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Original Article

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

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ABSTRACT

Objective: There are no community based, longitudinal, intra individual epidemiological studies on effect of weather and season on blood pressure. We evaluated the effect of season and temperature on prevalence and epidemiology of BP in tropical climate.

Methods and results: It was a longitudinal cross sectional survey of rural and urban subjects in their native surroundings. BP was measured in four different seasons in same subjects. A total of 978 subjects (452 rural and 521 urban) were included in the current analysis. Demographic characteristics such as age, gender, education, occupational based physical activity and body mass index were recorded. Mean BP, both systolic and diastolic were significantly higher in winter season as compared to summer season. Mean difference between winter and summer was 9.01 (95% CI: 7.74–10.28, $p < 0.001$) in systolic BP and 5.61 (95% CI: 4.75–6.47, $p < 0.001$) in diastolic BP. This increase in BP was more marked in rural areas and elderly subjects.Prevalence of hypertension was significantly higher during winter (23.72%) than in summer (10.12%).

Conclusion: BP increases significantly during winter season as compared to summer season. Increase is more marked in rural areas and elderly subjects. Seasonal variation in BP should be taken into account while looking at prevalence of hypertension in epidemiological studies.

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 labourers 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 blood pressure.[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

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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.[6] 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 blood pressure.

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 centre 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 sphygmomanometer. 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 $\geq 25\,kg/m^2$ as per the consensus statement of Asian classification.[13]

A preliminary report of this study was published earlier.[14] 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

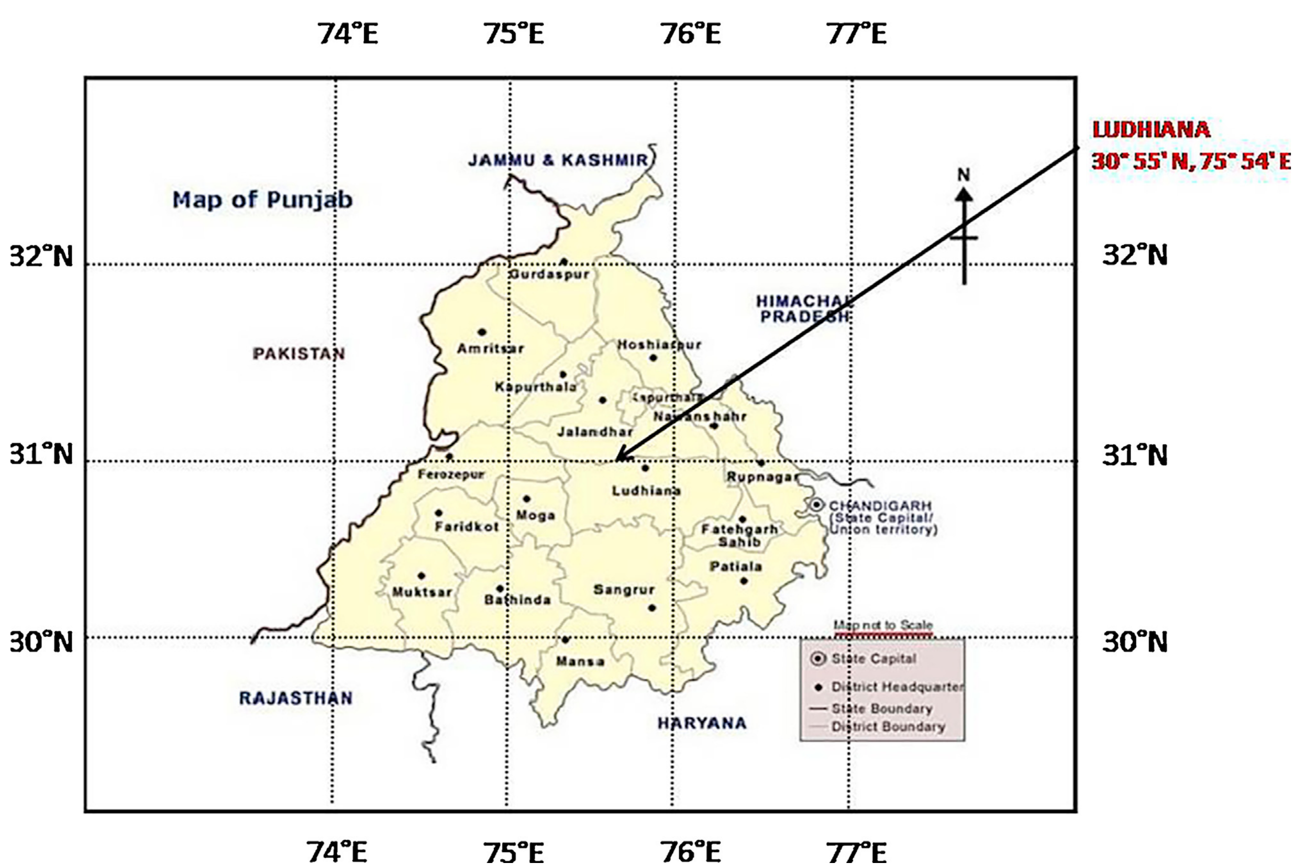

Fig. 1. Map of Punjab showing latitude and longitude of Ludhiana city.

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) ± standard deviation recorded in summer, post monsoon, winter and spring seasons were 30.93 ± 3.82,26.94 ± 2.32,11.36 ± 1.97 and 26.91 ± 2.18respectively.

4. Statistical analysis

The data was analyzed by statistical software SPSS version 20. Data was expressed as mean ± SD for quantitative variables and as frequency (%) for qualitative variables. Chi-square/Fisher's exact test was applied to compare the patient's characteristics between the rural and urban areas.Because the same subjects were studied across the four seasons, two-factors repeated measures ANOVA was applied (Blood pressure 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 blood pressure 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 blood pressure compared to other seasons. The standard deviation of difference of SBP 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 will be required. Considering, the similar differences between rural and urban subjects for SBP 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 ± 14.48 years. Mean age in rural was significantly higher than urban subjects (47.21 ± 17.0 vs 38.40 ± 10.21 years, $p < 0.001$). Other socio-demographic characteristics such as gender, education, 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 (SBP/DBP ≥ 140/90 mm Hg) was 10.12% during summer season which more than doubled (23.72%) during winter season. Prevalence of hypertension 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 SBP (mm Hg) was recorded in summer season (122.27 ± 17.30) and maximum SBP was seen in winter season (131.28 ± 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. SBP in spring season and post monsoon seasons were 127.28 ± 19.60 and 126.97 ± 16.28 respectively. The diastolic blood pressure (DBP) was also significantly different during four seasons (Table 2). DBP (mm Hg) was minimum during summer season (77.63 ± 10.87) (Fig. 1). During winter season, DBP 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 SBP and DBP, 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 SBP and DBP show a negative correlation with temperature ($r = -0.169$, $p = 0.038$ and $r = -0.065$; $p < 0.001$ for SBP and DBP respectively) (Fig. 3). The overall correlation is small but statistically significant due to large sample size. However,

Table 1
Socio-demographic characteristics of study population.

VARIABLE	CATEGORY	RURAL n = 457	URBAN n = 521	TOTAL n = 978	P value
Age(years)		47.21 ± 17.0	38.40 ± 10.21	42.52 ± 14.48	<0.001
Sex	Male	158(34.6)	344(66.0)	502(51.3)	<0.001
	Female	299(65.4)	177(34.0)	476(48.7)	
Obesity	Yes	221(48.35)	270(51.82)	491(50.20)	0.280
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	137(30.0)	87(16.7)	224(22.9)	
	Graduate & above	34(7.4)	385(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)	499(95.8)	577(59.0)	
Socioeconomic status	Lower	193(42.2)	73(14.0)	266(27.2)	<0.001
	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
Smoking	Yes	7(1.5)	48(9.2)	55(5.6)	<0.001

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

Season	SBP		DBP	
	Mean ± SD	p-value	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	
Spring vs Post monsoon	−0.32(−1.11 to 1.76)	p = 1.00	1.65(0.80–2.50)	p < 0.001
Spring vs Winter	−3.98(−5.35 to −2.61)	p < 0.001	0.28(−0.61–1.17)	p = 1.00
Spring vs Summer	5.03(3.74–6.31)	p < 0.001	5.89(4.97–6.81)	p < 0.001
Post monsoon vs Winter	−4.30(−5.74 to −2.86)	p < 0.001	-1.37(-2.22 to −0.52)	p < 0.001
Post monsoon vs Summer	4.70(3.37–6.03)	p < 0.001	4.24(3.35–5.13)	p < 0.001
Winter vs. Summer	9.01(7.74–10.28)	p < 0.001	5.61(4.75–6.47)	p < 0.001

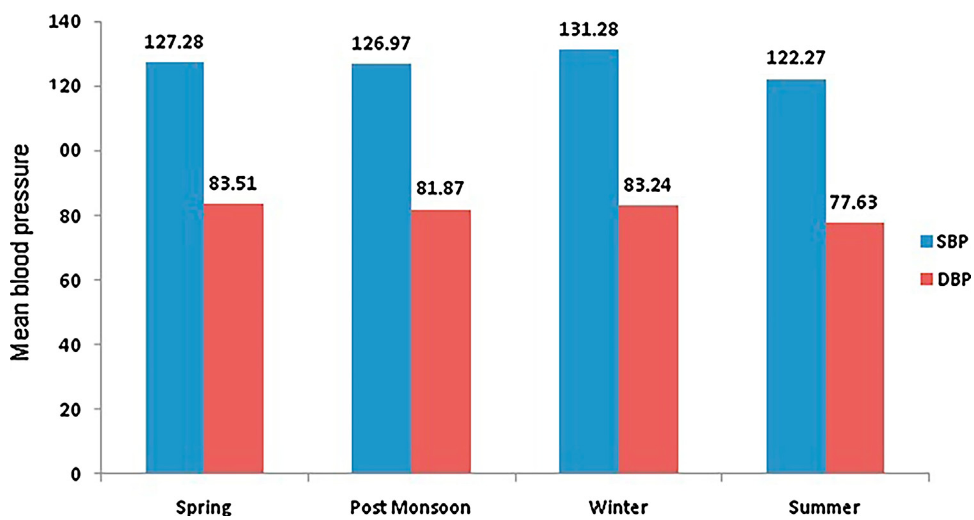

Fig. 2. The mean SBP and DBP across the four seasons of Total study population.

Table 3
Effect of each factor/variable on SBP (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			
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	
	60+				
Temp	Per unit	0.11(0.10)	−0.09 to 0.30	0.270	F = 0.1.22; p = 0.270
BMI	Obesity	6.06(0.95)	4.20 to 7.98	<0.001	F = 67.22, P < 0.001
Spring [a]area	Rural	6.58(1.08)	4.45 to 8.71	<0.001	F = 17.80; P < 0.001
Post monsoon[a]area	Rural	1.97(1.18)	−0.34 to 4.28	0.095	
Winter[a]area	Rural	2.59(1.09)	0.45 to 4.72	0.018	
Spring [a]BMI	Obesity	0.36(1.03)	−1.67 to 2.39	0.727	F = 3.113, P = 0.025
Post monsoon[a]BMI	Obesity	−2.09(1.03)	−4.11 to −0.7	0.043	
Winter[a]BMI	Obesity	0.81(1.02)	−1.20 to 2.83	0.429	
Spring [a]Age	18–40	−1.0(1.71)	−4.37 to 2.33	0.551	F = 8.754: P < 0.001
Post monsoon[a]Age	18–40	4.18(1.70)	0.83 to 7.53	0.014	
Winter[a]Age	18–40	−7.82(1.71)	−11.17 to −4.47	<0.001	
Spring [a]Age	40–60	−1.10(1.77)	−4.58 to 2.36	0.530	
Post monsoon[a]Age	40–60	2.22(1.77)	−1.25 to 5.68	0.210	
Winter[a]Age	40–60	−6.33(1.77)	−9.80 to −2.87	<0.001	

Variables whose effects was non-significant (education, occupation, socio economic status, alcohol and smoking) are not shown in the table.
[a] 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
Effect of each factor/variable on DBP (Linear Mixed Model).

Variable	Category	Estimate(SE)	95% CI	P-value	Overall *p*-value
Season	Spring	4.02(1.18)	1.70 to 6.34	0.001	F = 64.94 P < 0.001
	Post monsoon	4.26(1.21)	1.88 to 6.63	<0.001	
	Winter	7.38(1.72)	4.00 to 10.76	<0.001	
	Summer	Reference			
Gender	Female	−4.94(0.71)	−6.33 to −3.54	<0.001	F = 48.26;p < 0.001
Socio Economic status	Lower	−1.99(0.84)	−3.64 to −0.34	0.018	F = 2.892, P = 0.021
	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	−0.51(1.40)	−3.26 to 2.29	0.713	
	Upper middle	Reference			
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
Spring [a]area	Rural	7.53(1.02)	5.52 to 9.53	<0.001	F = 13.48; P < 0.001
Post monsoon[a]area	Rural	3.84(1.01)	1.86 to 5.81	<0.001	
Winter[a]area	Rural	5.20(1.02)	3.20 to 7.20	<0.001	
Spring [a]Age	18–40	0.44(1.11)	−1.74 to 2.62	0.691	F = 2.311: P = 0.031
Post monsoon[a]Age	18–40	0.07(1.11)	0.83 to 7.53	0.896	
Winter[a]Age	18–40	−2.79(1.11)	−4.97 to −0.61	0.012	
Spring [a]Age	40–60	−0.12(1.15)	-2.37 to 2.14	0.919	
Post monsoon[a]Age	40–60	−0.15(1.15)	-2.40 to 2.10	0.896	
Winter[a]Age	40–60	−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.
[a] 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).

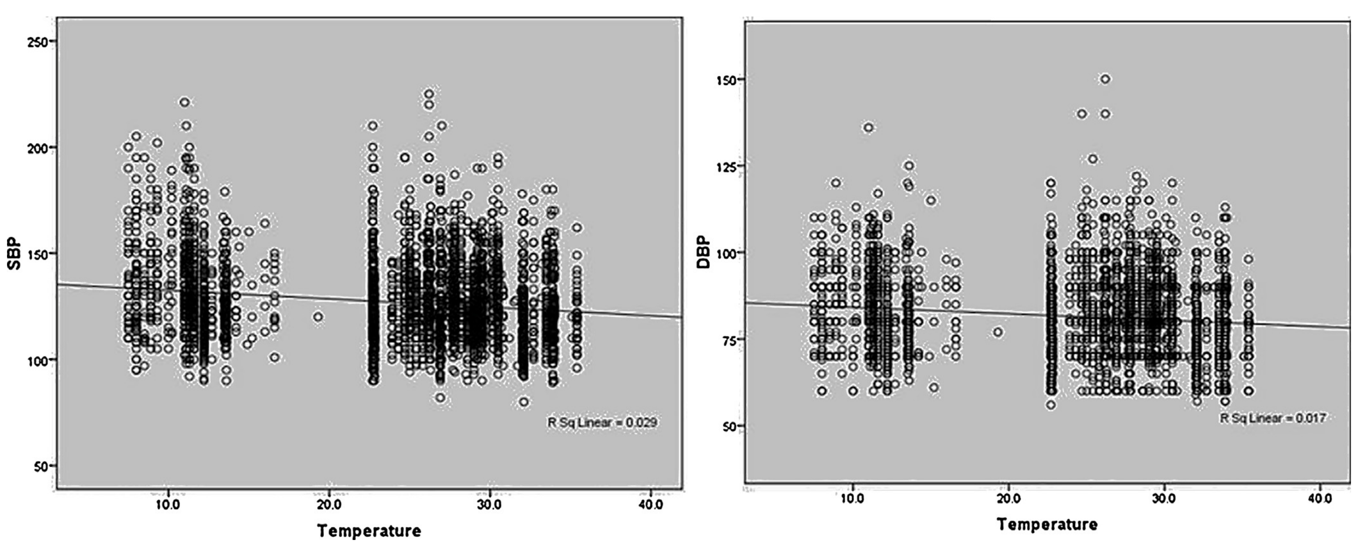

Fig. 3. Showing the correlation between temperature and BP.

temperature was not found to be an independent predictor of both SBP and DBP 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 DBP was higher in rural areas (7.63) as compared to urban areas (5.91).

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

Seasonal variation of SBP was slightly higher in obese subjects. The difference of winter and summer SBP in obese subjects was 13.2 while it was 12.4 in non obese subjects. Seasonal variation of DBP 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).

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Table 5
Comparison of SBP in various sub groups across the four seasons [a].

Season	Age Group (yrs)			Body Weight		Area	
	18–40	41–60	>60	Obese	Non Obese	Rural	Urban
Spring [b]	122.8[1.40]	130.9[1.40]	138.9[2.0]	134.0[1.39]	127.6[1.39]	137.5[1.37]	124.1[1.70]
Post monsoon[b]	123.5[1.4]	129.7[1.41]	134.3[2.01]	131.1[1.39]	127.1[1.40]	133.5[1.40]	124.7[1.67]
Winter[b]	126.7[1.84]	136.4[1.84]	149.6[2.34]	141.0[1.83]	134.1[1.85]	142.3[1.91]	132.8[1.99]
Summer[b]	117.1[1.52]	125.2[1.51]	132.0[2.11]	127.8[1.52]	121.7[1.51]	128.2[1.44]	121.4[1.85]
Spring vs Post monsoon[c]	−0.68[−2.5 to 1.2]	1.2[−1.1 to 3.5]	4.5[0.5 to 8.5]*	2.9[0.8 to 5.0]*	0.4[−1.7 to 2.6]	4.0[1.9 to 6.1]*	−0.6[−3.0 to 1.7]
Spring vs Winter[c]	−4.0[−8.3 to 0.4]	−5.5[−10.2 to −0.9]*	−10.8[−16.4 to −5.1]*	−7.0[−11.5 to −2.5]*	−6.5[−11.0 to −2.0]*	−4.8[−9.1 to −0.4]*	−8.7[−13.4 to −4.1]*
Spring vs Summer[c]	5.7[3.6 to 7.8] *	5.6[3.1 to 8.1]*	6.7[2.6 to 10.9]*	6.2[3.8 to 8.6]*	5.9[3.5 to 8.2] *	9.3[7.1 to 11.5]*	2.8[0.2 to 5.3]*
Post monsoon vs Winter[c]	−3.2[−7.5 to 1.0]*	−6.7[−11.5 to −2.0]*	−15.3[−20.9 to −9.6]*	−9.9[−14.4 to 5.4]*	−7.0[−11.5 to −2.4]*	−8.7[−13.6 to −3.9]*	−8.1[−12.4 to −3.8]*
Post monsoon vs Summer[c]	6.4[4.4 to 8.7]*	4.4[2.0 to 6.9] *	2.2[−1.9 to 6.4] *	3.3[1.0 to 5.6]*	5.4[3.1 to 7.7] *	5.3[3.3 to 7.4]*	3.4[0.6 to 6.2]*
Winter vs Summer[c]	9.7[4.4 to 14.0] *	11.2[5.7 to 16.6]*	17.5[11.1 to 25.0]*	13.2[7.7 to 18.6]*	12.4[7.0 to 17.8]*	14.1[8.9 to 19.3]*	11.5[5.8 to 17.2]*

[a] Adjusted for temperature and other factors.
[b] Mean BP(± standard error).
[c] Mean difference (95% CI).
* P value = significant (<0.05).

Table 6
Comparison of DBP in various sub groups across the four seasons [a].

Season	Age Group (yrs)			Area	
	18–40	41–60	>60	Rural	Urban
Spring[b]	83.04[0.88]	85.60[0.88]	86.10[1.26]	88.68[0.85]	81.15[1.06]
Post monsoon[b]	81.07[0.88]	83.97[0.88]	84.50[1.26]	85.10[0.88]	81.26[1.04]
Winter[b]	82.01[1.17]	86.31[1.17]	88.30[1.49]	88.14[1.22]	82.94[1.26]
Summer[b]	76.56[0.96]	79.68[0.95]	80.06[1.33]	80.51[0.90]	77.03[1.17]
Spring vs Post monsoon[c]	1.97[0.78 to 3.17]*	1.64[0.132 to 3.14]*	1.60[−1.04 to 4.21]	3.58[2.24 to 4.93]*	−0.11[−1.64 to 1.42]
Spring vs Winter[c]	1.03(−1.77 to 3.84)	−0.71[−3.70 to 2.30]	−2.20[−5.85 to 1.45]	0.54[−2.30 to 3.73]	−1.79[−4.79 to 1.22]
Spring vs Summer[c]	6.48(5.11 to 7.86]*	5.92[4.30 to 7.46]*	6.04[3.34 to 8.75]*	8.17[6.75 to 9.59]*	4.13[2.44 to 5.81]*
Post monsoon vs Winter[c]	−0.94[−3.73 to 1.85]	−2.34[−5.41 to 0.72]	−3.80[−7.50 to −0.11]*	−3.05[−6.20 to 0.11]	−1.68[−4.45 to 1.10]
Post monsoon vs Summer[c]	4.51[3.13 to 5.89]*	4.29[2.69 to 5.88]*	4.44[1.75 to 7.12]*	4.59[3.27 to 5.90]*	4.23[2.41 to 6.05]*
Winter vs Summer[c]	5.45[2.03 to 8.87]*	6.63[3.09 to 10.17]*	8.24[4.05 to 12.43]*	7.63[7.27 to 10.99]*	5.91[2.23 to 9.59]*

[a] Adjusted for temperature and other factors.
[b] Mean BP(± standard error).
[c] Mean difference (95% CI).
* P value = significant (<0.05).

The study shows that there was significant seasonal variation in BP. Highest BP (Mean SBP/DBP) were observed during winter (131.28/83.24 mm Hg) and lowest during summers (122.27/77.69 mm Hg). There are very few studies available from developing countries.[3,5,6] A study from China demonstrated a significant increase in clinic blood pressure (SBP/DBP) by 10/4 mm Hg between summer and winter which is similar to our study.[6] Another clinic based study from rural China also showed that there was significant difference in adjusted SBP/DBP (19.2/7.7 mm Hg) between winter and summer.[5] However, both these studies were clinic based. Our study is the largest study from a developing country in out-of-clinic settings.

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%).[5] Few other studies have also reported the same.[15–18] 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).[19]

An inverse relationship between outdoor temperature and BP was noticed in our study. A 10 °C lower outdoor temperature was associated with 3.9 mm Hg higher SBP and 2.1 mm Hg DBP 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 mm Hg higher SBP/DBP.[6] In another study from Norway, a 10 °C lower outdoor temperature was associated only with 1.5 mm Hg higher mean SBP in men and 2.4 mm Hg in women.[7] 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.[8,9] 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.[2,3,20,21] 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.[22–24] 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 where seasonal changes were more marked in rural areas.[6] 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 mm Hg; 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.[5,25] Also, More number of people were heavy workers in rural as compared to urban areas(17.7% vs 0.2% respectively) who work in extreme outside weather conditions.

Also, seasonal variations in both SBP and DBP were more pronounced in elderly. The Medical research council's treatment trial reported a higher increase in SBP and DBP in elderly subjects (55–64 years) as compared to younger subjects (35–54 years) during winter as compared to summer season.[26] This is attributed to impaired baroreflex control and enhanced vasoreactivity with advancing age. Seasonal variation of SBP 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.[6] Overall strength of this association is variable with some studies reporting only marginally larger effect.[27,28] 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.Secondly, 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 SBP and DBP 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 (SBP/DBP) 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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