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Original Article

Prevalence and risks of hypertension among Indian tribes and its status among the lean and underweight individuals

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ABSTRACT

Objective: With the increased worldwide prevalence of hypertension among the underprivileged populations, fewer studies have reported such risks among Indian tribes. In the context of high prevalence of undernutrition, no such study has examined hypertension among lean and underweight Indian tribal individuals separately.

Methods: We selected total samples of 1066 adult males and 1090 adult females in 20–60 years age-group cross-sectionally to examine the status of hypertension and its risks among nine major tribes in three Indian states; separate analyses for lean and underweight tribal individuals were done.

Results: Increased prevalence of hypertension (females, 14.2%; males, 9.3%) was observed among the tribes with the overall percentage of individuals at adversity (hypertensive + isolated hypertensive) at more than 20% (males 20.1%; females 26.5%). Age-group-wise prevalence showed a sharp rise in the prevalence of hypertension in the 40 + year individuals; additionally, this rise was alarming among females. Undernutrition was observed to be a potential risk factor as a remarkable prevalence of hypertension was observed among the undernourished (approximately 9%) and lean tribal participants (12%). Underweight females were observed to be at higher risk. Tribal statuses were observed to be alarming than the national trends due to their very low average BMI along with high average SBP. A curvilinear prevalence of hypertension was observed while comparing through both the nutritional extremes.

Conclusion: The increased prevalence and risks of hypertension in the background of lean and underweight status of Indian tribes indicates their epidemiological transition burdened with alarming cardio-metabolic health risks that warrant an early and consistent surveillance.

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1. Introduction

Hypertension and its associated CVD cases have gained an alarming rise of 47.8% worldwide by the year 2010 [1]. The disease is a major morbidity factor affecting 1.13 billion people [2] and bringing death to a minimum of nine million [3] in various countries in recent time; it has emerged as a serious public health problem among the poor and underprivileged groups, particularly those living in the low and middle-income countries (LMICs) [2].

Low socioeconomic status and poverty as the foremost inducing factors of undernourishment have evolved as major independent

risk factors for causing various non-communicable diseases including hypertension [2]. Such higher risks among the low and middle-income groups [2,4,5] are due to their high toxic stress out of their food scarcity and socio-economic deprivation [5,6]. India among other LMICs carries one-third of the hypertension burden [2] which is the largest in proportion among all other countries in the world [7].

Indian tribes, otherwise known as Scheduled Tribes (STs) are defined as the indigenous, endogamous, economically self-sufficient population groups with a customary social system, mostly using simple technology for a living and restricted to comparatively isolated geographic regions with less access to modern society. Scheduled Tribes (STs) constituting 8.6% of the total Indian population [8] are the most vulnerable section of the Indian society. Among the huge section of underprivileged population in India [21.9% under below-poverty-line (BPL) category

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along with 15.2% as undernourished] [9], STs with their >85% of the households belonging to the lowest two income quartiles are identified with the large-scale prevalence of poverty among them [10]. The burden of malnourishment among the tribal populations has remained huge during last several decades [5,11–13] with nearly half of the population still suffering from undernutrition [5]. Women and children have been observed to be worst sufferers of this heavy burden of malnourishment [5].

The available major studies on Indian tribal populations [14–19] including the one by NNMB in 2009 [13] have reported the prevalence of hypertension at an elevated level among Indian tribes. NNMB in its report showed an approximate 25% prevalence of hypertension among the adults of the Indian tribes. A meta-analysis has placed the prevalence of hypertension among the Indian tribes at 16% with substantial variation [14] at the population level. However, after the last major study by NNMB (2009) reporting the status of hypertension covering larger Indian tribal landscape, there is no such report from tribal population covering the broader picture of tribal hypertension status [13]. Furthermore, it is important to note that there is no such details reporting on other cardiovascular risks associated with elevated blood pressure like prehypertension and isolated systolic hypertension.

Furthermore, the relationship of BMI (in terms of obesity and undernutrition) with blood pressure (BP) has extensively been pursued in hypertension associated epidemiological research. Nutritional extremes like undernutrition and overweight/obesity have been explained as the major causes of elevated blood pressure in various contexts. However, such studies [20–25] reporting the coprevalence of underweight (low BMI) and elevated BP have less been pursued in developing countries context; the relationship between BMI and hypertension in underweight or lean population from Africa, Asia [26] and South America (Brazil) [27] have brought important inferences to nutritional epidemiology. Furthermore, findings from longitudinal studies [28–30] reporting higher incidences of hypertension and its associated cardiovascular mortality among underweight and lean hypertensive individuals is of high importance for population groups of developing countries like India, and particularly the vulnerable tribal sections with double burden of malnutrition [5]. A curvilinear risk of hypertension associated and other cardiovascular mortalities has been observed for underweight through overweight/obese individuals [28–30]. Evidence from population groups suffering from extreme food insecurity show undernourishment through early childhood as an important causative factor for elevated risk of hypertension in later stages of life [2,31]. It is more intriguing to examine the prevalence of hypertension in the context of adult tribal individuals as they are at the highest risk of experiencing hypertension due to the chronically undernourished childhood experienced by the majority of them. However, no such study has looked into the aspects of the prevalence of hypertension and its risks like prehypertension and isolated systolic hypertension among the underweight or lean adult tribal individuals.

The present study, conducted among the nine major Indian tribes that are experiencing the epidemiological transition continuum, has two major objectives. As the first objective, the study intends to examine the prevalence of hypertension and its risks like prehypertension (in its higher range) and isolated systolic hypertension. In the second point, it aims to examine that how the risk of hypertension is distributed in the lean and underweight sections of the population. The present study among Indian tribes and particularly among a lean or very lean population will generate important information regarding the patterns of prevalence of hypertension that will help towards the prevention and control of the disease.

2. Materials and methods

2.1. Sample

This cross-sectional study was conducted in five different phases by adopting random sampling method. Three states were selected from two different regions, two from the eastern region (West Bengal and Odisha) and one from the western region (Gujarat) of India (Fig. 1). Three tribes were selected from each state based on their predominance of distribution; four districts (as shown in Fig. 1) in three states were chosen for the selection of the sampling areas. The selected tribal settlements were having access to developmental activities and 'urban centers' [32]. Village listings for each of the tribes were prepared on the basis of their population concentration. We first estimated the number of men and women into four 10-year age interval groups (20–60 years) across several villages with the preponderance of specific tribal inhabitants in the population. A sample size of 30 men and women each from each of the four 10-year age interval groups was randomly selected.

Thus, the study comprised a total sample size of 2156 adult tribal participants, with 1066 men and 1090 women (four less than the target sample size). We analyzed the risks and status of hypertension in this total population while we further investigated the 1876 or about 87% of the total 2156 individuals that were either underweight or lean (normal weight) for the risks and prevalence of hypertension among them. The sample size of the present study was tested at 5% level of significance, with a power of 80%. During the study, the same instruments were used for recording the measurements of all the sampled participants. The inhabitants of the selected villages were informed before the commencement of the study. Participants who avoided the sampling were excluded.

Exclusion criteria were as follows: growth and developmental disorders, severe health issues in the past year, and the existence of any secondary cause of hypertension.

2.2. Measurement of anthropometric and metabolic variables

The primary information of the participants such as names, tribes' names, age, and sex were recorded in a structured format. Standard techniques were followed while taking all the anthropometric measurements [33]. The standing height and weight were measured to the nearest of 0.1 cm and 0.1 kg respectively. Stature was measured using a movable anthropometer while the weight was measured by using Omron Karada Scan Body Composition Monitor (Omron Health Care Co., Kyoto, Japan). The participants were encouraged to remove their shoes and heavy clothing before the measurements. BMI was calculated as weight in kilogram (kg) divided by height in meter squared (m^2): kg/m^2 . For measuring the blood pressure [34], the participants were comfortably seated with their arms bare at the heart level with uncrossed legs. The participants were required to refrain from consuming alcohol on the day of study as well as from smoking along with the use of caffeine during the half an hour (at least) before the measurement. The participants, as well as the investigators, maintained no or minimal talk during the time of measurement. Systolic and diastolic blood pressure (SBP and DBP respectively) were recorded twice by using a sphygmomanometer on the right arm of the participants. The cuff bladder was put to the upper arm of the participant covering more than 80% part. A minimum 15-minute rest before the measurement and a 5-min interval between two measurements were maintained and then the average of the two readings was recorded for final analysis.

2.3. Individual classifications

Previous studies reporting from south-east Asian countries have

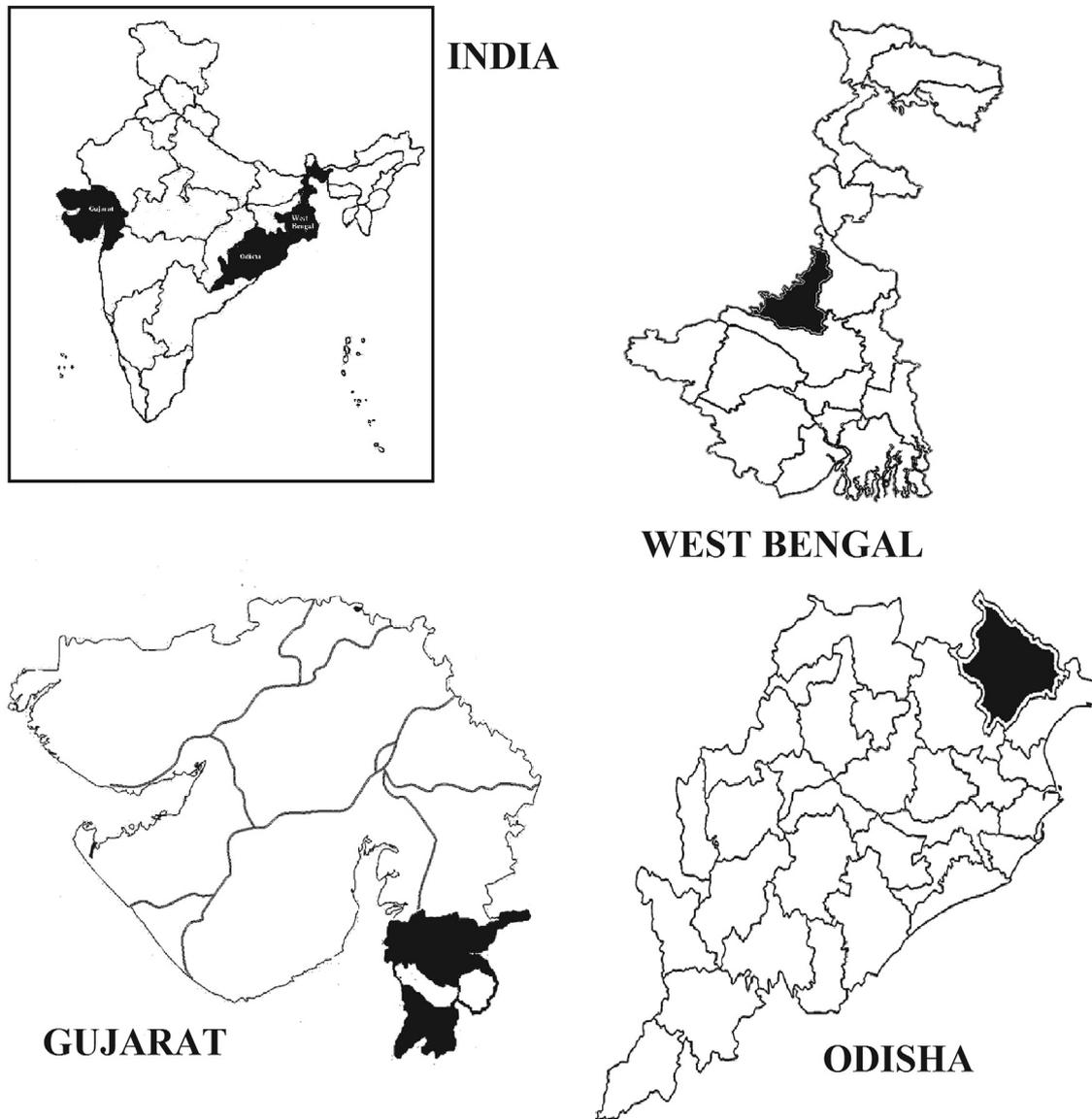


Fig. 1. Geographic locations of the selected districts in West Bengal, Odisha and Gujarat on map of India.

indicated the association of low BMI with hypertension [26,35]. Therefore, we, in the present study, examined the prevalence of hypertension and such risks among both low and normal BMI individuals from selected indigenous tribal populations of India. According to the World Health Organization (WHO) guidelines for Asian populations, individuals with $\text{BMI} < 18.5 \text{ kg/m}^2$ were considered as underweight; $< 18.5 \text{ kg/m}^2$ and $\geq 17 \text{ kg/m}^2$ as mildly underweight; $\geq 16 \text{ kg/m}^2$ and $< 17 \text{ kg/m}^2$ as moderately underweight; $< 16 \text{ kg/m}^2$ as severely underweight while among the normal ($\geq 18.5 \text{ kg/m}^2 < 23 \text{ kg/m}^2$) weight category $\geq 18.5 \text{ kg/m}^2$ and < 20 as low normal and ≥ 20 and $< 23 \text{ kg/m}^2$ as high normal; $\geq 23 \text{ kg/m}^2$ as overweight/obese [36].

Hypertension categories were defined according to the 7th US JNC recommendations [37]. A systolic blood pressure of (SBP) $\geq 130 \text{ mmHg}$ and less than 140 mmHg was considered as pre-hypertensive SBP while $\geq 140 \text{ mmHg}$ was considered as hypertensive. Similarly, a diastolic blood pressure (DBP) of $\geq 85 \text{ mmHg}$ and less than 90 mmHg was considered as pre-hypertensive DBP, while $\geq 90 \text{ mmHg}$ was taken as hypertensive. Participants with blood pressure $\geq 130/85 \text{ mmHg}$ and $< 140/90 \text{ mmHg}$ were considered as

pre-hypertensive. Those with blood pressure $\geq 140/90 \text{ mmHg}$ or under antihypertensive medication were considered as hypertensive. Further, participants with $\text{SBP} \geq 140 \text{ mmHg}$ and $\text{DBP} < 90 \text{ mmHg}$ were considered as Isolated Systolic Hypertensive. Considering the independent cardiovascular risk possessed by Isolated Systolic Hypertension [38] we have included such prevalence in calculating the prevalence rate of hypertension. A similar approach was previously adopted by NNMB (2009) study to map the prevalence of hypertension among Indian tribes [13].

2.4. Statistical analysis

After incorporating and systematizing the data into Microsoft Excel 2007, further analyses were conducted using SPSS version 16.0 for Windows (SPSS Inc., Chicago, Illinois, USA). The integrity of the sampled data was maintained using double entry. The data were cross-checked multiple times to ensure its validity and accuracy. Descriptive statistics, such as mean and standard deviation (SD), were used for the selected anthropometric and physiological variables. The prevalence of normal and selected risk categories

was calculated for each selected variable in percentages, with a 95% confidence interval (CI). The age differentiated prevalence percentages of pre-hypertension, hypertension, isolated systolic hypertension and nutritional status in men, women, and the overall population was calculated. The mean SBP and the mean BMI among the males and females in the present study was plotted as line graphs along with the mean SBP and the mean BMI among the males and females in general Indian population in the past 40 years [39] and those observed among the tribal males and females in NNMB, 2009 report for broader comparison [13].

3. Results

The present study has two major perspectives while analyzing and presenting the findings, such as 1) bringing in the larger scenario of the prevalence and risks of hypertension among Indian tribal populations and 2) the patterns of such prevalence and risks among lean and underweight tribal individuals. The demographics and characteristics of the population with respect to selected variables were presented separately.

Table 1 presents the demographics and population characteristics of the selected tribes of India. The mean BMI among the males ($20.0 \pm 2.9 \text{ kg/m}^2$) females ($19.2 \pm 3.1 \text{ kg/m}^2$) and the total population (19.6 ± 3.1) was observed to be very low and falling far below the national average (WHO, 2017). So such low average BMI levels with increased levels of mean SBP [which is at par with the national average (WHO, 2015)] among the males ($126.7 \pm 19.3 \text{ mmHg}$) females (127.6 ± 21.4) and the total population ($127.1 \pm 20.4 \text{ mmHg}$) indicates an alarming state of physio-metabolic health among these indigenous populations. Similarly, the average SBP of males, females and the total population among the tribes like Bhumij (128.7 mmHg , 129.9 mmHg and 129.4 mmHg for males, and females and overall respectively), Bathudi (132.8 mmHg and 129.1 mmHg for females and overall respectively), Dhudia

(129.0 mmHg , 129.6 mmHg and 129.3 mmHg for males, and females and overall respectively) and Kukna (128.4 mmHg , 127.1 mmHg and 127.8 mmHg for males, and females and overall respectively) going above the national average (for males 127.3 mmHg and for females 124.9 mmHg [40]) (Fig. 2) signifies an increased risk among them.

3.1. Analysis of findings on the prevalence and risks of hypertension

Table 2 represents the tribe wise distribution of normal, risk and hypertensive individuals in SBP, DBP and BP categories. Pre-hypertension was found to vary between 11% and 19% while hypertension varied between 6% and 17%. Furthermore, isolated systolic hypertension was found to vary between 4% and 14%.

The details prevalence trend of normal, pre-hypertensive and hypertensive SBP among the males and females in nine tribes in four age groups (Supplementary Table 1) shows a higher prevalence of pre-hypertensive SBP among the males while the hypertensive SBP rate prevailed at a higher rate among the females across all the tribes and age groups. Furthermore, a major section of women showed a normotensive SBP during youth (<40 years) while such a trend significantly changes among them (in comparison to males) while moving towards the late age (≥ 40 years). Further, though the pre-hypertensive trait with respect to SBP is less prevalent among women in comparison to men, such a status does not contribute to the better cardiovascular health of women. Particularly, tribes like Oraon and Bathudi show a consistent trend of increased prevalence of isolated hypertensive SBP. Except for Santals of Odisha, one-third of the females among all other tribes in the age group of 50 years and above were observed of suffering from isolated systolic hypertension, out of which 4 tribes show such prevalence with more than 50%. Similarly, the prevalence trend of normotensive, pre-hypertensive and hypertensive DBP among the males and females from nine tribes in four age groups shows a

Table 1
Demographics and population characteristics of the selected tribes (N = 2156).

Name of the tribes	Sex	Sample Size	SBP (mmHg)	DBP (mmHg)	BMI (kg/m ²)
Santal (West Bengal)	Males	123	127.5 ± 18.2	79.7 ± 11.1	19.9 ± 2.6
	Females	122	123.9 ± 24.0	78.6 ± 13.2	19.5 ± 3.2
	Total	245	125.7 ± 21.3	79.1 ± 12.2	19.7 ± 2.9
Kora	Males	114	124.9 ± 21.0	80.3 ± 11.5	18.9 ± 2.0
	Females	121	124.5 ± 22.3	79.3 ± 14.1	17.6 ± 2.9
	Total	235	124.7 ± 21.6	79.8 ± 12.9	18.3 ± 2.6
Oraon	Males	112	124.1 ± 15.4	79.6 ± 9.9	19.6 ± 2.5
	Females	124	130.9 ± 20.0	84.7 ± 14.0	18.1 ± 2.8
	Total	236	127.7 ± 18.3	82.3 ± 12.5	18.8 ± 2.8
Santal (Odisha)	Males	121	125.8 ± 16.9	76.1 ± 13.1	20.2 ± 2.8
	Females	119	125.4 ± 15.1	82.2 ± 10.6	20.3 ± 3.0
	Total	240	125.6 ± 16.0	79.1 ± 12.3	20.3 ± 2.9
Bhumij	Males	116	128.7 ± 21.4	76.4 ± 13.3	20.9 ± 3.1
	Females	122	129.9 ± 25.1	82.9 ± 13.2	19.7 ± 2.9
	Total	238	129.4 ± 23.4	79.7 ± 13.6	20.3 ± 3.1
Bathudi	Males	119	125.4 ± 17.9	75.8 ± 11.6	19.5 ± 2.8
	Females	121	132.8 ± 23.2	86.2 ± 14.7	18.0 ± 2.8
	Total	240	129.1 ± 21.0	81.1 ± 14.2	18.6 ± 3.3
Dhodia	Males	121	129.0 ± 20.4	80.2 ± 11.6	20.5 ± 3.2
	Females	120	129.6 ± 20.4	82.3 ± 13.5	20.7 ± 3.5
	Total	240	129.3 ± 20.4	81.2 ± 12.6	20.6 ± 3.3
Kukna	Males	120	128.4 ± 17.4	79.3 ± 11.1	20.3 ± 3.1
	Females	120	127.1 ± 16.8	80.1 ± 9.5	19.9 ± 2.9
	Total	240	127.8 ± 17.1	79.7 ± 10.3	20.1 ± 3.0
Chaudhari	Males	120	125.7 ± 23.5	75.1 ± 11.5	19.8 ± 3.1
	Females	121	123.7 ± 21.7	80.1 ± 13.8	18.9 ± 2.9
	Total	241	124.7 ± 22.5	77.6 ± 12.9	19.4 ± 3.0
Total	Male s	1066	126.7 ± 19.3	78.1 ± 11.83	20.0 ± 2.9
	Females	1090	127.6 ± 21.4	81.9 ± 13.2	19.2 ± 3.1
	Total	2156	127.1 ± 20.4	80.0 ± 12.7	19.6 ± 3.1

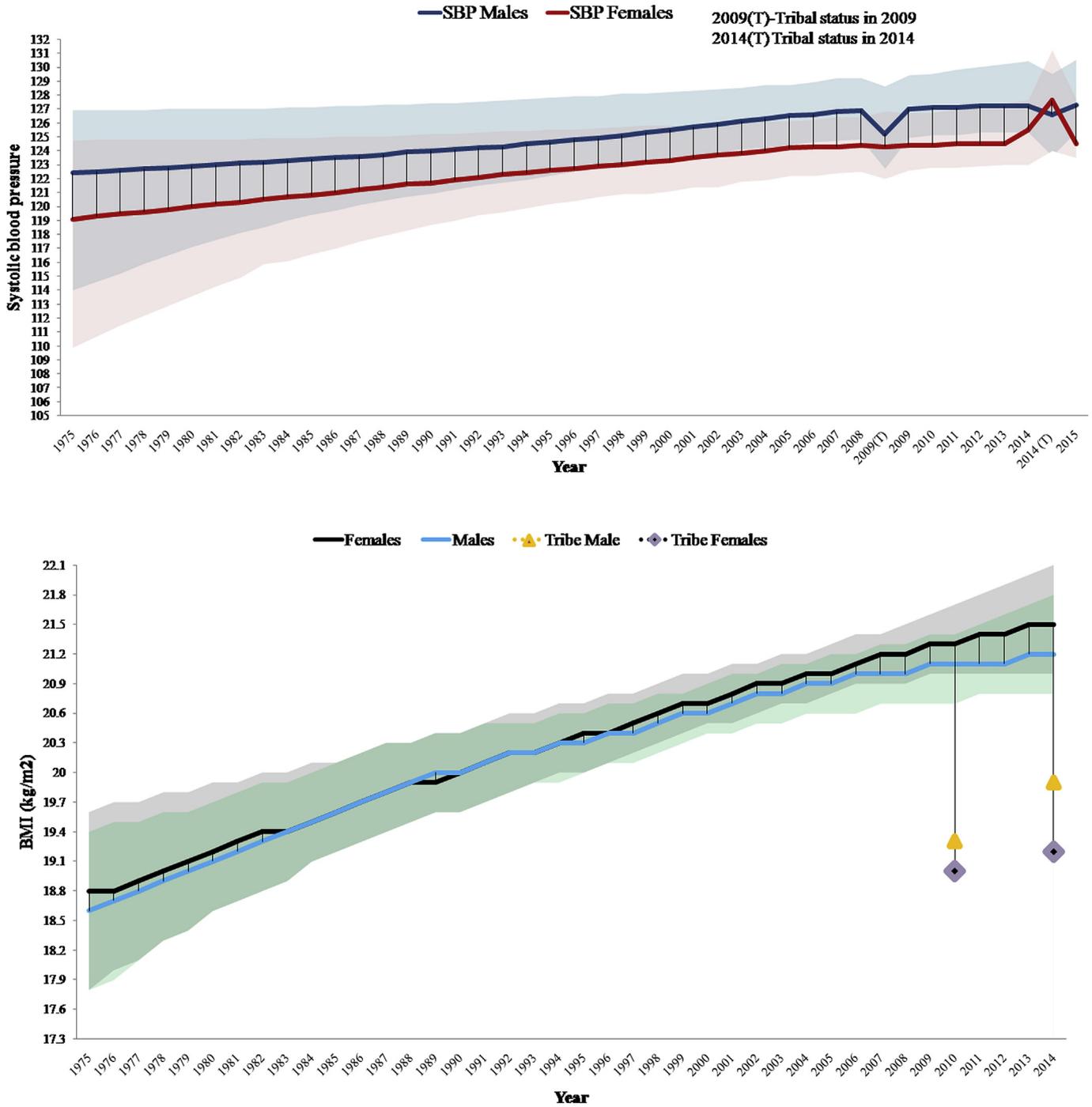


Fig. 2. Trends of SBP (mmHg) (A) and BMI (kg/m²) (B) among males and females in general population of India, and that of among tribal populations of the present study.

similar pattern like SBP (Supplementary Table 2). The prevalence of prehypertensive SBP and prehypertensive DBP varied between 28.9% (Oraon) to 43.9% (Santal of Odisha) and 23.8% (Santal of Odisha) to 29.9% (Chaudhari) respectively among all the tribes.

On an average, the prevalence of pre-hypertension is higher among the males while the hypertension rate prevails at a much higher rate among the females in most of the age groups in all the tribes. The prevalence pattern of blood pressure (SBP/DBP) categories such as normotension, pre-hypertension, hypertension and isolated systolic hypertension among the males and females in the nine tribes across the four age groups also show a similar pattern

like SBP (Supplementary Table 3).

Isolated systolic hypertension exhibited a higher prevalence rate among females in seven of the nine tribes in 20–29 years age group; six of the nine tribes in 30–39 years age group and seven of the nine tribes in the age group 50 years and above. However, females in five of the nine tribes show a lower prevalence rate in 40–49 age groups. Overall, isolated systolic hypertension is observed to be a persistent risk among women.

Table 3 represents the age group wise distribution of normal, risk and hypertensive individuals in SBP, DBP and BP categories. Prehypertension status with respect to SBP, DBP, and BP in various

Table 2
Tribe wise distribution (%) of normal, risks and hypertensive individuals in various blood pressure categories (N = 2156).

Names of the tribes	Normotensive	Pre-hypertensive	Hypertensive	Isolated Systolic Hypertension
Systolic Blood pressure(mmHg)				
Santal (WB)	47.3	33.7	18.9	
Kora	51.5	28.9	19.6	
Oraon	39.4	39.0	21.6	
Santal (O)	39.3	43.9	16.7	
Bhumij	41.2	31.9	26.9	
Bathudi	36.7	38.3	25.0	
Dhudia	36.5	39.4	24.1	
Kukna	37.1	40.0	22.9	
Chaudhari	46.9	35.7	17.4	
Total	41.7	36.9	21.3	
Diastolic Blood pressure(mmHg)				
Santal (WB)	54.7	28.8	16.5	
Kora	56.6	26.8	16.6	
Oraon	48.7	26.3	25.0	
Santal (O)	56.9	23.8	19.2	
Bhumij	54.6	23.9	21.4	
Bathudi	54.2	26.3	19.6	
Dhudia	53.9	25.3	20.7	
Kukna	54.6	29.6	15.8	
Chaudhari	60.6	29.9	9.5	
Total	55.1	26.8	18.1	
Blood pressure(mmHg)				
Santal (WB)	63.7	17.6	11.8	6.9
Kora	65.1	12.3	10.6	11.9
Oraon	56.8	15.7	16.5	11.0
Santal (O)	64.0	13.8	9.6	4.0
Bhumij	60.5	10.9	14.7	13.9
Bathudi	58.3	15.8	12.1	13.8
Dhudia	58.5	14.5	13.3	13.7
Kukna	59.2	18.8	11.3	10.8
Chaudhari	68.0	16.2	6.2	9.5
Total	61.6	15.1	11.8	11.6

Abbreviations: West Bengal (WB) and Odisha (O).

age groups shows an inconsistent trend with respect to the increase in age. On the other hand hypertensive status in SBP, DBP and BP demonstrate a clear trend of increase with age. There are two types of trends in prevalence rate observed within the four age groups. It is most striking to find that the rate of increase in the prevalence of hypertension in the age groups of 20–29 and 30–39 years is steady, but it takes a double or more percentage point jump while entering into 40–49 years age group. Further, this rate of increase becomes steady to the next age group.

3.2. The pattern of prevalence and risks of hypertension among the various nutritional states

We analyzed the prevalence of prehypertension, hypertension and isolated hypertension among various nutritional statuses, categorized on the basis of BMI (Table 4). It shows a significantly high prevalence of hypertension and related risks in the underweight as well as normal weight individuals. Less number of females was observed to be with normal cardiac as well as nutritional health than men. Similarly, increased number of females was observed of suffering from hypertension and isolated hypertension with the increase in worsening state of nutrition. There were about 12% and 9% of the participants in the bracket of hypertension in the overall normal and underweight states respectively.

Fig. 3 represents the averages SBP and DBP in 8 age groups (Fig. 3-A) along with the percentages distributions of blood pressure in various categories like hypertensive SBP, hypertensive DBP, hypertensive and isolated systolic hypertensive (Fig. 3 B–D). The classification of the age into 8 five year age groups (20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years, 45–49 years, 50–54 years and 55–60 years) was made to understand the change

in blood pressure precisely. It shows the cardiovascular health of young individuals in <40 years age segment as normal (Fig. 3-A); individuals in the age group of 40 years and above show a consistent increase in average SBP and DBP. The trend of prevalence percentage of hypertension in the categories of SBP (Fig. 3-B), DBP (Fig. 3-C), BP (Fig. 3-D) and Isolated Systolic Hypertension (Fig. 3-D) among the males, females and total population indicates a curvilinear pattern where the prevalence of cardiovascular risks is high at the two extremes of the severely malnourished and the overweight/obese. However, the prevalence of cardiovascular risk in normal nutritional states was not less.

Fig. 4 exhibits the distribution of normotensive, pre-hypertensive and hypertensive among the underweight, normal and overweight and/or obese categories. There are two striking features observable from the figure; firstly, the individuals in the underweight category demonstrate 8.8% hypertension prevalence with another 10.7% at very high risk and 11.3% in pre-hypertensive states; secondly, individuals in the normal weight category also show an increased prevalence of hypertension (12.1%), pre-hypertension (17.8%) and isolated systolic hypertension (11.4%). It is also important to note that among the total overweight or obese individuals (12.8%) there were about 20% of individuals who suffered from hypertension. A high prevalence of pre-hypertension among the normal population group is another cause of concern.

4. Discussion

Hypertension is increasingly becoming a major health problem among Indian tribes. Increased prevalence of prehypertension and isolated systolic hypertension are additional causes of concern. The present study has brought out several important findings on the

Table 3
Age group wise distribution (%) of normal, risks and hypertensive individuals in blood pressure categories in the pooled population (N = 2156).

Age groups	Systolic Blood pressure			Diastolic Blood pressure			Blood pressure		
	Normotensive	Pre-Hypertensive	Hypertensive	Normotensive	Pre-Hypertensive	Hypertensive	Normotensive	Pre-Hypertensive	Hypertensive
20–29	53.9	38.1	8.0	67.7	22.1	10.2	75.0	13.8	2.9
30–39	48.5	39.8	11.7	58.1	28.3	13.5	67.4	16.7	7.0
40–49	39.5	33.0	27.5	50.5	26.0	23.5	56.2	14.0	17.3
50+	24.6	36.7	38.7	43.6	30.7	25.7	47.3	15.8	20.3

prevalence of hypertension and its risks like prehypertension and isolated systolic hypertension among the tribal populations along with examining the patterns of co-prevalence of such elevated blood pressure issues among under and normal weight individuals. Our findings showing the prevalence and risks of hypertension among the normal weight and undernourished tribal individuals highlights the physio-metabolic intolerance in the context of the undergoing epidemiological transition among the studied populations.

The present study finds the prevalence of hypertension in the total pooled population at 11.6% (a minimum of 6.2% among the Chaudharis and a maximum of 16.5% among the Oraons) which combined with isolated systolic hypertension (11.2%) raises the overall hypertension risk to approximate 23% (Table 2). It is important to note that like hypertension, isolated systolic hypertension possesses equal adverse prognosis [38,40] which, in the present study, was observed with an approximately 10% or above prevalence rate among 7 of the 9 selected tribes. Moreover, six of the nine studied tribes were observed with a >20% overall hypertension (hypertension and isolated systolic hypertension combined) prevalence rate in the present study. The observed increased prevalence rate of hypertension among tribal populations is in the line of the recently reported Indian national conversing trend of rural (23–27%) -urban (30–33%) prevalence rates of hypertension [41]. Similarly, the present study found the overall prevalence rates of hypertension among the males and the females at 20.1% (9.3% as hypertensive and 10.8% as isolated systolic hypertensive) and 26.5% (14.2% as hypertensive and 12.3% as isolated systolic hypertensive) respectively (Supplementary Table 1).

From prehypertension perspective, the findings of the present study are important, as no such large-scale details study has been undertaken among Indian tribes previously. Findings from Framingham, JNC-7, and MCS India study have identified prehypertension as an independent CVD risk factor [38,42,43]. Framingham study finds prehypertension causing mortality among men and women at 1.6 and 2.5 HR (hazard ratio) [42]. It was observed in the present study that there was a 15.1% (varying between 10.9% among the Bhumij and 18.8% among the Kukna; Table 2) prevalence of pre-hypertension in the pooled population with 14.7% and 15.5% (Supplementary Table 1) among men and women respectively. Similarly, the prevalence of prehypertension among underweight and normal weight populations was also high (Table 4).

Furthermore, SBP has been observed as a stronger predictor of cardiovascular morbidity and mortality [44–46]. Considering the trends among Indian tribes, a significantly elevated mean SBP in the age groups of >44 years (Fig. 4-A) indicated an early aging and associated arterial dysfunction [47]. It is imperative to state that, tribal individuals (both males and females) in this age group were also previously observed of experiencing a higher burden of malnourishment or such risks [5]. Further, while comparing the SBP and BMI of the tribes of the present study with the 40-year trend of SBP and BMI in Indian national population (Fig. 2), a prevailing higher risk of raised blood pressure was observed among the Indian tribes with a very low average BMI.

It is, therefore, desirable that the physio-metabolic risk factors afflicting tribal groups in India should be screened immediately for timely and successful intervention.

The age group wise distribution of hypertension (in SBP, DBP and BP categories) shows a sudden leap in prevalence while transiting to the 40–49 years age group and above (Table 3) from the preceding age group of 30–39 years. This immediate leap in prevalence significantly explains an early age cardio-metabolic health transition in terms of vulnerabilities along with a multifold risk of hypertension among the Indian tribes in recent time. It was

Table 4
Prevalence of hypertension, isolated systolic hypertension and prehypertension among various weight categories in undernutrition and normal individuals (N = 1876).

BP categories	Nutrition status (BMI categories)																			
	Low normal				High normal				Mild Undernutrition				Moderate Undernutrition				Severe Undernutrition			
	Nor	Pr Hy	Hy	ISHy	Nor	PrHy	Hy	ISHy	Nor	PrHy	Hy	ISHy	Nor	PrHy	Hy	ISHy	Nor	PrHy	Hy	ISHy
Blood pressure																				
Males	71.4	13.9	7.7	6.9	57	21	8.9	13.1	75.2	8.8	5.8	10.2	79.5	11	6.8	2.7	71.7	15.2	2.2	10.9
Females	55.6	17.2	15.7	11.6	50.8	18.2	17.4	13.6	64	13.8	10.9	11.7	71.3	9.8	9.8	9	60.4	11.5	12.2	15.8
Total	64.6	15.3	11.2	9	54.1	19.7	12.8	13.4	69.3	11.4	8.5	10.8	74.4	10.3	8.7	6.7	63.2	12.4	9.7	14.6
Systolic Blood pressure																				
Males	45.6	38.2	16.2		32.5	47.2	20.3		50.4	32.2	17.3		52.1	32.9	15.1		60.9	30.4	8.7	
Females	42.9	34.3	22.7		36.4	36.4	27.3		45.3	37.2	17.4		57.4	23	19.7		45.3	31.7	23	
Total	44.4	36.5	19		34.3	42.2	23.6		47.8	34.9	17.3		55.4	26.7	17.9		49.2	31.4	19.5	
Diastolic Blood pressure																				
Males	68	21.6	10.4		54.1	31.8	14.1		69	22.1	8.8		76.7	16.4	6.8		67.4	23.9	8.7	
Females	46.5	30.3	23.4		42	32.6	25.4		55.1	24.7	20.2		61.5	23.8	14.8		50.4	28.1	21.6	
Total	58.6	25.4	16		48.5	32.2	19.3		61.7	23.5	14.8		67.2	21	11.8		54.6	27	18.4	

Abbreviations: Nor-Normotension, Pr Hy = -Pre-hypertension, Hy-hypertension, ISHy-Isolated systolic hypertension.

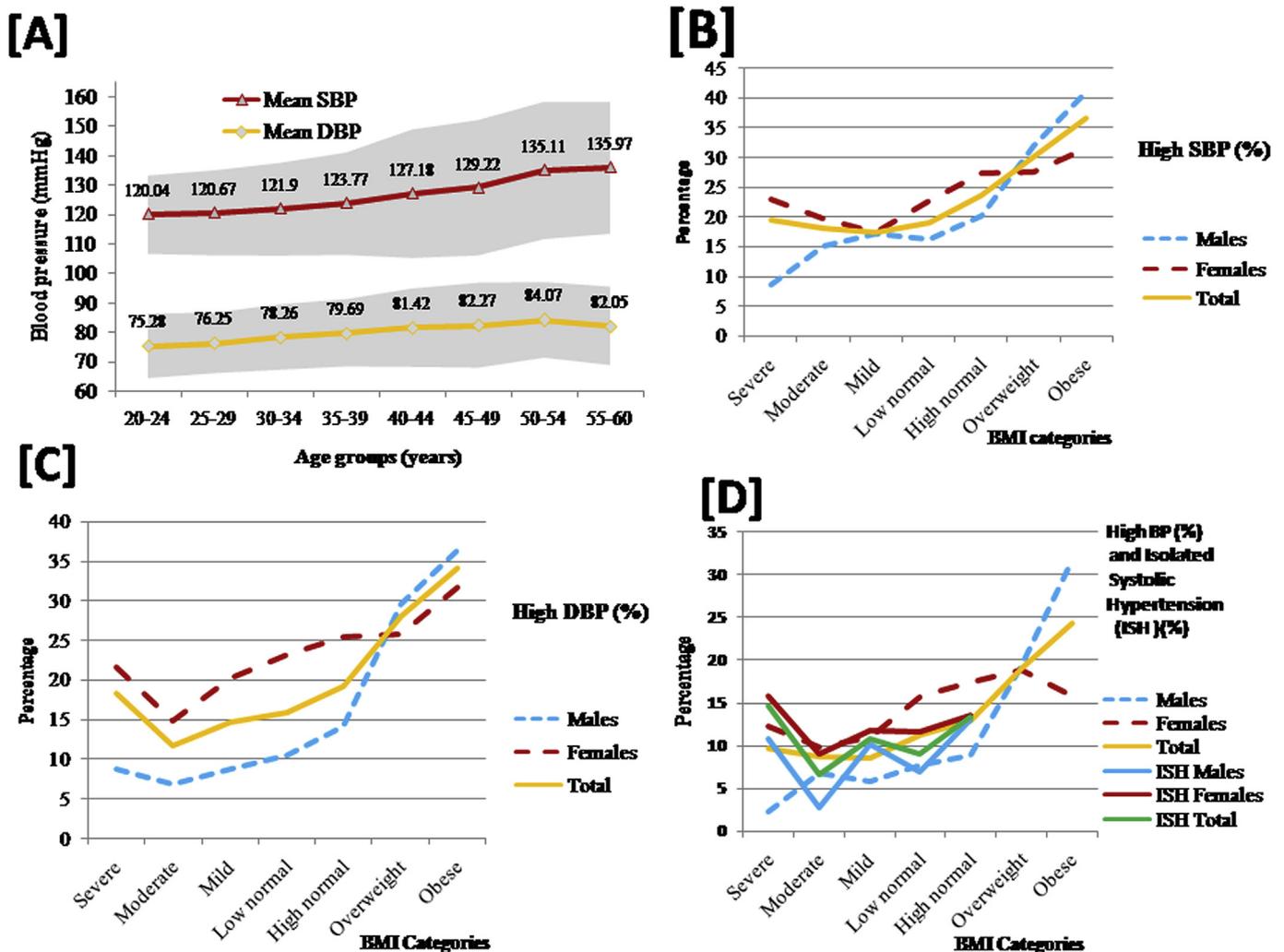


Fig. 3. Distribution of age group-wise mean SBP and DBP (A) along with prevalence percentages of hypertension in selected categories of blood pressure (B,C and D) among the tribes.

further observed that such risks and vulnerability were observed of affecting the women at an alarming rate. Schall (1995) demonstrated the profound role of age particularly among women in their hypertensive state [48]. In her report on elevated and wider range

of hypertension among men and women in the elderly age group, she put women at a higher risk; such risk was more than double in traditional tribes than modernized ones. The findings of the present study demonstrated similar observations. Further, in her meta-

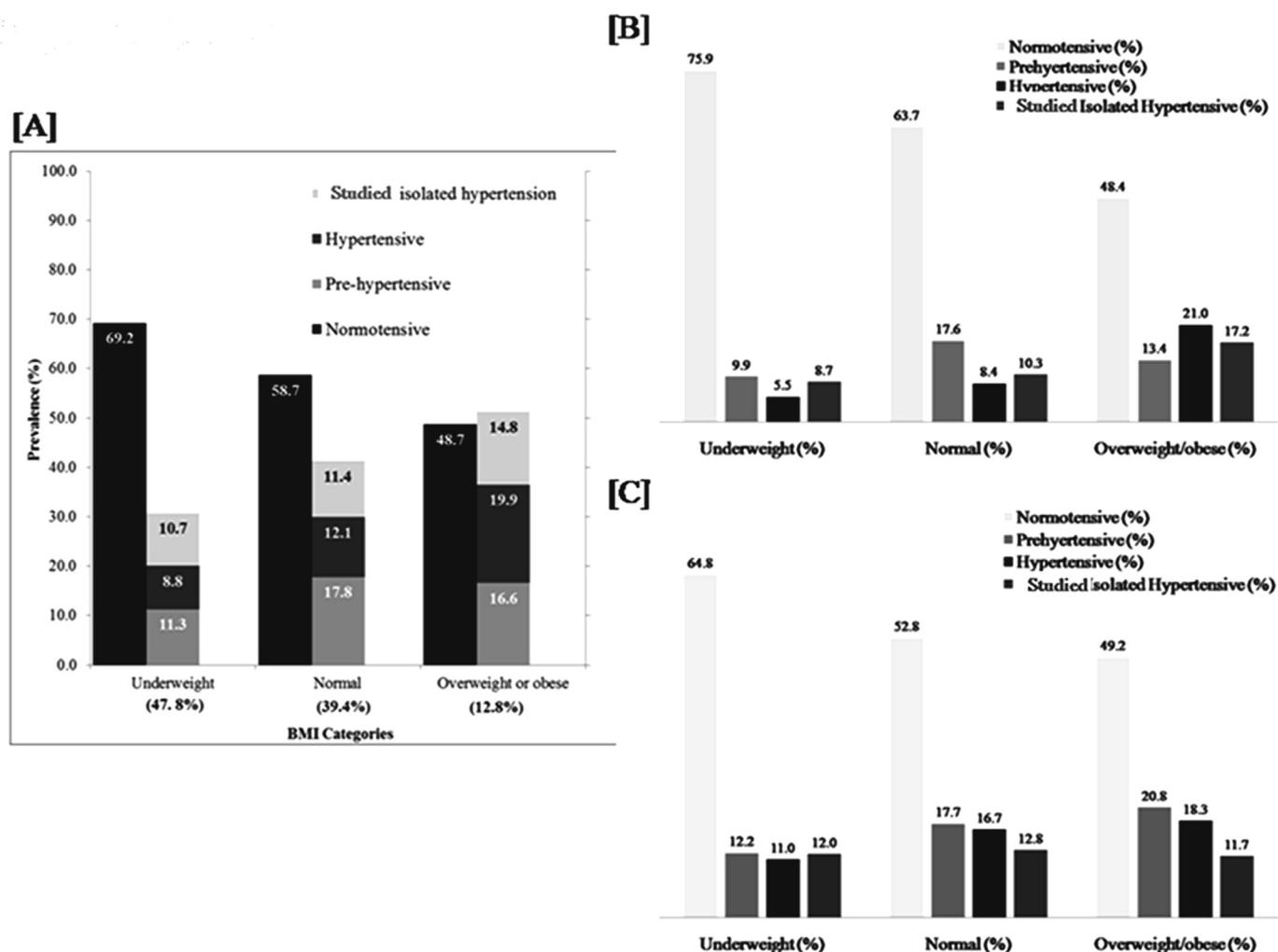


Fig. 4. Distribution (%) of normal, risks (prehypertension and isolate systolic hypertension) and hypertension categories among the underweight, normal and overweight and/or Obese BMI categories among overall.

analysis of hypertension, Schall showed tribal women in traditional society were at marginally higher risk than men [48]. The present findings exhibit women and particularly those in the elderly age group with a higher prevalence of hypertension (Supplementary Table 3) and increased rate of related risks further with a sharply high prevalence of undernutrition and/or low-normal weight than men. Here the particular cases of the females in Oraon and Bathudi tribes need mention. These two tribes exhibited an average BMI ($18.0 \pm 2.8 \text{ kg/m}^2$ for Bathudi; $18.1 \pm 2.8 \text{ kg/m}^2$ for Oraon) of $<18.5 \text{ kg/m}^2$ while their average SBP ($130.9 \pm 20.0 \text{ mmHg}$ for Oraon; $132.8 \pm 23.2 \text{ mmHg}$ for Bathudi) was observed of shooting to an increased state of pre-hypertensive condition in comparison to other tribal women indicating their worsening cardiovascular health on one hand, and the possible association of such cardiovascular risk with undernutrition on other.

The finding of the present study highlights an elevated range of averages of SBP and increased rates of hypertension among most of the tribes (Table 1) along with a low or below the normal status of mean BMI (Table 1). It was due to the reason that a considerably large portion of the population was in the bracket of undernutrition (ranging from mild to severe forms) which dragged the overall average BMI status in the population to the low extremes. Additionally, it is important to note that the mean BMI status among males and females in each tribe demonstrates a clear gender

division (Table 1). In a study it was reported that tribal women suffer from serious social and gender disparity which are major reasons behind their chronic poverty and its induced undernutrition; they further demonstrated an elevated risk among the >40 years age category women to suffer from the state of severe undernutrition [49]. The present study finds a significantly increased risk of hypertension among the studied individuals and particularly the women belonging to the >40 years age category. So, with an early onset of age-related degenerative diseases, elderly tribal individuals need additional attention with respect to their aging and associated cardiovascular health.

Of the studied total individuals, approximately 40% were underweight, of which women constituted about 60%. The situation was observed to be more alarming when nearly 9% of the underweight tribal individuals were found to be in a hypertensive state (Fig. 4-A); the prevalence of hypertension among underweight women was observed at 11% while it was 5.5% among the men (Fig. 4-B and C). Furthermore, 12% in the normal weight individuals with 16.7% females (a major section of which is in the low normal range of BMI) and 8.4% males were found hypertensive (Fig. 4-A, B, and C). Such prevalence patterns clearly indicate that women are at increased cardiovascular risks while experiencing highly vulnerable physiological conditions. Research suggests that maternal undernutrition affects the intra-uterine development of kidney

causing impaired intra-uterine growth along with fewer nephrons; the less number of nephrons is a determining factor of blood pressure and renal function in such a way that it presents arterial hypertension and such risks throughout the life of the individual [43]. Considering the findings of present study as well as other reports [5,13] it can be said that increased prevalence of undernutrition among the tribal women through generations has a strong possibility of playing a pivotal role towards continuance of hypertension and such risks to the next generation males and females. Secondly, the analysis of the present findings, highlights that the increased and prolonged prevalence of undernutrition, as well as such prolonged stress possibly during the crucial developmental period of the life [43], carry high risk of progression to compromised immunity in later phases of life; this might be one of the major confounding factors in adulthood and growing age, particularly among the women in their prior, early as well as in late phases of menopause [50,51], towards early progression to hypertensive state and related risks even having a normal weight. Here, the case of Bathudi females presented an inquisitive case among all the nine tribes as they were found of suffering from extreme adversities of nutritional insecurity (mean BMI = $18.0 \pm 2.8 \text{ kg/m}^2$). It is observable that Bathudi females were under the risk of hypertension (with a prevalence rate of 19%) both in younger (with a total prevalence of 16.2% in the two younger age groups) as well as in the later phases (with a total prevalence of 57% in the two older age groups) of their lives, exhibiting a totally different trend than other tribes where younger women demonstrated lesser risk and prevalence of hypertension. Such a state highlights the possible association of prolonged and severe suffering from a high rate of undernutrition and its resultant adversities leading to hypertension.

It is here noteworthy that in Asia-Pacific regions, the hazards of higher blood pressure are being experienced at all levels of metabolic risks triggered by factors like malnutrition which is just a reverse trend to western countries [52]. Hawkes (2006) demonstrated that the globalization-driven nutritional transition has brought significant changes in food habits with the poor as the worst affected of food insecurity due to the cultural convergence towards low-quality diets (such as inexpensive vegetable oil and *trans-fat*) [53]. In the NNMB (2009) report, tribal women have been observed with an elevated intake of fats, oils, sugar at an overall level along with a fall in intake of vegetables [13]. The report further suggests an essential 'food gap' among the Indian tribes due to the highly pronounced dietary energy and protein inadequacy. Additionally, on the dietary front, other studies have reported excess intake of salt as an important associated factor of increasing prevalence of hypertension among Indian tribal [54,55] as well as non-tribal population [56].

4.1. Policy perspective

Present observations highlighting the prevalence of hypertension and such risks among the malnourished as well as normal weight tribal populations indicates the urgent needs of strengthening the general healthcare system in such tribal inhabited areas. It is imperative in the context of present findings that immediate steps are taken with an extensive and consistent focus on tracking of such chronic epidemiological conditions for a timely and successful intervention. Hypertension being a major attributing factor towards causation of two third CVD incidences underscores the immediate need of strategies to address the issue of the elevated level of blood pressure [57] in underprivileged population groups. The NNMB-2009 report demonstrated that 44% of tribal men and 38% tribal women have heard about hypertension, while only 8.4% adult population were aware of the disease [13]. High level of

ignorance was also reported by other studies [58]. So, it is necessary to increase the awareness regarding the etiology of the elevated blood pressure level and its consequences. In the context of rapid lifestyle changes and its driven nutritional and dietary insecurity, not only increased awareness but a better food policy is also required to improve the affordability of this economically deprived section for enhancing their access to better quality of foods.

Contributions of the authors

GKK and SKA designed the study. SKA analyzed the data and drafted the manuscript. GKK directed implementation and data collection. SKA collected the data. GKK edited the manuscript for intellectual content and provided critical comments on the manuscript. Both the authors contributed equally.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dsx.2019.01.028>.

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