subjects was 13.2 while it was 12.4 in non obese subjects. Seasonal variation of diastolic BP was similar in obese and non obese subjects.

BP change with season was similar in both the genders as the interaction between the gender and season was not significant.
Educational status, occupation based physical activity, alcohol intake and smoking had no effect on seasonal variation.

### 6. Discussion

The present study was conducted in a community setting, both rural and urban areas of North India and BP was recorded in out-of-clinic settings in native surroundings (either home or workplace). The study shows that there was significant seasonal variation in BP. Highest BP (Mean systolic BP/diastolic BP) were observed during winter (131.28/83.24 mmHg) and lowest during summers (122.27/77.69 mmHg). There are very few studies available from developing countries. A study from China demonstrated a significant increase in clinic blood pressure (systolic BP/diastolic BP) by 10/4 mmHg between summer and winter which is similar to our study. Another clinic based study from rural China also showed that there was significant difference in adjusted systolic BP/ diastolic BP (19.2/7.7 mmHg) between winter and summer. However, both these studies were clinic based. Our study is the largest study from a developing country in such clinic-based setting.

An increase in prevalence of hypertension during winter as compared to other seasons was noticed in the current study. Prevalence became more than doubled during winter (23.72%) as compared to summer season (10.12%). Similar finding was reported recently in a study from rural China where hypertension detection during winter was twice high (50.6%) as compared to summer (19.4%). Few other studies have also reported the same. However, most of these studies were hospital based. A recent epidemiological survey reported that an increase of 1°C in air temperature reduced hypertension prevalence at two survey visits with an odds ratio of 0.98 (95% confidence interval: 0.96–0.99).

An inverse relationship between outdoor temperature and BP was noticed in our study. A 10°C lower outdoor temperature was associated with 3.9 mmHg higher systolic BP and 2.1 mmHg diastolic BP pressure in the current study. This is in accordance with other studies. In study from China, each 10°C lower outdoor temperature was associated with 5.7/2.0 mmHg higher systolic BP/ diastolic BP. In another study from Norway, a 10°C lower outdoor temperature was associated only with 1.5 mmHg higher mean systolic BP in men and 2.4 mmHg in women. The strength of association is variable among different studies. There is a considerable heterogeneity in the size of BP change between winter and summer across different parts of world. A much stronger association has been reported from western studies. This may be partly due to diverse climatic conditions and difference in winter summer temperature across the globe. Climatic conditions in tropical countries like India are quite different. Tropics witness large difference in summer winter
temperature. Maximum temperature recorded during summer varies between 40 °C – 50 °C and it drops down to near zero during winters.

There are multiple mechanisms by which cold exposure results in increased blood pressure. Studies have shown that as the temperature decreases, various physiological changes occur which result in increase in blood pressure such as increased sympathetic activity, arteriolar vasoconstriction, endothelial dysfunction, reduced sweating and increased aldosterone levels etc.

Also, the physical activity tends to be less and diet is richer in calories during winters specially in north India. There is growing evidence suggesting that ultraviolet (UV) exposure lowers blood pressure either by direct vasodilatation or by release of nitric oxide from intra-cutaneous photolabile nitric oxide derivates. In our study also, BP during summer season is lowest, though there was no much difference in temperature between summer, spring and post monsoon seasons. This may be due to fact that skies are clearer, with more UV exposure during summer. However, we did not measure UV exposure in our study.

Important finding of the current study is that BP response to changing weather was more marked in rural areas. Interaction between rural area and seasonal change in BP was found to be significant (p < 0.001). This phenomenon has also been reported from a large study wherein seasonal changes were more marked in rural areas. Overall, the mean difference between winter and summer was more extreme in the rural than in the urban areas in that study (12 vs. 8 mmHg; p for interaction < 0.0001). This may be due to the fact that rural population is worse affected by season change due to lack of adequate housing and central heating.

Also, seasonal variations in both systolic BP and diastolic BP were more pronounced in elderly. The Medical research council’s treatment trial reported a higher increase in systolic BP and diastolic BP in elderly subjects (55–64 years) as compared to younger subjects (35–54 years) during winter as compared to summer season. This is attributed to impaired baroreflex control and enhanced vaso-reactivity with advancing age. Seasonal variation of systolic BP was slightly higher in obese subjects as compared to non-obese. This is in contradiction to the previous studies which reported that seasonal BP variation were more marked in non obese subjects than in obese subjects. Overall strength of this association is variable with some studies reporting only marginally larger effect. More studies are needed to clarify this issue.

This is the first adequately powered study from South Asia to evaluate seasonal change of BP in out of clinic settings in native surroundings (either home or workplace). We included only those subjects in final analysis who completed four seasons follow up whereas previous studies included different subjects in different seasons. Also, this is the first study from India reporting rural urban difference in seasonal variation in blood pressure.

There are few limitations in our study. Firstly, temperature data was obtained by local agency of National Weather Service which is located in urban area. No separate weather lab was setup for rural areas. However, the urban and rural areas were located nearby. All the villages were located within 20–40 km geographical distance from the urban area. Also, temperature at the site of BP measurement may not be same as the temperature measured in the weather lab. Second, BP was recorded by three different observers and is subject to inter individual variability. However, these were experienced and well trained observers with a good interobserver agreement. Intraclass correlation for systolic BP and diastolic BP was 0.95 (CI: 0.903 – 0.977) and 0.938 (CI: 0.880-0.971) respectively. Lastly, other weather parameters such as UV exposure and cloud free hours were not studied.

To conclude, the present study shows that there is significant variation in BP (systolic BP/diastolic BP) with change in season. BP increases significantly during winter as compared to summer. This has important implications for epidemiological studies on prevalence of hypertension in tropical climate. Seasonal variation should be taken into account when looking at prevalence of hypertension. This could partly explain the variation in prevalence of hypertension in some studies from our country. This effect is even more marked in certain subgroups such as those living in rural areas, elderly individuals and obese population.

Conflict of interest
None.

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References
1. Sheth T, Nair C, Muller J, Yusuf S. Increased winter mortality from acute myocardial infarction and stroke: the stroke of age. J Am Coll Cardiol. 1999;33:1916–1919.2.
2. Keatinge WR, Coleshaw SR, Cotter F, Mattock M, Murphy M, Chelliah R. Increases in platelet and red cell counts, blood viscosity, and arterial pressure during mild surface cooling: factors in mortality from coronary and cerebral ischaemia in winter. Br Med J. 1984;289:1405–1408.
3. Sharma BK, Sagar S, Sood GK, Varma S, Kalra OP. Seasonal variations of arterial blood pressure in normotensive and essential hypertensives. Indian Heart J. 1990;42:66–72.
4. AubinéEurope-B, Jefferys P, Haste CE, et al. Blood pressure response to patterns of weather fluctuations and effect on mortality. Hypertension. 2013;62:190–196.
5. Su D, Du H, Zhang X, et al. Season and outdoor temperature in relation to detection and control of hypertension in a rural Chinese population. Int J Epidemiol. 2014;43(6):1835–1845.
6. Lewington S, Li L, Sherliker P, et al. Seasonal variation in blood pressure and its relationship with outdoor temperature in 10 diverse regions of China: the China KadoorieBiobank. J Hypertens. 2012;30(7):1383–1391.
7. Madsen C, Nafstad P. Associations between environmental exposure and blood pressure among participants in the Oslo Health Study (HUDBR). Eur J Epidemiol. 2006;21:485–491.
8. Barnett AG, Sains S, Salomaa V, Kuulasmaa K, Dobson AJ. The effect of temperature on systolic blood pressure. Blood Press Monit. 2007;12:195–203.
9. Jenner DA, English DR, Vandongen R, Beilin LJ, Armstrong BK, Dunbar D. Environmental temperature and blood pressure in 5-year-old Australian children. J Hypertens. 1987;5:683–686.
10. Sega R, Cesana G, Bombelli M, et al. Seasonal variations in home and ambulatory blood pressure in the PAMELA population. PressioniArterosclerMonitorateE LoroAssociazioni. J Hypertens. 1998;16:1585–1592.
11. Modiﬁ, PA. Season, temperature and blood pressure: a complex interaction. Eur J Intern Med. 2013;24:1016/j.ejim.2013.08.002.
12. Modiﬁ, PA, Rapi S, Ramoshmooch M, et al. Impact of one or two visits strategy on hypertension burden estimation in HYDP, a population-based cross-sectional study: implications for healthcare resource allocation decision making. BMJ Open. 2012;2(4):e00106210.1136/bmjopen-2012-001062.
13. Misra A, Chowhey P, Makkat BM, et al. For consensus group: Consensus statement for diagnosis of obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Phys India. 2009;57:163–170.
14. Kaur S, Midha V, Wander CS, SoniRRGarg R, Pal R. Seasonal variation in arterial blood pressure. Ann Int Med Dent Res. 2016;2:139–145.
15. Kamazoaki F, Sonoda S, Tomotsune Y, Yunaka H, Otsuji Y. Seasonal variation in metabolic syndrome prevalence. Hypertens Res. 2010;33:568–572.
16. Handler J. Seasonal variability of blood pressure in California. J Clin Hypertens. 2011;13:856–860.
17. Fletcher RD, Andur RL, Kolodner R, et al. Blood pressure control among US veterans: a large multiyear analysis of blood pressure data from the Veterans Administration health datarepository. Circulation. 2012;125:2462–2468.
18. Narang R, Wasir HS. Seasonal variation in the incidence of hypertension and coronary artery disease. Int J Cardiol. 1996;56:90–92.
19. Modiﬁ, PA, Ramoshmooch M, Rapi S, et al. Epidemiology of hypertension in Yemen: effects of urbanization and geographical area. Hypertens Res. 2013;36 (August (8)):717–717.
20. Sun Z, Cade R, Morales C. Role of central angiotensin II receptors in cold-induced hypertension. Am J Hypertens. 2002;15:85–92.
21. Sun Z, Cade R, Zhang Z, Aloudor J, Van H. Angiotensinogen gene knockout delays and attenuates cold-induced hypertension. *Hypertension*. 2003;41:322–327.

22. Liu D, Fernandez BO, Hamilton A, et al. UVA irradiation of human skin vasodilates arterial vasculature and lowers blood pressure independently of nitric oxide synthase. *J Invest Dermatol*. 2014;134:1839–1846.

23. Oplander C, Volkmar CM, Paunel-Gorgulu A, et al. Whole body UVA irradiation lowers systemic blood pressure by release of nitric oxide from Intracutaneous Photolabile nitric oxide derivates. *Circ Res*. 2009;105:1031–1040.

24. Weller RB. The health benefits of UV radiation exposure through vitamin D production or non-vitamin D pathways. Blood pressure and cardiovascular disease. *Photochem Photobiol Sci*. 2017;16:374–380.

25. Modesti PA. The hazard of rounding Cape Horn: is it changing? *Heart*. 2014;100 (October (19)):1489–1490.

26. Brennan PJ, Greenberg G, Miall WE, Thompson SG. Seasonal variation in arterial blood pressure. *Br Med J*. 1982;285:919–923.

27. Alperovitch A, Lacombe JM, Hanon O, et al. Relationship between blood pressure and outdoor temperature in a large sample of elderly individuals: the Three-City study. *Arch Intern Med*. 2009;169:75–80.

28. Kristal-Boneh E, Harari G, Green MS, Ribak J. Body mass index is associated with differential seasonal change in ambulatory blood pressure levels. *Am J Hypertens*. 1996;9:1179–1185.