Seasonal Variation in Blood Pressure and Hypertension: A Study of the Indian National Family Health Survey IV

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B.S.

American University

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Abstract

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By: Madison Hayes

Background: Although evidence suggests that blood pressure varies seasonally, seasonal effects on blood pressure have not been well described in countries with tropical climates such as India. We examined the cross-sectional association of season of measurement with blood pressure and hypertension in a nationally representative study of Indian adults.

Methods: Using the 2015-16 Indian National Family and Health Survey IV, we analyzed systolic and diastolic blood pressure (SPB and DBP, respectively) measurements of 596,052 men aged 15-54 and women aged 15-49 by season of measurement. Mean SBP and DBP and prevalence of hypertension (taking blood pressure control medication, SBP ≥ 140 mmHg, or DBP ≥ 90 mmHg) were described in the total population and by sex, rurality, age group, and weight status. Multiple linear regression models estimated mean differences in SBP and DBP, while multiple logistic regression models estimated the odds ratios (OR) of hypertension, by season. Adjusted models accounted for demographic and social factors, and blood-pressure altering behaviors at the time of measurement.

Results: Mean SBP and DBP were 112.85 (112.78, 112.93) and 76.0 (75.95, 76.05) for women and 112.85 (119.81, 120.11) and 78.83 (78.71, 78.96) for men, respectively. In adjusted analyses, SBP, DBP, and hypertension were statistically significantly lower in pre-monsoon, monsoon, and post-monsoon as compared to winter. Nationally, mean SBP in pre-monsoon was -1.95 mmHg (-1.96, -1.95) compared with winter SBP, the largest seasonal difference observed. DBP was similarly lower in pre-monsoon season and monsoon season compared with winter (-2.10 mmHg [-2.11, -2.10]; and -2.13 mmHg [-2.13, -2.12], respectively). Relative to winter, the odds of hypertension were lowest in the monsoon season (OR=0.53 [0.53, 0.58]). Seasonal differences in blood pressure were larger in rural as compared with the urban population.

Conclusion: To our knowledge, this is the first study to utilize nationally representative data to assess the association between season of measurement and blood pressure outcomes in India. On average, SBP, DBP, and hypertension were lower in pre-monsoon, post-monsoon, and monsoon seasons compared to winter. Clinical management and epidemiologic studies of blood pressure may be improved by taking into account seasonality.

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Table of Contents

Chapter I: Literature Review

Burden of Hypertension

The World Health Organization (WHO) estimates 1.13 billion people worldwide lived with hypertension—or elevated blood pressure—in 2015, doubling 1975's estimate of 594 million (World Health Organization, 2019). This dramatic rise is predominantly attributed to the increase of risk factors in low- and middle-income countries (LMICs) like India. Analysis of the seminal 2015 Global Burden of Disease Study found that elevated systolic blood pressure (SBP) is the leading contributor to global preventable death for all specific risks including obesity and smoking (Forouzanfar et al., 2017). Elevated blood pressure, or hypertension, is also a leading major modifiable risk factors for the world's number one cause of death—cardiovascular disease (CVD) (Devi et al., 2013). In India, high systolic blood pressure contributed to an estimated 55% of disability-adjusted life years (DALYs)—the number of years lost to ill-health, disability or death—due to CVD from 1990 to 2016 (India State-Level Disease Burden Initiative CVD Collaborators, 2018).

Impact of Season on Blood Pressure Levels

The impact of season on SBP and diastolic blood pressure (DBP) is a well-known, but little researched, phenomenon. Studies have reported strong seasonal patterning of blood pressure in temperate regions of the world (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010). Generally, this patterning is such that blood pressure and hypertension prevalence is highest in the winter season. Evidence is inconclusive, but researchers contend that the few studies showing little seasonal variation were impacted by their small sample sizes (Goyal et al., 2018, 2019; Modesti et al., 2006; Sinha et al., 2010).

Temperature is hypothesized to be the leading biological mechanism through which season impacts blood pressure. It is well documented that blood pressure increases as temperatures decrease (Alpérovitch et al., 2009; Barnett et al., 2007; Goyal et al., 2018, 2018, 2019; Sinha et al., 2010). There is variable information on the strength of the association of indoor as compared to outdoor temperature on blood pressure. Some studies have reported that outdoor temperature had greater impact than indoor temperature, but this appears to be region-dependent as others indicated that the impact of outdoor temperature was mediated by access to air conditioning or central heating (Alpérovitch et al., 2009, 2009; Barnett et al., 2007; Goyal et al., 2018, 2018, 2019; Sinha et al., 2010).

Seasonal variation in blood pressure has potential implications for individual health and epidemiologic measures of blood pressure in the population. Individuals are more likely to experience a number of cardiovascular disease events in the winter months when blood pressure is also highest (Fares, 2013; Stewart et al., 2017). Therefore, exploring the impact of seasonal blood pressure variation may therefore have implications for the management of blood pressure. For example, those with high blood pressure could need to be more closely monitored in winter to ensure their blood pressure remains adequately controlled. Medication dosage could also be impacted with the potential for over medication in the summer and undermedication in the winter.

Additionally, there are increasing efforts to compare the global burden of disease for public health planning and to stimulate etiologic research. County income category, demographic background, and other characteristics are routinely taken into consideration. These comparisons generally fail to take into account seasonal variation in blood pressure, and its potential implication on mis-estimation of differences in blood pressure and hypertension across and within countries.

Seasonality and Blood Pressure Outcomes in India

Research thus far has been focused in temperate European countries that often define season differently than many tropical countries (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010). According to the national Meteorological Department, India experiences four seasons: winter (January, February), pre-monsoon (March, April, May), monsoon (June, July, August, September), and post-monsoon (October, November, December) (*Annual Climate Summary-2018*). The first mention of seasonality's relationship to blood pressure in India was in 1996 (Narang & Wasir, 1996). Over the last nearly 25 years, seasonal variation in blood pressure has not been investigated systematically using population-based data in the country.

Existing Research of Blood Pressure and Hypertension Variation in Non-Temperate Countries

Given the focus of this study on India, this review focuses on literature from the country or other non-European countries. The literature revealed two approaches to assessing the relationship between season of measurement and SBP, DBP, and hypertension: 1) Longitudinal studies tracking the same individuals over time; and 2) Cross-sectional studies observing population measures in different seasons.

Most recently, two longitudinal studies were completed in Punjab by Daynard Medical College and Hospital researchers. The first measured the blood pressure of 978 rural and urban subjects at their homes across the four seasons. This study verified that both mean SBP and DBP were higher in the winter with a mean difference of 9.01 (95% CI: 7.74, 10.28) and 5.61 (95% CI: 4.75, 6.47), respectively. The prevalence of hypertension was additionally found to be doubly higher in the winter (23.72%) than in the summer (10.12%) (Goyal et al., 2018). The second study by the same group followed 28 medical professionals across four seasons for 24-hour ambulatory blood pressure (ABP). The study found that ambulatory daytime SBP and DBP were found to be significantly higher in winter as compared to summer, with a mean SBP difference of -6.32 mm Hg (95% CI: -10.69, -1.95) and mean DBP difference of -7.50 mm Hg (95% CI: -12.49, -2.51) (Goyal et al., 2019).

Another longitudinal study conducted in India followed 132 women who were visited once in winter (December-January) and once in summer (May-June) in an urban slum of eastern Dehli. Researchers calculated a mean decrease from winter to summer of 11.07 mm Hg of SBP and 6.79 mm Hg of DBP (Sinha et al., 2010).

The second approach utilized population measures across various seasons. One of the largest studies thus far utilizing this approach tested this research question across 25 populations in 16 countries. The 2007 study utilized WHO MONICA Project risk factor surveys to conclude that seasonality had a statistically significant effect on SBP. The mean effect was a 2.06 mm Hg (95% CI:

1.05, 3.08) increase in midwinter as compared to midsummer—with larger effects in warmer populations as compared to temperate climates (Barnett et al., 2007).

Finally, one study assessed the relationship across 10 regions of China. Over a four-year period, 500,000 men and women were measured for their blood pressure via the China Kadoorie Biobank study. Researchers concluded that there was an apparent seasonal variation for systolic and diastolic blood pressure. On average, the mean SBP in the summer was 10 mm Hg lower than in winter, with more extreme differences recorded in rural areas and among the elderly. In addition to seasonality, the study looked at the relationship between blood pressure and outdoor temperature. Above 5 degrees C, SBP increased 5.7 mm Hg for every 10 degree C decrease in outdoor temperature (Lewington et al., 2012).

Effect Modifiers

Apart from season, there are a number of other factors that should be taken into consideration as potential effect modifiers. First, several geographic and biological characteristics may modify the impact of season on blood pressure. Those in rural districts were more likely to experience seasonal variation of blood pressure—which may be due to greater exposure to outdoor temperature and humidity among other factors (Goyal et al., 2018, 2019; Lewington et al., 2012). Exposure to increased particulate air matter, of which levels vary regionally, can also increase both SBP and DBP (Giorgini et al., 2015). Older individuals and the elderly were demonstrated to be more influenced by the effects of seasonality and temperature in a number of studies (Alpérovitch et al., 2009; Goyal et al., 2018, 2019; Modesti et al., 2006). Lean individuals were also more likely to have their blood pressure impacted the same seasonal and temperature factors (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010). One study indicated that women may be more susceptible to the effects of outdoor temperature on blood pressure (Barnett et al., 2007). Certain behavioral factors are also known to affect blood pressure such as physical activity, smoking, alcohol consumption, and certain dietary patterns, all of which may be impacted by season (Barnett et al., 2007; Goyal et al., 2018, 2019; Lewington et al., 2012; Modesti et al., 2006; Sinha et al., 2010).

Knowledge Gap

While season of measurement has been demonstrated to impact blood pressure values, it is rarely taken into account in our estimates of population-based studies or by individual clinicians. Generally, population-based data on directly measured hypertension are limited within India (Geldsetzer et al., 2018). Without accounting for season of measurement, reported differences in blood pressure across states, countries, and regions may be biased and clinicians may be misdiagnosing individuals without taking season into account. Additionally, as countries often define season differently, it is important to conceptualize this research question on a country by country basis. When comparing populations across the seasons, we must ensure that seasons are comparable.

This question is of particular significance in India due to the country's size and variation in geography and climate, and also the epidemiologic transition in which elevated blood pressure, among other noncommunicable disease (NCD) risk factors, are increasingly contributing to the burden of disease. DALYs due to NCDs and injuries exceeded those due to communicable, maternal, neonatal, and nutritional diseases (CMNNDs) in 2003 (India State-Level Disease Burden Initiative CVD Collaborators, 2017). In order to effectively prevent, manage, and control cardiovascular disease, countries and their health workers must understand the true nature of their population's burden of hypertension.

Study Objectives

National Family Health Survey IV (NFHS-4) provides an excellent opportunity to study seasonal variation in blood pressure across India. NFHS-4 is utilized by India's Ministry of Health and Family Welfare as a primary tool to understand the burden of disease within India and inform programmatic and policy decisions for the health sector (*National Family Health Survey (NFHS-4): India (2015-16)*, 2017). NFHS-4 collect basic demographic information, household characteristics, and health information representative of the general population at the state and district levels. This iteration of the survey marks the first time a NFHS in India has included biometric data. Specifically, the biomarker survey measures height, weight, hemoglobin, blood pressure, HIV status, and random blood glucose in adult men and women, as well as other markers specific to children (*National Family Health Survey (NFHS-4): India (2015-16)*, 2017). For each consenting and eligible adult respondent, trained staff conducted three separate blood pressure readings at intervals of five minutes. Respondents showing measurements of average SBP greater than 140 mm Hg or average DBP greater than 90 mm Hg were informed of their elevated blood pressure and encouraged to seek the advice of a medical professional.

This study seeks to address the aforementioned gaps in research by utilizing NFHS-4 data to examine the association between season and SBP, DBP, and hypertension using the government of India's definition of seasons. This study will add to the expanding body of literature on this association focused on non-temperate and non-European countries.

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Chapter II: Manuscript

Seasonal Variation in Blood Pressure: A Study of the Indian National Family Health Survey 4

Madison Hayes and Shivani A. Patel

Abstract

Background: Although evidence suggests that blood pressure varies seasonally, seasonal effects on blood pressure have not been well described in countries with tropical climates such as India. We examined the cross-sectional association of season of measurement with blood pressure and hypertension in a nationally representative study of Indian adults.

Methods: Using the 2015-16 Indian National Family and Health Survey IV, we analyzed systolic and diastolic blood pressure (SPB and DBP, respectively) measurements of 596,052 men aged 15-54 and women aged 15-49 by season of measurement. Mean SBP and DBP and prevalence of hypertension (taking blood pressure control medication, SBP ≥ 140 mmHg, or DBP ≥ 90 mmHg) were described in the total population and by sex, rurality, age group, and weight status. Multiple linear regression models estimated mean differences in SBP and DBP, while multiple logistic regression models estimated the odds ratios (OR) of hypertension, by season. Adjusted models accounted for demographic and social factors, and blood-pressure altering behaviors at the time of measurement.

Results: Mean SBP and DBP were 112.85 (112.78, 112.93) and 76.0 (75.95, 76.05) for women and 112.85 (119.81, 120.11) and 78.83 (78.71, 78.96) for men, respectively. In adjusted analyses, SBP, DBP, and hypertension were statistically significantly lower in pre-monsoon, monsoon, and post-monsoon as compared to winter. Nationally, mean SBP in pre-monsoon was -1.95 mmHg (-1.96, -1.95) compared with winter SBP, the largest seasonal difference observed. DBP was similarly lower in pre-monsoon season and monsoon season compared with winter (-2.10 mmHg [-2.11, -2.10]; and -2.13 mmHg [-2.13, -2.12], respectively). Relative to winter, the odds of hypertension were lowest in the monsoon season (OR=0.53 [0.53, 0.58]). Seasonal differences in blood pressure were larger in rural as compared with the urban population.

Conclusion: To our knowledge, this is the first study to utilize nationally representative data to assess the association between season of measurement and blood pressure outcomes in India. On average, SBP, DBP, and hypertension were lower in pre-monsoon, post-monsoon, and monsoon seasons compared to winter. Clinical management and epidemiologic studies of blood pressure may be improved by taking into account seasonality.

Key words: season, India, blood pressure, hypertension, tropical countries, national demographic health survey

Key Messages

- To our knowledge, this is the first study utilizing NFHS-4 to assess the association between season of measurement and systolic blood pressure, diastolic blood pressure, and hypertension.
- Systolic blood pressure, diastolic blood pressure, and odds of hypertension were statistically significantly lower in adjusted models for post-monsoon, pre-monsoon, and monsoon seasons as compared to winter in India.
- Estimates of average blood pressure and hypertension prevalence that do not account for the season of measurement may yield biased estimates of the burden of disease
- Seasonal variation of blood pressure has potential implications for blood pressure management in India.

Introduction

The World Health Organization (WHO) estimates 1.13 billion people worldwide lived with hypertension—or elevated blood pressure—in 2015, doubling 1975's estimate of 594 million (World Health Organization, 2019). This dramatic rise is predominantly attributed to the increase of risk factors in low- and middle-income countries (LMICs) like India. Analysis of the seminal 2015 Global Burden of Disease Study found that elevated systolic blood pressure (SBP) is the leading contributor to global preventable death for all specific risks including obesity and smoking (Forouzanfar et al., 2017). Elevated blood pressure, or hypertension, is also a leading major modifiable risk factors for the world's number one cause of death—cardiovascular disease (CVD) (Devi et al., 2013). In India, high systolic blood pressure contributed to an estimated 55% of disability-adjusted life years (DALYs)—the number of years lost to ill-health, disability or death—due to CVD from 1990 to 2016 (India State-Level Disease Burden Initiative CVD Collaborators, 2018).

The impact of season on blood pressure is a well-known but little researched phenomenon. Temperature is among the main factors driving this seasonal patterning, as blood pressure and hypertension prevalence tend to increase as temperature decreases (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010). As hypertension is a key risk factor, CVD morbidity and mortality has shown to exhibit similar patterning by increasing in colder months (Alpérovitch et al., 2009; Goyal et al., 2018, 2019; Lewington et al., 2012; Modesti et al., 2006; Sinha et al., 2010). Overall, research on this phenomenon have focused on high-income countries in temperate regions, which often define seasons differently and experience different temperature variations within and across seasons as compared to other regions of the world (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010).

In order to effectively prevent, diagnose, and control hypertension, countries must have accurate estimations of disease burden and its related variables to implement specific health planning for each state and region (India State-Level Disease Burden Initiative Collaborators, 2017). Additionally, seasonal variation of blood pressure and hypertension can have implications for the diagnoses and treatment by individual clinicians and health workers. Yet, whether blood pressure levels vary by season has not been systematically investigated in India. To our knowledge, no studies have utilized nationally representative survey data to assess the association between season of measurement and systolic blood pressure, diastolic blood pressure, and hypertension. We sought to examine the distribution of blood pressure and hypertension by season in India using recent national data.

Methods

Study Population and Data Source

The Indian Ministry of Health and Family Welfare (MoHFW) carried out the NFHS-4 between 2015 to 2016 which consisted of a questionnaire, health, and biomarker data collected among co-residing household members collected by trained field staff in respondent households (*National Family Health Survey (NFHS-4): India (2015-16)*, 2017). These questionnaires were designed to collect basic demographics, household characteristics, and health information on a total of 2,869,043 men, women, and children covering all 29 states and 7 union territories in the local language. By design, 842,800 men ages 15-54 and non-pregnant women ages 15-49 were eligible for the biomarker assessment, which included blood pressure measurement. We excluded from analysis 23.7% of those eligible for lack of consent to blood pressure measurements, 1.7% for missing or implausible SBP, diastolic blood pressure (DBP), or body mass index (BMI) values, and 3.9% for missing sociodemographic or location data. In total, 596,052 men and women were included in the primary analysis.

Blood pressure Measurement

Biomarker measurements, including SBP, DBP, and BMI were collected by field staff with specialized trainings. For each consenting and eligible respondent, staff conducted three separate blood pressure readings at intervals of five minutes with Omron blood Pressure monitors. An individual's SBP and DBP was calculated as the mean of the second and third readings with values more than five standard deviations from the mean excluded. Respondents were additionally asked about their behavior 30 minutes prior to the first measurement—if they consumed food, alcohol, smoked tobacco, or used other tobacco. Hypertension or elevated blood pressure was defined as either taking blood pressure control medication, having SBP greater than or equal to 140 mm Hg, or having DBP greater than or equal to 90 mm Hg. This definition aligns with the NFHS-4 final report definition (*National Family Health Survey (NFHS-4): India (2015-16)*, 2017).

Definition of Season

We categorized the month of interview into four seasons based on definitions from the India Meteorological Department's Annual Climate Summary in 2018 (*Annual Climate Summary-2018*, 2018). The four seasons were defined as winter (January, February), pre-monsoon (March, April, May), monsoon (June, July, August, September), and post-monsoon (October, November, December).

Covariates

Sociodemographic and location information were also collected and analyzed from the women, men, and household interviews. Models were estimated with and without adjustment for individual demographic factors (for sex, age, rurality), social characteristics (highest education level attained, household head's religion, household head's type of caste or tribe, wealth index), and living conditions relevant to blood pressure (source of drinking water, presence of indoor air conditioning, and coastal [versus inland] state location), blood-pressure altering behaviors within 30 minutes of measurement, and state of residence. Indoor air conditioning and behavior 30 minutes prior to measurement (including eating, drinking alcohol, smoking tobacco, or utilizing other types of tobacco) can temporarily increase or decrease blood pressure and were therefore adjusted for in the models. Coastal states were included as a covariate as humidity has been shown to impact blood pressure in conjunction with temperature. State of residence may be a proxy for multiple socio-environmental characteristics relevant to blood pressure.

Age was categorized for stratified analysis into the following groups—15-19 years, 20-29 years, 30-39 years, 40-49 years, and 50-54 years. BMI was calculated as weight in kilograms divided by the square of height in meters. Weight and height were measured by Seca 874 digital scales and Seca 213 stadiometers, respectively. BMI was additionally categorized for stratified analysis based on cutoff points endorsed by the WHO—underweight (less than 18.5 kg/m^2), normal (18.5 – 25 kg/m^2), overweight (25 -30 kg/m^2), and obese (greater than 30 kg/m^2) (WHO Expert Committee on

Physical Status & Organization, 1995). We excluded BMI values less than 12 kg/m² or greater than 50 kg/m² as extreme values (Balarajan & Villamor, 2009).

Statistical Analysis

We conducted stratified descriptive analysis to assess whether seasonal patterns were present by key population subgroups. In the first set of stratified analyses, we estimated the mean of each of the three outcomes by sex, rurality, and age group. In a second set of stratified analyses, we estimated the mean SBP and DBP and prevalence of hypertension by sex, rurality, and weight status (underweight, normal, overweight, and obese). These stratifications were chosen as age and BMI were suggested in previous studies to be potential confounders on the association between season and blood pressure outcomes.

We utilized multiple linear regression models to estimate the association between season (a 4-level categorical variable) and continuously specified SBP and DBP. Winter was chosen as the reference group as it is the coldest season and the previous studies suggest has the highest blood pressure (Alpérovitch et al., 2009; Goyal et al., 2018, 2019; Lewington et al., 2012; Modesti et al., 2006; Sinha et al., 2010). We additionally used a multiple logistic regression model to estimate the odds ratio (OR) describing the association between season (reference=winter) and hypertension status. All models were estimated in the total population as well as in urban and rural strata.

Survey sample weights, strata, and clusters were applied to all analyses as the NFHS-4 sample employed a multistage complex survey design. We considered significance to be $p < .05$. Statistical analyses were conducted using SAS 9.4 statistical software (SAS Institute, Cary, NC).

Results

Table 1 presents the sociodemographic, biological, and location information of the analytic sample. The majority of respondents by design were women (n= 503,030 women versus n= 93,022 men). The average age of women (29.48 years) was slightly lower than that of men (31.56 years). We also found that BMI was relatively consistent amongst men (21.99 kg/m²), and women (22.0 kg/m²).

The majority of respondents belonged to a scheduled caste or other backwards class, with higher rates among rural populations. As expected, higher wealth status, piped water, and air conditioning were more prevalent in urban areas. We found the Southern region to have the greatest representation among men (24.7%) and women (25.2%) and the Northeastern region to have the least representation among men (2.7%) and women (3.1%).

We observed seasonal variation in mean SBP and DBP and percentage of hypertension across strata defined by sex, rurality, and age group (Tables 3, 5, and 7) and sex, rurality, and BMI group (Table 4, 6, and 8). SBP and DBP typically increased with the age groups, with higher average measurements among men and rural populations. Similarly, SBP and DBP typically increased with BMI group, with higher average measurements of men and rural populations. We found that hypertension prevalence also increased with age group and BMI group. Unlike SBP and DBP, hypertension prevalence was often higher in urban populations.

Table 9 shows the adjusted and unadjusted results of the multiple linear regression models estimating the average difference in SBP by season in the total, urban, and rural Indian populations. In the unadjusted and adjusted models, seasonal variation was apparent with post-monsoon, pre-monsoon, and monsoon seasons showing statistically significant differences compared to winter. Adjusted for sex, age, rurality, highest education level attained, household head's religion, household head's type of caste or tribe, wealth index, source of drinking water, presence of indoor air conditioning, behavior 30 minutes prior to measurement, state of residence, and coastal (versus inland) state location, the pre-monsoon season demonstrated the largest mean difference with -1.95 mm Hg (95% CI: -1.96, -1.95) followed by monsoon season with an average difference of -1.84 mm Hg (95% CI: -1.85, -1.83). Post-monsoon season was calculated to have the smallest average difference -1.47 mm Hg (95% CI: -1.52, -1.42). This pattern was consistent amongst adjusted models for urban and rural populations, but there were greater average differences of SBP in rural populations. Unadjusted models for all populations displayed greatly different patterning with post-monsoon season showing an increase in SBP in comparison to winter.

Table 10 shows similar results for DBP as the adjusted and unadjusted models all demonstrated statistically significant differences of DBP in pre-monsoon, monsoon, and post-monsoon as compared to winter. Adjusted for the same covariates, DBP for the total population followed similar patterns as SBP with all seasons showing a decrease in comparison to winter. Pre-monsoon season and monsoon season displayed similarly large mean differences of -2.10 mm Hg (95% CI: -2.11, -2.10) and -2.13 mm Hg (95% CI: -2.13, -2.12), respectively. Post-monsoon season showed the smallest mean difference with 1.16 mm Hg (95% CI: -1.20, -1.11). Adjusted rural models also estimated larger mean differences in DBP as compared to urban populations. Additionally, unadjusted models differed in that post-monsoon season was estimated to have an increase in average difference of DBP versus winter.

We observed a statistically significant association between season and hypertension in all adjusted and unadjusted models. As expected, the relative odds of hypertension were lower in monsoon, pre-monsoon, and post-monsoon seasons as compared to winter in fully adjusted models (Table 11). The odds of hypertension were lowest in monsoon season with an OR of 0.53 (95% CI: 0.53, 0.58) followed by pre-monsoon season with an OR of 0.64 (95% CI: 0.62, 0.67). The odds of hypertension were greatest in the post-monsoon season with an OR of 0.82 (95% CI: 0.76, 0.90). Similar to previous unadjusted models, odds of hypertension were greater in post-monsoon season. When stratified by rurality, adjusted models demonstrated differing patterns from SBP and DBP. The adjusted urban models estimated higher odds of hypertension in pre-monsoon and monsoon seasons as compared to adjusted rural models.

Discussion

This large cross-sectional study utilized nationally representative data from India to evaluate the association of season of measurement with systolic blood pressure, diastolic blood pressure, and percentage of hypertension among men and non-pregnant women. This research makes a novel contribution to the scant body of literature on this question in India. We found that mean SBP, DBP, and percentage of hypertension varied by season, and that these patterns were consistent across strata of sex, rurality, age, and weight status. We found that SBP, DBP, and hypertension were statistically significantly lower in pre-monsoon, post-monsoon, and monsoon seasons as compared to winter in fully adjusted models across urban and rural settings.

In the total population, all three blood pressure outcomes in the post-monsoon season differed the least from those observed in the winter season. Pre-monsoon season demonstrated the largest average decrease in SBP, while we found the largest average decrease in DBP in the monsoon season. The odds of hypertension were the greatest in post-monsoon as compared to winter, reflecting the smallest average decrease in SBP and DBP. Additionally, monsoon season demonstrated the smallest odds of hypertension in comparison to winter. It is important to note that the NFHS-4 definition of hypertension includes self-reported use of blood pressure control medication, which would influence the odds of hypertension as compared to the average SBP and DBP statistics. Higher odds of hypertension in urban as compared to rural models could be partially due to a greater access to healthcare and therefore blood pressure control medication in urban populations.

Comparing pre-monsoon with winter, SBP differences were similar among urban (-1.94 mm Hg; 95% CI: -1.9.5, -1.93) and rural (-1.93 mm Hg; 95% CI: -1.9.4, -1.91) populations. However, seasonal differences were otherwise larger in rural settings than in urban ones. For example, average difference of SBP as compared to winter was -2.02 mm Hg (95% CI: -2.03, -2.01) for rural populations, but only -1.56 mm Hg (95% CI: -1.57, -1.56) for urban populations. DBP displayed similar patterns. This difference is likely due to a greater seasonal variation in lifestyle and diets and increased exposure to external factors that impact blood pressure such as outdoor temperature and humidity amongst rural populations. As expected, the odds of hypertension were higher in urban populations as compared to rural.

These general trends in the data are consistent with previous studies in India and other global surveys. A review of the literature highlights two main approaches to assessing the relationship between season of measurement and SBP, DBP, and hypertension: 1) Longitudinal studies tracking the same individuals over time; and 2) Cross-sectional studies observing measures for a population in different seasons.

Studies using a longitudinal analysis approach had much smaller sample sizes, ranging from 28 subjects to 978 subjects, and demonstrated larger mean differences between winter and summer than our analyses. One study by the Daynard Medical College and Hospital in Punjab verified that both mean SBP and DBP were higher in the winter as compared to summer with a mean difference of 9.01 (95% CI: 7.74, 10.28) and 5.61 (95% CI: 4.75, 6.47), respectively. The prevalence of hypertension was additionally found to be higher in the winter (23.72%) than in the summer (10.12%) (Goyal et al., 2018). A second study by the same group found that ambulatory daytime SBP and DBP were significantly higher in winter as compared to summer, with a mean SBP difference of -6.32 mm Hg (95% CI: -10.69, -1.95) and mean DBP difference of -7.50 mm Hg (95% CI: -12.49, -2.51) (Goyal et al., 2019). Finally, a study in women of an urban slum in eastern Delhi calculated a mean decrease from winter to summer of 11.07 mm Hg of SBP and 6.79 mm Hg of DBP (Sinha et al., 2010).

Other large cross-sectional studies demonstrated similar seasonal patterning. The most closely aligned to our results and the largest of which utilized the WHO MONICA Project Risk Factor Surveys from 25 populations in 16 countries. Researchers concluded that the mean effect was a 2.06 mm Hg (95% CI: 1.05, 3.08) increase in midwinter as compared to midsummer—with larger effects in warmer populations as compared to temperate climates (Barnett et al., 2007). Another study assessed the relationship across 10 regions of China via the China Kadoorie Biobank study. On average, the mean SBP in summer was 10 mm Hg lower than in winter, with more extreme differences recorded in rural areas and among the elderly (Lewington et al., 2012).

To our knowledge, this is the first study utilizing the 2015-16 NFHS-4 to assess the association of seasonality and blood pressure measurements. As noted above, other studies have taken a similar approach with other survey data, but did not focus on India specifically. The large sample size allowed us several advantages including relative precision of our results. Additionally, we had access to biological, location, and sociodemographic characteristics from NFHS-4, which allowed us to create tables stratified on these factors and adjust for them in the linear and logistic regression models. This approach aligns with current efforts in etiologic research which routinely take into consideration wealth status, demographic background, and other characteristics. Furthermore, previous studies in India were focused on urban populations, while our study includes estimates for rural populations specifically.

This study has several limitations. The largest limitation was that the survey was not conducted evenly across the months of the year, particularly with low percentages in the winter months of November, December, and January. This was likely due to seasonal holiday patterns in India, which tend to provide vacation time in the winter months. Due to the nature of NFHS-4, only men ages 15-54 and women 15-49 were sampled for their blood pressure measurements leaving out the elderly, who are at higher risk for elevated blood pressure. Additionally, there were a large percentage (23.7%) of people who were excluded from the biomarker sample because they did not consent to participate in the blood pressure measurement portion. Others were excluded for lack of complete sociodemographic, location, and biological information. These exclusions could contribute to bias in the estimates. Finally, blood pressure was only measured on one occasion and therefore we were limited to measurements taken in one sitting when two separate occasions would have been preferable in estimated the odds of hypertension.

To better understand the causes of seasonal variation, future research could seek to incorporate data external to the variables available within NFHS. Two such variables are temperature and air particulate on the day of measurement, which could be easily collected from external resources. Both temperature and air particulate matter have been demonstrated to temporarily increase or decrease blood pressure (Alpérovitch et al., 2009; Barnett et al., 2007; Giorgini et al., 2015; Goyal et al., 2018, 2019; Sinha et al., 2010).

In summary, we found that average SBP, DBP, and hypertension were statistically significantly lower in pre-monsoon, post-monsoon, and monsoon seasons as compared to winter. Seasonal variation of blood pressure and hypertension has potential implications for blood pressure management and etiologic research. Particularly as CVD events appear to follow similar patterning, those with high blood pressure could need to be more closely monitored in winter to ensure their blood pressure remains adequately controlled. Additionally, there are increasing efforts to compare the global burden of disease for public health planning and to stimulate etiologic research. These comparisons generally fail to take into account seasonal variation in blood pressure, and its potential implication on mis-estimation of differences in blood pressure and hypertension across and within countries. Individual clinicians and population-based studies should take season into account for their diagnoses, treatment, and epidemiological analyses, particularly those that compare across populations.

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Tables

Table 1: Characteristics of Indian Women ages 15-49 (n=503,030)

			Women		
			Total	**Urban**	**Rural**
			(n= 503,030)	**(n= 163,587)**	**(n= 339,443)**
Sociodemographic					
	Age, years, mean		29.48	30.37	28.96
		95% CI	29.44, 29.52	30.29, 30.46	28.92, 29.00
	Highest Education Attained, %				
		No Education, preschool	17.4	10.0	21.6
		Primary	14.0	10.6	15.9
		Secondary	53.7	54.9	53.0
		Higher	14.8	24.2	9.3
		Don't know	0.2	0.2	0.2
	Religion, %				
		Hindu	82.3	77.3	85.4
		Muslim	11.8	16.3	9.2
		Other	5.7	6.4	5.3
	Type of Caste or Tribe, %				
		Scheduled Caste	21.4	17.9	23.5
		Scheduled Tribe	7.9	4.0	10.2
		Other Backwards Class	45.2	45.8	44.9
		General	25.4	32.2	21.5
	Wealth Index, %				
		Poorest	14.3	2.0	21.5
		Poorer	18.0	5.5	25.2
		Middle	20.9	14.2	24.7
		Richer	23.0	30.8	18.4
		Richest	23.9	47.5	10.2
	Source of Drinking Water, %				
		Piped Water	46.8	68.2	34.4
		Tube Well Water	39.3	18.6	52.2
		Dug Well Water	7.3	4.6	8.9
		Surface Water	1.3	0.7	1.6
		Other	5.4	8.0	4.0
	Air Conditioner/Cooler, %		21.0	35.0	12.8
Biological					
	Body Mass Index, kg/m2, mean		22	23.29	21.24
		95% CI	21.97, 22.02	23.24, 23.35	21.22, 21.27
	Eaten 30 minutes prior, %		28.7	28.1	29.1

	Coffee/Tea 30 minutes prior, %		21.1	22.4	20.4
	Smoke 30 minutes prior, %		0.9	0.6	1.1
	Other Tobacco 30 minutes prior, %		2.8	2.0	3.3
Location					
	Region, %				
		North	12.0	13.5	11.2
		Central	22.2	20.0	23.4
		East	23.1	13.7	28.6
		Western	14.4	19.8	11.3
		Southern	25.2	30.9	21.8
		Northeastern	3.1	2.0	3.7
	Coast, %				
		Coastal State	47.7	54.8	43.6
		Inland State	52.3	45.2	56.4
Season of measurement, %					
	Winter		9.3	6.1	11.2
	Pre-monsoon		59.8	61.8	58.6
	Monsoon		29.5	31.2	28.6
	Post-monsoon		1.4	1.0	1.7

Source: NFHS-4, 2015-2016

Table 2: Characteristics of Indian Men ages 15-54 (n=93,022)

			Men		
			Total	**Urban**	**Rural**
			(n= 93,022)	**(n= 30,636)**	**(n= 62,386)**
Sociodemographic					
	Average, years, mean		31.56	31.98	31.31
		95% CI	31.47, 31.66	31.79, 32.18	31.21, 31.42
	Highest Education Attained, %				
		No Education, preschool	8.2	5.4	9.9
		Primary	12.4	9.4	14.2
		Secondary	60.5	58.1	62.0
		Higher	18.6	26.9	13.6
		Don't know	0.2	0.2	0.2
	Religion, %				
		Hindu	83.7	79.2	86.4
		Muslim	10.9	15.1	15.1
		Other	5.3	5.7	5.7
	Type of Caste or Tribe, %				
		Scheduled Caste	20.9	17.0	23.3
		Scheduled Tribe	8.3	4.2	10.7
		Other Backwards Class	45.9	46.9	45.3
		General	24.9	31.9	20.7
	Wealth Index, %				
		Poorest	13.2	2.1	19.8
		Poorer	18.5	6.3	25.7
		Middle	21.5	14.8	25.5
		Richer	22.8	30.0	18.6
		Richest	23.9	46.8	10.3
	Source of Drinking Water, %				
		Piped Water	48.3	69.5	35.6
		Tube Well Water	37.7	18.1	49.3
		Dug Well Water	7.4	4.3	9.2
		Surface Water	1.3	0.6	1.7
		Other	5.4	7.5	4.2
	Air Conditioner/Cooler, %		20.3	32.6	12.9
Biological					
	Body Mass Index, kg/m2, mean		21.99	22.91	21.44
		95% CI	21.93, 22.04	22.80, 23.02	21.39, 21.49
	Eaten 30 minutes prior, %		28.1	27.8	28.3
	Coffee/Tea 30 minutes prior, %		22.3	23.6	21.5

	Smoke 30 minutes prior, %		10.5	8.8	11.4
	Other Tobacco 30 minutes prior, %		12.8	9.8	14.5
Location					
	Region, %				
		North	12.7	13.0	12.5
		Central	23.1	19.9	25.0
		East	19.0	12.2	23.0
		Western	17.7	22.8	14.7
		Southern	24.7	30.3	21.4
		Northeastern	2.7	1.7	3.4
	Coast, %				
		Coastal State	49.2	56.7	44.8
		Inland State	50.8	43.3	55.2
Season of measurement, %					
	Winter		7.0	4.7	8.3
	Pre-monsoon		58.6	61.4	57.0
	Monsoon		33.0	33.0	33.1
	Post-monsoon		1.3	0.9	1.6

Source: NFHS-4, 2015-2016

Table 3: Seasonal Variation in SBP by Age

			Mean SBP (mm Hg) by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		15-19	109.0 (108.4,109.7)	105.1 (104.8,105.4)	105.6 (105.2,106.0)	108.0 (106.4,109.7)
		20-29	111.5 (111.0,111.9)	108.4 (108.2,108.7)	108.9 (108.6,109.1)	111.9 (110.8,113.0)
		30-39	117.1 (116.6,117.7)	114.3 (114.0,114.7)	114.1 (113.8,114.4)	117.6 (116.3,118.8)
		40-49	124.2 (123.3,125.0)	120.9 (120.5,121.3)	120.6 (120.1,121.0)	124.4 (123.0,125.8)
	Rural (n= 339,443)					
		15-19	111.4 (111.1,111.7)	108.1 (107.9,108.3)	107.7 (107.5,107.9)	111.8 (111.1,112.4)
		20-29	113.3 (113.0,113.5)	110.3 (110.2,110.4)	109.7 (109.5,109.8)	114.5 (114.0,115.0)
		30-39	117.7 (117.4,117.9)	114.4 (114.3,114.6)	113.8 (113.6,114.1)	118.6 (117.9,119.3)
		40-49	123.1 (122.7,123.6)	120.0 (119.7,120.2)	119.6 (119.3,120.0)	125.4 (124.4,126.4)
	Total (n= 503,030)					
		15-19	110.9 (110.7,111.2)	107.1 (107.0,107.3)	107.0 (106.8,107.2)	111.0 (110.4,111.6)
		20-29	112.8 (112.6,113.1)	109.6 (109.5,109.7)	109.4 (109.2,109.5)	113.9 (113.4,114.4)
		30-39	117.5 (117.3,117.8)	114.4 (114.2,114.6)	113.9 (113.8,114.1)	118.3 (117.7,118.9)
		40-49	123.4 (123.0,123.8)	120.4 (120.1,120.6)	120.0 (119.8,120.3)	125.1 (124.3,125.9)
Men						
	Urban (n= 30,636)					
		15-19	116.8 (115.5,118.2)	113.3 (112.5,114.0)	112.9 (112.2,113.6)	114.7 (112.5,116.9)
		20-29	121.6 (120.1,123.2)	118.4 (117.8,119.0)	118.4 (117.9,119.0)	120.0 (118.4,121.6)
		30-39	124.1 (122.5,125.7)	121.5 (120.8,122.1)	121.0 (120.4,121.6)	125.6 (121.6,129.7)
		40-49	127.4 (125.7,129.1)	125.7 (124.8,126.5)	124.1 (123.3,124.9)	127.9 (125.2,130.6)
		50-54	130.5 (127.6,133.4)	126.1 (124.5,127.6)	126.4 (125.0,127.8)	130.7 (122.9,138.4)
	Rural (n= 62,386)					
		15-19	118.5 (117.7,119.3)	114.1 (113.7,114.4)	113.8 (113.3,114.3)	118.1 (116.4,119.9)
		20-29	120.9 (120.2,121.5)	118.6 (118.3,118.9)	118.0 (117.6,118.4)	119.9 (118.5,121.3)
		30-39	122.6 (121.8,123.5)	120.6 (120.2,121.0)	119.8 (119.3,120.3)	123.4 (122.0,124.9)
		40-49	124.5 (123.4,125.6)	122.9 (122.5,123.4)	121.6 (121.0,122.2)	125.6 (123.3,128.0)
		50-54	127.5 (125.6,129.4)	124.6 (123.8,125.5)	124.5 (123.2,125.8)	131.1 (126.9,135.2)
	Total (n= 93,022)					
		15-19	118.1 (117.4,118.8)	113.8 (113.4,114.1)	113.5 (113.1,113.9)	117.5 (116.0,118.9)
		20-29	121.1 (120.4,121.7)	118.5 (118.3,118.8)	118.1 (117.8,118.5)	119.9 (118.8,121.0)
		30-39	123.0 (122.2,123.7)	120.9 (120.6,121.3)	120.2 (119.9,120.6)	123.9 (122.5,125.3)
		40-49	125.2 (124.3,126.2)	124.0 (123.6,124.5)	122.6 (122.0,123.1)	126.2 (124.3,128.1)
		50-54	128.4 (126.8,129.9)	125.3 (124.4,126.1)	125.2 (124.3,126.2)	131.0 (127.2,134.7)

Source: NFHS-4, 2015-2016

Table 4: Seasonal Variation in SBP by Weight Status

			Mean SBP (mm Hg) by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		Underweight	108.3 (107.7,109.0)	104.7 (104.4,105.1)	105.8 (105.4,106.1)	109.4 (107.7,111.1)
		Normal	114.7 (114.2,115.1)	111.4 (111.2,111.7)	111.5 (111.2,111.7)	115.2 (114.3,116.2)
		Overweight	119.8 (119.0,120.5)	116.7 (116.3,117.1)	116.8 (116.4,117.2)	121.7 (120.2,123.1)
		Obese	122.2 (121.1,123.4)	119.1 (118.5,119.6)	119.0 (118.4,119.6)	122.1 (119.3,124.9)
	Rural (n= 339,443)					
		Underweight	112.1 (111.8,112.4)	108.3 (108.1,108.4)	107.7 (107.5,107.9)	113.4 (112.7,114.1)
		Normal	115.7 (115.5,115.9)	113.0 (112.9,113.1)	112.4 (112.2,112.6)	117.8 (117.3,118.2)
		Overweight	122.5 (121.9,123.0)	118.7 (118.4,118.9)	118.1 (117.7,118.5)	123.8 (122.5,125.1)
		Obese	123.2 (122.2,124.2)	120.8 (120.2,121.3)	120.8 (119.9,121.8)	124.0 (120.9,127.2)
	Total (n= 503,030)					
		Underweight	111.4 (111.2,111.7)	107.4 (107.2,107.5)	107.1 (106.9,107.3)	112.7 (112.1,113.4)
		Normal	115.5 (115.3,115.7)	112.4 (112.3,112.6)	112.0 (111.9,112.2)	117.2 (116.7,117.6)
		Overweight	121.5 (121.0,121.9)	117.6 (117.4,117.9)	117.4 (117.2,117.7)	122.9 (121.9,123.8)
		Obese	122.7 (122.0,123.5)	119.7 (119.3,120.1)	119.7 (119.1,120.2)	122.9 (120.8,125.0)
Men						
	Urban (n= 30,636)					
		Underweight	116.6 (114.8,118.4)	111.9 (111.1,112.7)	112.5 (111.6,113.3)	120.5 (115.5,125.5)
		Normal	122.1 (120.9,123.3)	120.0 (119.6,120.5)	119.6 (119.2,120.1)	121.8 (119.9,123.7)
		Overweight	129.2 (127.4,131.1)	125.4 (124.6,126.3)	125.2 (124.4,126.0)	128.3 (125.2,131.4)
		Obese	128.4 (125.4,131.3)	126.7 (124.6,128.8)	125.2 (123.6,126.8)	133.9 (117.6,150.2)
	Rural (n= 62,386)					
		Underweight	116.4 (115.7,117.2)	113.3 (112.9,113.7)	112.9 (112.4,113.4)	118.8 (117.0,120.7)
		Normal	122.8 (122.2,123.3)	120.1 (119.8,120.3)	119.2 (118.9,119.6)	122.4 (121.2,123.6)
		Overweight	129.5 (128.3,130.7)	126.3 (125.7,126.8)	125.4 (124.6,126.1)	128.4 (125.6,131.3)
		Obese	134.1 (131.4,136.7)	128.4 (127.1,129.8)	126.2 (124.0,128.4)	130.0 (124.3,135.8)
	Total (n= 93,022)					
		Underweight	116.5 (115.8,117.2)	112.9 (112.5,113.3)	112.8 (112.4,113.2)	119.1 (117.3,120.9)
		Normal	122.6 (122.1,123.1)	120.1 (119.8,120.3)	119.4 (119.1,119.6)	122.3 (121.3,123.3)
		Overweight	129.4 (128.3,130.4)	125.8 (125.3,126.3)	125.3 (124.7,125.8)	128.4 (126.3,130.5)
		Obese	130.9 (128.7,133.1)	127.4 (126.0,128.8)	125.7 (124.3,127.0)	131.2 (124.6,137.9)

Source: NFHS-4, 2015-2016

Table 5: Seasonal Variation in DBP by Age

			Mean DBP (mm Hg) by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		15-19	73.2 (72.6,73.7)	70.1 (69.8,70.3)	70.5 (70.2,70.7)	73.3 (72.0,74.6)
		20-29	76.0 (75.7,76.4)	73.7 (73.5,73.9)	74.0 (73.8,74.3)	76.7 (76.0,77.5)
		30-39	80.7 (80.3,81.1)	78.3 (78.1,78.5)	78.3 (78.1,78.5)	81.2 (80.1,82.2)
		40-49	83.4 (83.0,83.9)	81.4 (81.1,81.7)	81.3 (81.1,81.6)	83.2 (82.3,84.1)
	Rural (n= 339,443)					
		15-19	73.7 (73.5,73.9)	70.7 (70.5,70.8)	70.7 (70.5,70.9)	74.0 (73.5,74.5)
		20-29	76.4 (76.2,76.6)	74.0 (73.9,74.1)	73.8 (73.7,73.9)	77.0 (76.7,77.4)
		30-39	80.1 (79.9,80.4)	77.8 (77.7,78.0)	77.6 (77.4,77.7)	80.2 (79.7,80.7)
		40-49	82.4 (82.1,82.7)	80.3 (80.2,80.5)	80.2 (80.0,80.5)	83.1 (82.5,83.7)
	Total (n= 503,030)					
		15-19	73.6 (73.4,73.8)	70.5 (70.4,70.6)	70.6 (70.5,70.8)	73.9 (73.4,74.3)
		20-29	76.3 (76.1,76.4)	73.9 (73.8,74.0)	73.9 (73.8,74.0)	77.0 (76.6,77.3)
		30-39	80.3 (80.1,80.5)	78.0 (77.9,78.1)	77.9 (77.7,78.0)	80.5 (80.0,80.9)
		40-49	82.7 (82.4,82.9)	80.8 (80.6,80.9)	80.7 (80.5,80.9)	83.1 (82.6,83.6)
Men						
	Urban (n= 30,636)					
		15-19	74.0 (72.7,75.3)	71.2 (70.6,71.7)	71.5 (71.0,72.0)	73.8 (72.0,75.7)
		20-29	79.9 (78.9,81.0)	77.6 (76.9,78.2)	77.5 (77.1,78.0)	80.0 (78.7,81.2)
		30-39	84.4 (83.2,85.6)	81.9 (81.4,82.4)	81.5 (81.1,82.0)	84.5 (81.6,87.5)
		40-49	87.0 (85.8,88.2)	84.6 (84.0,85.2)	84.1 (83.4,84.8)	85.9 (84.0,87.7)
		50-54	87.2 (85.6,88.8)	84.2 (83.2,85.2)	83.9 (82.9,84.9)	86.5 (81.2,91.9)
	Rural (n= 62,386)					
		15-19	73.8 (73.1,74.4)	71.0 (70.7,71.3)	71.3 (70.9,71.7)	73.8 (72.9,74.8)
		20-29	78.3 (77.7,78.8)	76.3 (76.1,76.6)	76.1 (75.8,76.5)	78.5 (77.4,79.6)
		30-39	82.3 (81.7,82.9)	80.4 (80.1,80.7)	80.1 (79.7,80.5)	83.1 (81.8,84.5)
		40-49	84.3 (83.4,85.1)	82.7 (82.4,83.1)	82.1 (81.7,82.6)	83.5 (82.0,84.9)
		50-54	84.7 (83.5,85.9)	82.6 (82.0,83.2)	82.6 (81.8,83.4)	87.0 (84.3,89.6)
	Total (n= 93,022)					
		15-19	73.8 (73.2,74.4)	71.1 (70.8,71.3)	71.4 (71.1,71.7)	73.8 (73.0,74.7)
		20-29	78.7 (78.2,79.2)	76.8 (76.5,77.1)	76.6 (76.4,76.9)	78.9 (78.0,79.8)
		30-39	82.8 (82.3,83.4)	81.0 (80.7,81.3)	80.6 (80.3,80.9)	83.4 (82.2,84.6)
		40-49	84.9 (84.2,85.6)	83.5 (83.1,83.8)	82.9 (82.5,83.3)	84.1 (82.9,85.3)
		50-54	85.4 (84.4,86.4)	83.3 (82.8,83.9)	83.1 (82.5,83.8)	86.8 (84.3,89.3)

Source: NFHS-4, 2015-201

<u>Table 6:</u> Seasonal Variation in DBP by Weight Status

			Mean DBP (mm Hg) by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		Underweight	73.6 (73.1,74.1)	70.7 (70.4,71.0)	71.4 (71.2,71.7)	74.5 (73.4,75.5)
		Normal	77.5 (77.2,77.9)	75.1 (74.9,75.3)	75.1 (74.9,75.3)	78.6 (77.9,79.3)
		Overweight	81.9 (81.4,82.3)	79.6 (79.4,79.9)	80.0 (79.7,80.2)	83.0 (82.0,84.1)
		Obese	85.0 (84.2,85.7)	82.3 (82.0,82.7)	82.8 (82.4,83.2)	83.5 (82.1,85.0)
	Rural (n= 339,443)					
		Underweight	75.2 (75.0,75.4)	72.2 (72.1,72.3)	72.1 (72.0,72.3)	76.2 (75.7,76.6)
		Normal	77.7 (77.5,77.8)	75.5 (75.4,75.6)	75.3 (75.2,75.4)	78.6 (78.3,79.0)
		Overweight	83.1 (82.7,83.4)	80.4 (80.2,80.5)	80.2 (79.9,80.5)	83.8 (83.0,84.6)
		Obese	84.6 (83.9,85.2)	82.8 (82.4,83.1)	83.2 (82.7,83.7)	84.1 (82.1,86.1)
	Total (n= 503,030)					
		Underweight	74.9 (74.7,75.2)	71.8 (71.7,72.0)	71.9 (71.8,72.1)	75.9 (75.4,76.3)
		Normal	77.7 (77.5,77.8)	75.4 (75.3,75.5)	75.2 (75.1,75.3)	78.6 (78.3,78.9)
		Overweight	82.6 (82.3,82.9)	80.0 (79.8,80.1)	80.1 (79.9,80.3)	83.5 (82.8,84.1)
		Obese	84.8 (84.3,85.2)	82.5 (82.2,82.8)	83.0 (82.6,83.3)	83.7 (82.5,85.0)
Men						
	Urban (n= 30,636)					
		Underweight	76.1 (74.2,78.0)	72.6 (72.0,73.2)	73.8 (73.2,74.5)	80.7 (77.5,83.8)
		Normal	81.0 (80.2,81.7)	79.0 (78.6,79.4)	78.9 (78.5,79.3)	80.8 (79.4,82.2)
		Overweight	86.9 (85.6,88.3)	84.2 (83.5,84.9)	83.6 (83.1,84.2)	86.1 (83.6,88.7)
		Obese	87.7 (85.7,89.7)	85.7 (84.3,87.0)	85.2 (83.9,86.4)	87.5 (81.2,93.7)
	Rural (n= 62,386)					
		Underweight	76.0 (75.3,76.6)	73.1 (72.8,73.4)	73.1 (72.7,73.5)	77.9 (76.6,79.1)
		Normal	80.6 (80.2,81.0)	78.4 (78.2,78.6)	78.2 (77.9,78.5)	80.0 (79.3,80.7)
		Overweight	86.1 (85.0,87.2)	83.9 (83.5,84.3)	83.3 (82.8,83.9)	88.1 (85.2,91.1)
		Obese	89.5 (87.3,91.7)	86.0 (84.9,87.0)	85.1 (83.5,86.7)	87.4 (84.3,90.4)
	Total (n= 93,022)					
		Underweight	76.0 (75.4,76.6)	73.0 (72.7,73.2)	73.3 (73.0,73.7)	78.3 (77.1,79.6)
		Normal	80.7 (80.3,81.0)	78.6 (78.4,78.8)	78.5 (78.2,78.7)	80.2 (79.5,80.8)
		Overweight	86.5 (85.6,87.3)	84.1 (83.6,84.5)	83.5 (83.1,83.9)	87.4 (85.3,89.4)
		Obese	88.5 (87.0,90.0)	85.8 (84.9,86.7)	85.2 (84.2,86.2)	87.4 (84.5,90.3)

Source: NFHS-4, 2015-2016

Table 7: Seasonal Variation in the Prevalence of Hypertension by Age

			% of Adults with Hypertension by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		15-19	4.7	2.2	2.0	4.4
		20-29	8.5	5.4	4.6	8.8
		30-39	18.1	13.7	12.1	20.3
		40-49	32.1	26.7	23.6	32.2
	Rural (n= 339,443)					
		15-19	4.4	2.8	2.4	4.9
		20-29	8.8	5.6	4.3	9.4
		30-39	18.1	12.2	10.7	18.3
		40-49	28.6	21.8	20.5	29.5
	Total (n= 503,030)					
		15-19	4.5	2.6	2.3	4.8
		20-29	8.7	5.6	4.4	9.3
		30-39	18.1	12.8	11.3	18.9
		40-49	29.5	23.9	21.9	30.3
Men						
	Urban (n= 30,636)					
		15-19	6.4	2.8	2.6	2.3
		20-29	16.5	10.4	9.3	13.7
		30-39	27.2	19.9	18.3	32.2
		40-49	43.3	33.4	27.7	33.7
		50-54	47.8	35.3	30.7	39.7
	Rural (n= 62,386)					
		15-19	6.6	3.2	3.1	4.9
		20-29	13.4	9.0	7.7	11.8
		30-39	23.5	17.2	15.1	25.4
		40-49	29.3	25.9	22.7	28.6
		50-54	36.6	28.5	27.5	44.8
	Total (n= 93,022)					
		15-19	6.5	3.1	2.9	4.4
		20-29	14.2	9.5	8.2	12.3
		30-39	24.4	18.3	16.2	26.8
		40-49	32.7	28.9	24.6	29.9
		50-54	39.7	31.4	28.8	43.1

Source: NFHS-4, 2015-2016

<u>Table 8:</u> Seasonal Variation in the Prevalence of Hypertension by Weight Status

			% of Adults with Hypertension by Season			
			Winter	**Pre-Monsoon**	**Monsoon**	**Post Monsoon**
Women						
	Urban (n= 163,587)					
		Underweight	6.6	3.8	3.4	6.6
		Normal	12.1	8.7	6.9	14.7
		Overweight	24.2	18.3	17.5	28.0
		Obese	33.6	28.3	27.9	32.3
	Rural (n= 339,443)					
		Underweight	8.9	5.2	3.9	10.4
		Normal	12.2	8.7	7.5	14.3
		Overweight	27.4	19.5	17.7	28.6
		Obese	35.5	27.7	29.1	33.9
	Total (n= 50,030)					
		Underweight	8.5	4.8	3.8	9.7
		Normal	12.2	8.7	7.3	14.4
		Overweight	26.2	18.9	17.6	28.4
		Obese	34.6	28.0	28.4	33.0
Men						
	Urban (n= 30,636)					
		Underweight	14.8	5.3	5.6	15.9
		Normal	19.1	14.8	13.3	20.6
		Overweight	41.8	30.3	27.2	32.2
		Obese	42.3	39.4	33.1	52.5
	Rural (n= 62,386)					
		Underweight	10.1	6.2	5.3	12.7
		Normal	19.1	13.4	12.2	17.9
		Overweight	38.7	31.0	25.6	42.6
		Obese	54.7	41.7	37.5	43.5
	Total (n= 93,022)					
		Underweight	10.9	5.9	5.4	13.3
		Normal	19.1	13.9	12.6	18.5
		Overweight	40.0	30.6	26.4	38.6
		Obese	47.9	40.3	35.2	46.4

Source: NFHS-4, 2015-2016

Table 9: Association of Season of Measurement with SBP Levels

		Season	β (mm Hg)	95% CI	
All India (n=596,052)	**Unadjusted**	Pre-monsoon	-2.60	-2.61	-2.59
		Monsoon	-2.97	-2.98	-2.97
		Post-Monsoon	1.31	1.27	1.35
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-1.95	-1.96	-1.95
		Monsoon	-1.84	-1.85	-1.83
		Post-Monsoon	-1.47	-1.52	-1.42
		Winter (ref)	1.00		
Urban (n=194,223)	**Unadjusted**	Pre-monsoon	-2.50	-2.51	-2.49
		Monsoon	-2.69	-2.70	-2.68
		Post-Monsoon	0.73	0.58	0.89
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-1.94	-1.95	-1.93
		Monsoon	-1.56	-1.57	-1.56
		Post-Monsoon	-1.18	-1.39	-0.98
		Winter (ref)	1.00		
Rural (n=401,829)	**Unadjusted**	Pre-monsoon	-2.62	-2.63	-2.61
		Monsoon	-3.10	-3.11	-3.09
		Post-Monsoon	1.50	1.48	1.52
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-1.93	-1.94	-1.91
		Monsoon	-2.02	-2.03	-2.01
		Post-Monsoon	-1.47	-1.49	-1.46
		Winter (ref)	1.00		

Note: Coefficients were estimated from linear regression models. Adjusted models accounted for sex, age, rurality, highest education level attained, household head's religion, household head's type of caste or tribe, wealth index, source of drinking water, presence of indoor air conditioning, behavior 30 minutes prior to measurement, state of residence, and coastal (versus inland) state location.

Source: NFHS-4, 2015-2016

Table 10: Association of Season of Measurement with DBP Levels

		Season	β (mm Hg)	95% CI	
All India (n=596,052)	**Unadjusted**	Pre-monsoon	-1.99	-2.00	-1.98
		Monsoon	-2.10	-2.11	-2.10
		Post-Monsoon	0.70	0.66	0.73
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-2.10	-2.11	-2.10
		Monsoon	-2.13	-2.13	-2.12
		Post-Monsoon	-1.16	-1.20	-1.11
		Winter (ref)	1.00		
Urban (n=194,223)	**Unadjusted**	Pre-monsoon	-2.03	-2.04	-2.01
		Monsoon	-2.09	-2.10	-2.07
		Post-Monsoon	0.66	0.55	0.78
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-2.10	-2.11	-2.08
		Monsoon	-1.97	-1.98	-1.96
		Post-Monsoon	-1.13	-1.30	-0.97
		Winter (ref)	1.00		
Rural (n=401,829)	**Unadjusted**	Pre-monsoon	-2.13	-2.14	-2.12
		Monsoon	-2.28	-2.29	-2.27
		Post-Monsoon	0.70	0.68	0.72
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	-2.09	-2.10	-2.09
		Monsoon	-2.23	-2.24	-2.22
		Post-Monsoon	-1.17	-1.19	-1.15
		Winter (ref)	1.00		

Note: Coefficients were estimated from linear regression models. Adjusted models accounted for sex, age, rurality, highest education level attained, household head's religion, household head's type of caste or tribe, wealth index, source of drinking water, presence of indoor air conditioning, behavior 30 minutes prior to measurement, state of residence, and coastal (versus inland) state location.

Source: NFHS-4, 2015-2016

Table 11: Association of Season of Measurement with Hypertension

		Season	Odds Ratio	95% CI	
All India (n=596,052)	**Unadjusted**	Pre-monsoon	0.75	0.72	0.78
		Monsoon	0.64	0.62	0.67
		Post-Monsoon	1.10	1.02	1.17
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	0.64	0.62	0.67
		Monsoon	0.55	0.53	0.58
		Post-Monsoon	0.82	0.76	0.90
		Winter (ref)	1.00		
Urban (n=194,223)	**Unadjusted**	Pre-monsoon	0.76	0.71	0.82
		Monsoon	0.64	0.59	0.68
		Post-Monsoon	1.09	0.97	1.24
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	0.68	0.63	0.74
		Monsoon	0.59	0.54	0.65
		Post-Monsoon	0.79	0.66	0.94
		Winter (ref)	1.00		
Rural (n=401,829)	**Unadjusted**	Pre-monsoon	0.71	0.68	0.74
		Monsoon	0.62	0.59	0.65
		Post-Monsoon	1.10	1.01	1.19
		Winter (ref)	1.00		
	Adjusted	Pre-monsoon	0.63	0.60	0.66
		Monsoon	0.52	0.50	0.56
		Post-Monsoon	0.83	0.75	0.92
		Winter (ref)	1.00		

Note: Coefficients were estimated from linear regression models. Adjusted models accounted for sex, age, rurality, highest education level attained, household head's religion, household head's type of caste or tribe, wealth index, source of drinking water, presence of indoor air conditioning, behavior 30 minutes prior to measurement, state of residence, and coastal (versus inland) state location.

Source: NFHS-4, 2015-2016

Chapter III: Summary, Public Health Implications, and Possible Future Directions

Summary

The impact of season on SBP and diastolic blood pressure (DBP) is a well-known, but little researched, phenomenon. Studies have reported strong seasonal patterning of blood pressure in temperate and European regions of the world (Goyal et al., 2018, 2019; Lewington et al., 2012; Sinha et al., 2010). Generally, this patterning is such that blood pressure and hypertension prevalence is highest in the winter season.

This research question has not been systematically investigated in India. In particular, no studies have utilized the Indian demographic health survey. We examined the cross-sectional association of season of measurement with blood pressure and hypertension in the nationally representative National Family and Health Survey IV. Initial descriptive analysis reported variation in average SBP, DBP, and percentage of hypertension based on sex, rurality, age, and weight status. We found also that SBP, DBP, and odds of hypertension were statistically significantly lower in pre-monsoon, post-monsoon, and monsoon seasons as compared to winter for adjusted models for total, urban, and rural populations.

Public Health Implications

The World Health Organization estimates 1.13 billion people worldwide lived with hypertension—or elevated blood pressure—in 2015, doubling 1975's estimate of 594 million (World Health Organization, 2019). This dramatic rise is predominantly attributed to the increase of risk factors in low- and middle-income countries like India. Hypertension remains one of the major modifiable risk factors for the world's number one cause of death—cardiovascular disease (Devi et al., 2013).

Seasonal variation in blood pressure has potential implications for individual health and epidemiologic measures of blood pressure in the population. Individuals are more likely to experience a number of cardiovascular disease events in the winter months, when blood pressure is also highest (Fares, 2013; Stewart et al., 2017). Therefore, the results of our study may have implications for the management of blood pressure. For example, those with high blood pressure could require up-titration of medication during the winter season, or need to be more closely monitored in winter to ensure their blood pressure remains adequately controlled. Medication dosage could also be impacted with the potential for over medication in the summer and undermedication in the winter.

Additionally, there are increasing efforts to compare the global burden of disease for public health planning and to stimulate etiologic research. Area-level socioeconomic measures, demographic composition, and other characteristics are routinely taken into consideration. These comparisons generally fail to take into account seasonal variation in blood pressure, and its potential implication on mis-estimation of differences in blood pressure and hypertension across and within countries.

Possible Future Directions

To better understand the causes of seasonal variation, future research could seek to incorporate data external to the variables available within NFHS. Two such variables are temperature and air particulate on the day of measurement, which could be easily collected from external resources. Both temperature and air particulate matter have been demonstrated to temporarily increase or decrease blood pressure (Alpérovitch et al., 2009; Barnett et al., 2007; Giorgini et al., 2015; Goyal et al., 2018, 2019; Sinha et al., 2010). In order to effectively prevent, diagnose, and control hypertension, countries must have accurate estimations of disease burden and its related variables to implement specific health planning for each state and region (India State-Level Disease Burden Initiative Collaborators, 2017).

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