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Original Article

Comparing the ability of anthropometric indicators in determining the prevalence of hypertension among Indian tribes

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ABSTRACT

Objective: We compared the ability of the selected anthropometric indicators to best predict the prevalence of hypertension among the Indian tribes.

Methods: A cross-sectional study was undertaken among 1431 adult participants (705 males and 726 females) between the ages of 20 and 60 years from six major tribes in India. Selected anthropometric indicators such as body mass index (BMI), waist-hip-ratio (WHR), waist-height-ratio (WHtR), percentage body fat (PBF), visceral fat (VF), minimum-waist-circumference (MWC) and sum-of-the-four skinfold thickness (SF4), along with the physiological parameters such as blood pressure were recorded. Discriminant analysis (DA) was performed to examine and compare the ability of the selected anthropometric indicators towards classifying hypertension among males, females and the total population.

Results: Significant independent association was observed for hypertension and similar conditions within gender and selected age-group categories. The overall hypertension prevalence among the studied tribes was observed at 12.6%. Standardized function coefficients (SFCs) in discriminant analysis revealed PBF(0.89, 0.36, and 0.76 for overall, males, and females respectively) as the most powerful discriminator of hypertension. In addition, visceral fat (0.74, 1.46, and 0.58 for overall, males and females respectively) was observed to be the other significant indicator of hypertensive blood pressure. These exploratory findings for the first time indicate fat deposition, rather than body density alone, as an emerging physiological and metabolic risk among Indian tribes.

Conclusion: In the context of the highly prevalent chronic undernutrition, internal fat deposition is a major classifying factor of physiological and metabolic intolerance. It also indicates the increasing trend in lifestyle changes and the associated adversities among the Indian tribes.

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1. Introduction

Hypertension is one of the major emerging public health problems among the various ethnic groups and the traditional communities in the developing countries [1–6]. Rapid urbanization, increased adaptation to the western lifestyle, and the changing food habits are the major contributing factors causing increased prevalence of high blood pressure and its related risk conditions among indigenous populations in India [1,5,7–13]. Adiposity among adults directly attributes to 60–70% of cases of hypertension [14,15], whereas the Indian tribes suffer from the burden of

hypertension in the context of high prevalence of underweight and increasing adiposity (overweight/obesity) [5]; this indicates a 'triple burden of diseases' among them. It may be mentioned here that overweight and obesity [2,16] as well as, undernutrition [17,18] have a detrimental effect on hypertension. Therefore, low and middle-income countries with their increasing double burden of malnutrition are at a higher disposition for hypertension [2]. In the Indian context, there is a consistent increase in the prevalence of hypertension that indicates a convergence trend in the rural-urban prevalence pattern [19,20]. In such a situation, the Indian tribes with majority of the population below poverty line and more than 80% of them constituting the two lowest economic strata are the foremost sufferers. Recent evidence substantiate this trend; high prevalence of raised blood pressure has been found among aboriginal Nicobarese tribes of Car Nicobar Island [21], Nomad tribes of Rajasthan [22], tribal population in Salem districts of

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Tamilnadu [23], and tribal women in Visakhapatnam district of Andhra Pradesh [6]. Kshatriya & Acharya (2016) in their recent study have shown the trend of systolic blood pressure (SBP) among the Indian tribes that are at par with the rural-urban blood pressure pattern [5]. Other studies among the Indian tribal populations have also reported the high prevalence of hypertension [1,3,4,24–27].

Several studies have been conducted worldwide, as well as in India highlighting the relationship of different anthropometric markers with hypertension [28–31]. Rizwan et al. (2014). Their meta-analysis have highlighted an increased prevalence of hypertension among the Indian tribes with highly diverse prevalence pattern [32]. It is important in this context to note that, a majority of the Indian studies although has reported the prevalence of hypertension and similar risk conditions, there is a significant vacuum in identifying anthropometric predictors or such specific cut-offs. In the context of the highly prevalent chronic undernutrition, increasing adiposity and hypertension among the Indian tribes, it is relevant to identify the appropriate anthropometric screening tools. Here, it is worth mentioning that, though the global cut off of body mass index (BMI) for adiposity risk prediction was lowered in Asian context [33], no such study identifies its reliability among the Indian tribal population which has a shorter average stature than the rest of the population, along with suffering from high and chronic undernutrition.

Anthropometric indices such as minimum waist circumference (MWC), waist-hip ratio (WHR), waist-height ratio (WHtR), visceral fat (VF), percentage body fat (PBF) etc. have been used as the adiposity markers with strong association to hypertension in the worldwide studies [34–39]. However, no study examines the ability of such anthropometric variables in predicting hypertension among the Indian tribes. In the context of the increasing lifestyle changes, undergoing epidemiological transition, and the age-old morbidity risks among the Indian tribes, it is highly relevant to identify the appropriate tools for measuring the rapidly emerging cardio-metabolic health conditions.

In view of the above context, the present study has performed a discriminant analysis on selected anthropometric indicators to identify the best predictor(s) for hypertension and similar risk conditions (hypertensive SBP and hypertensive DBP) among the males, females, and the total population of the selected six tribes of India. It may be mentioned here that discriminant analysis has been used in several studies in order to find out the best predictors for identifying hypertension [40–42]. We, in the present study, have used this technique as an explorative tool in the Indian tribal context to evaluate and compare the ability of selected major anthropometric indicators to best predict hypertension and similar risk conditions like hypertensive SBP and hypertensive DBP among them.

2. Materials and methods

2.1. Ethical statement

Prior ethical clearance to conduct the study was obtained from the Department Review Committee of Department of Anthropology, University of Delhi. Informed written consent was obtained from each participant during the study and the sample collection.

2.2. Area and people

The present study included six major tribes namely – Santal, Bhumij, and Bathudi from Mayurbhanj district of Odisha; and, Kora, Oraon, and Santal from the Birbhum district of West Bengal. The tribal villages in the study were selected on the basis of the tribal population concentration (>50%). (Fig. 1).

Santals in West Bengal and Odisha are among the progressive tribes of India with fast acculturating practices. Oraon in West Bengal and Bhumij in Odisha are the other major tribal communities in Eastern India. These two tribes were observed to practice a mix of occupations by following the traditional practices along with embracing the new and locally available income options. Visible changes were observed in their daily lifestyle and dietary patterns from the traditional indigenous ones to urbanization influenced modern practices. Koras in West Bengal and Bathudis in Odisha have a significant presence in their respective states. Koras and Bathudis were observed to be the most economically deprived tribes among the selected six tribes. In the present study, we have considered Santals of West Bengal and Santals of Odisha as two different population groups.

2.3. Sampling and study design

The sample collection was based on a simple random sampling method. 1431 participants were enrolled in the study consisting of 705 adult males and 726 females. The samples were categorized into four 10-year age interval groups (20–60 years) stratified by sex. From each of the four 10-year age interval groups, 30 men and an equal number of women were randomly selected for the purpose of the present study.

2.4. Anthropometric measurements

A standard questionnaire was used to collect the demographic information of the selected populations such as names of the participants, names of the communities, and the individual age and sex of each of the participants etc. Standard techniques [43] were followed while taking all the anthropometric measurements. Participants were requested to come with light clothes prior to the measurement. The standing height and weight were measured to the nearest 0.1 cm and 0.1 kg respectively. A movable anthropometer was used to measure the height. Measures such as weight, body fat percentage (PBF), and visceral fat (VF) were calculated by bioelectrical impedance analysis (BIA) method using the Omron Karada Scan Body Composition Monitor (Omron Health Care Co., Kyoto, Japan) [44]. BIA gives the information about the impedance from foot-to-hand and is easy to use, inexpensive, and portable providing a better accuracy in field circumstances [45]. Precaution was taken to ensure that each participant is relaxed for at least 15 min prior to the measurements. Participants were encouraged not to eat heavily (at least an hour before) and to avoid consumptions of alcohol, as well as plenty of water on the day of measurement. Minimum waist circumference (MWC) was taken following the standard anthropometric techniques [43]. The participants stood straight with the abdomen relaxed, arms at side and feet together. Measurements were taken at the end of normal expiration.

BMI was calculated as weight in kilogram (kg) divided by height in meter squared (kg/m^2). WHtR was calculated by dividing the waist circumference to height and WHR was calculated as the ratio of the waist circumference to hip circumference. Skinfold thickness at biceps, triceps, subscapular and suprailiac was measured using Holtain skinfold calipers and the sum of these four skinfolds (SF4) was used for defining the adiposity in the present study.

Blood pressure was measured following the American Heart Association (AHA) guidelines [46]. Participants were made to sit comfortably with their arms at the heart level with uncrossed legs and bared arms. The participants were required to refrain from consuming alcohol, smoking, and caffeine at least half an hour before the measurement. Systolic and diastolic blood pressure (SBP and DBP respectively) were recorded twice by using a standard mercury sphygmomanometer (Diamond, Amrit Scientific Industrial



Fig. 1. Map of India highlighting selected states of the fieldwork.

Corp., Delhi, India) [47] on the right arm of the participants. The mercury sphygmomanometer is a manually operated blood pressure measuring apparatus which was checked, standardized and calibrated to the standard error of ± 5 mmHg (American Medical Association [AMA] [48]). The mercury meniscus at the zero mark level when the cuff is fully deflated was maintained. The cuff bladder was placed on the right upper arm of the participant covering more than 80% part. The participants, as well as the investigators, maintained no or minimal talk during the time of measurement. A minimum 15-min rest before the measurement and a 5-min interval between two measurements were maintained and then the average of the two readings was recorded.

2.5. The research team and sample collection method

The field research team conducted the data collection. Two

trained anthropologists guided by the principal investigator formed the research team. All the anthropometric measurements in the field were taken by one anthropologist and the data entry to the datasheet was done by the other in order to avoid biases. The same measuring instruments were used for recording the measurements of all the sampled participants to avoid differences. The participants of the selected villages were informed before the commencement of the study. Those participants who avoided sampling were excluded from the study.

Exclusion criteria are as follows – Growth and developmental disorders, severe health issues in the past year, and the existence of any secondary cause of hypertension.

2.6. Individual classification

The participants with blood pressure $\geq 140/90$ mmHg were

Table 1
Characteristics of the studied tribal populations (n = 1431).

Tribe	Sex		Age	MWC	SBP	DBP	PBF	VF	BMI	WHR	WHtR	SF4
Bathudi	M	Mean	39.97	74.77	125.44	75.79	16.61	4.11	19.46	0.92	0.48	36.34
		SD	±12.46	±7.66	±17.94	±11.64	±5.39	±3.00	±2.67	±0.05	±0.05	±15.29
	F	Mean	40.17	66.53	132.75	86.23	24.34	2.18	17.97	0.84	0.45	34.67
		SD	±12.20	±4.56	±23.21	±14.67	±6.09	±1.54	±2.76	±0.05	±0.04	±12.92
	T	Mean	40.07	70.65	129.13	81.05	20.47	3.15	18.71	0.88	0.47	35.50
		SD	±12.30	±6.11	±21.04	±14.22	±5.74	±2.27	±2.81	±0.05	±0.04	±14.10
Bhumij	M	Mean	42.22	77.69	128.74	76.42	18.95	5.84	20.93	0.90	0.48	42.60
		SD	±12.52	±8.91	±21.40	±13.25	±6.20	±3.39	±3.05	±0.05	±0.05	±28.17
	F	Mean	40.83	68.91	129.94	82.89	27.25	3.07	19.70	0.84	0.46	37.80
		SD	±11.43	±5.96	±25.14	±13.20	±5.81	±2.28	±2.94	±0.05	±0.04	±13.24
	T	Mean	41.51	73.3	129.36	79.74	23.1	4.46	20.30	0.87	0.47	40.2
		SD	±11.97	±7.43	±23.35	±13.59	±12.01	±2.84	±3.05	±0.05	±0.05	±20.70
Kora	M	Mean	40.05	68.27	124.91	80.32	17.29	3.53	18.94	0.86	0.43	24.22
		SD	±12.86	±6.26	±21.00	±11.50	±6.48	±2.04	±1.97	±0.06	±0.04	±6.60
	F	Mean	40.16	61.87	124.51	79.26	23.51	2.07	17.64	0.82	0.42	29.65
		SD	±12.32	±5.60	±22.31	±14.08	±6.54	±1.34	±2.86	±0.06	±0.04	±11.30
	T	Mean	40.11	65.07	124.71	79.78	20.4	2.80	18.27	0.84	0.43	26.93
		SD	±12.56	±5.93	±21.64	±12.88	±6.51	±1.69	±2.55	±0.06	±0.04	±8.95
Oraon	M	Mean	39.04	70.71	124.10	79.63	17.20	4.21	19.58	0.86	0.44	28.38
		SD	±12.60	±6.68	±15.41	±9.93	±6.51	±2.69	±2.51	±0.05	±0.04	±10.00
	F	Mean	39.74	63.11	130.90	84.68	25.38	2.21	18.13	0.81	0.43	27.94
		SD	±11.79	±6.06	±20.00	±13.98	±6.07	±1.74	±2.79	±0.05	±0.04	±10.94
	T	Mean	39.41	66.91	127.67	82.28	21.29	3.21	18.82	0.83	0.43	28.16
		SD	±12.16	±6.37	±18.25	±12.46	±12.58	±2.22	±2.75	±0.05	±0.04	±10.47
Santal (O)	M	Mean	41.38	75.25	125.79	76.09	18.73	4.89	20.20	0.91	0.47	31.60
		SD	±13.37	±8.02	±16.89	±13.10	±6.24	±2.99	±2.80	±0.06	±0.05	±12.63
	F	Mean	39.25	71.14	125.42	82.21	27.72	3.50	20.30	0.85	0.48	46.64
		SD	±12.57	±7.81	±15.07	±10.60	±7.02	±2.69	±3.04	±0.06	±0.05	±20.54
	T	Mean	40.32	73.19	125.61	79.13	46.45	4.19	20.25	0.88	0.47	39.12
		SD	±12.99	±7.91	±15.98	±12.29	±23.22	±2.84	±2.92	±0.06	±0.05	±33.17
Santal WB	M	Mean	39.81	71.67	127.54	79.65	18.43	4.50	19.88	0.87	0.44	28.38
		SD	±13.29	±7.70	±18.22	±11.05	±5.71	±2.83	±2.59	±0.06	±0.05	±10.93
	F	Mean	39.76	66.14	123.93	78.60	27.29	3.05	19.46	0.82	0.44	37.67
		SD	±12.13	±6.28	±23.96	±13.22	±6.09	±2.39	±3.19	±0.05	±0.04	±14.57
	T	Mean	39.79	68.90	125.74	79.13	22.86	3.78	19.68	0.84	0.44	33.02
		SD	±12.67	±6.99	±21.31	±12.17	±5.90	±2.61	±2.91	±0.05	±0.04	±12.75
Total	M	Mean	40.42	73.10	126.11	77.96	17.88	4.51	19.84	0.89	0.46	31.94
		SD	±12.85	±8.19	±18.59	±11.93	±6.13	±2.82	±2.69	±0.06	±0.05	±16.59
	F	Mean	39.99	66.26	127.93	82.32	25.91	2.68	18.86	0.83	0.45	35.67
		SD	±12.04	±6.86	±22.08	±13.59	±6.46	±1.99	±3.09	±0.06	±0.05	±15.46
	T	Mean	40.20	69.68	127.03	80.18	21.89	3.59	19.34	0.86	0.45	33.80
		SD	±12.45	±7.52	±20.45	±12.98	±6.29	±2.41	±2.94	±0.06	±0.05	±16.02

MWC- minimum waist circumference; VF- visceral fat; BMI-body mass index; WHR-waist hip ratio; WHtR-waist height ratio; SF4- sum of four skinfolds; PBF- body fat percentage; SBP-systolic blood pressure; DBP-diastolic blood pressure, Santal of Odisha (O) and Santal of West Bengal (WB), M-males; F-females; T- Total (males and females combined).

considered as hypertensive, individuals with SBP ≥ 140 mmHg irrespective of the DBP were classified as hypertensive SBP and those with DBP ≥ 90 mmHg irrespective of the SBP were classified as hypertensive DBP. Similarly, individuals with SBP ≥ 140 mmHg and DBP < 90 mmHg were considered as isolated hypertensive SBP, and those with DBP ≥ 90 mmHg and SBP < 140 mmHg were considered as isolated hypertensive DBP (JNC VII, 2003).

According to the WHO guidelines for Asian populations, individuals with BMI < 18.5 kg/m² were considered as underweight; ≥ 18.5 kg/m² but < 23 kg/m² as normal; ≥ 23 kg/m² but < 27.5 kg/m² as overweight (high risk) and ≥ 27.5 kg/m² as obese (very high risk) [33,49,50]. In the present study, we have combined the overweight and obese categories as one risk category. Similarly, WHtR was classified into two categories: (1) < 0.50 as normal and (2) ≥ 0.50 as risk for both males and females [51]. In case of minimum waist circumference (MWC), males with < 90 cm and females with < 80 cm were considered as normal, while males with ≥ 90 cm and females with ≥ 80 cm were classified under risk category [52]. WHR was classified into two categories: 1) males with < 0.90 and females with < 0.85 were classified as normal and (2) males with ≥ 0.90 and females with ≥ 0.85 were classified under risk category (WHO, 2008). Participants with VF < 9 and ≥ 10 were classified as normal

and risk category [44] respectively. PBF was classified into two categories: 1) male participants with PBF $< 25\%$, and females with $< 30\%$ were classified as normal, and 2) males with PBF $\geq 25\%$ and females with PBF $\geq 30\%$ were classified under risk category [53].

2.7. Statistical analysis

The collected data was first manually entered into Microsoft Excel 2007, while further analyses were conducted using SPSS version 16 for Windows (SPSS Inc., Chicago, Illinois, USA). Double entry of data was carried out to maintain the integrity of the sampled data. The data was crosschecked multiple times to ensure validity and accuracy. Descriptive statistics such as mean and standard deviation (SD) were used for the selected anthropometric measurements and physiometric variables to describe the characteristics of the studied populations. Prevalence of raised blood pressure by age and sex in various selected categories was calculated. Univariate analysis was performed by independent sample *t*-test and Pearson's chi-square for continuous and discrete variables respectively.

Linear discriminant function analysis was used to compare the predictability of selected anthropometric indicators and to further

Table 2
Prevalence of raised blood pressure in its various categories among the studied populations (n = 1431).

Sex	Hypertension (%)	Chi-square test	Hypertensive SBP (%)	Chi-square test	Hypertensive DBP (%)	Chi-square test	Isolated hypertensive SBP (%)	Chi-square test	Isolated hypertensive DBP (%)	Chi-square test
Males	9.1	15.25***	18.3	8.14**	13.3	33.18***	9.2	0.147	4.3	15.14***
Females	15.9	(df = 1)	24.6	(df = 1)	25.4	(df = 1)	8.6	(df = 1)	9.5	(df = 1)
Total	12.6		21.5		19.5		8.9		6.9	
Age group (year)	Hypertension (%)	Chi-square test	Hypertensive SBP (%)	Chi-square test	Hypertensive DBP (%)	Chi-square test	Isolated hypertensive SBP (%)	Chi-square test	Isolated hypertensive DBP (%)	Chi-square test
20–29	2.4	83.04***	7.6	13.30***	10.6	55.72***	5.2	43.47***	8.2	2.71
30–39	7.5	(df = 3)	12.0	(df = 3)	13.1	(df = 3)	4.5	(df = 3)	5.6	(df = 3)
40–49	19.1		28.4		27.0		9.3		7.8	
50–59	21.6		38.5		27.7		16.9		6.1	

***p < 0.001

**p < 0.01.

(Abbreviations -df-degree of freedom; SBP-systolic blood pressure; DBP-diastolic blood pressure).

classify them; the dependent categorical outcome variable i.e. blood pressure was grouped into hypertensive and normotensive. Discriminant analysis in its function is similar to the multiple linear regressions. However, it does not require continuous dependent variable as it happens in the case of regression [42]. On the other hand, discriminate analysis like regression weights the relative predictability of the independent variables and selects the set of best variables that discriminate the categorical outcome variable [54]; canonical discriminant function significantly distinguishes between hypertensives and normotensives [41]. Therefore, discriminant function coefficients show the best indicators for discriminating between the two groups (hypertensive versus normotensive).

3. Results

Table 1 shows the characteristics of the study population. The mean age for overall adult males and females was 40.4 ± 12.85 years and 39.9 ± 12.04 years, respectively. Mean values for MWC,

BMI, WHR, WHtR and VF were observed to be higher in adult males as compared to females in most of the tribes. Women, however, exhibited significantly higher means in the categories of SF4, PBF, SBP and DBP in comparison to males.

Table 2 shows the age and sex wise distribution of the prevalence of raised blood pressure in its various categories. Increased rate of prevalence of hypertension was observed among the tribal women in almost all the categories of hypertension (15.9%, hypertensive; 24.6% hypertensive SBP; 25.4%, hypertensive DBP; 9.5% isolated hypertensive DBP) in comparison to their male counterpart (9.1%, hypertension; 18.3% hypertensive SBP; 13.3%, hypertensive DBP; 4.3% isolated hypertensive DBP). The overall prevalence of hypertension was observed to be 12.6%. The age group wise analysis shows a twofold or more elevation in all the blood pressure categories from 30 to 39 age group to 40–49 age group which continues to rise further in the next age group category as well.

Fig. 2 illustrates the sex and age disaggregated prevalence of hypertension among the selected six tribes. For females, the highest percentage (43.3%) of hypertension was observed among the

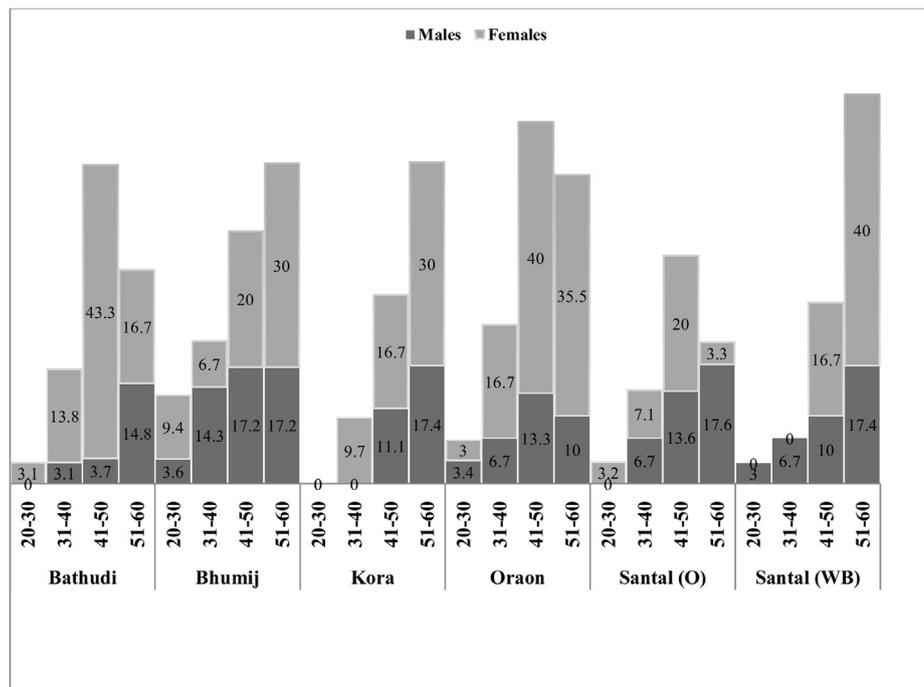


Fig. 2. Sex and age (in years) wise prevalence (%) of hypertension among selected six tribes of Odisha (O) and West Bengal (WB), India.

Table 3

Sex-wise distribution of hypertensive and normotensive individuals among selected categories of anthropometric indicators of the studied populations (n = 1431).

Anthropometric indicators	Categories	Hypertensive (%)	Normotensive (%)	χ^2
BMI (kg/m ²)	Underweight (<18.5)	4.5	38.6	10.43**
	Normal (18.5–22.9)	6.0	41.0	
	Overweight and obese (≥ 23.0)	2.0	7.9	
WHtR	Normal (<0.50)	10.0	74.3	3.68*
	Risk (≥ 0.50)	2.6	13.1	
VF	Normal (<9)	10.4	76.4	5.97*
	Risk (≥ 10)	2.2	11.0	
PBF	Normal (<25%)	7.1	81.0	6.65**
	Males Risk ($\geq 25\%$)	2.0	9.9	
Females	Normal (<30%)	9.3	65.8	20.24***
	Risk ($\geq 30\%$)	6.6	18.2	
WHR	Normal (<0.90)	3.8	58.6	12.27***
	Males Risk (≥ 0.90)	5.2	32.3	
Females	Normal (<0.85)	11.7	56.0	2.011 (NS)
	Risk (≥ 0.85)	4.3	28.1	
MWC	Normal (<90 cm)	8.4	87.9	0.06 (NS)
	Males Risk (≥ 90 cm)	0.7	3.0	
Females-	Normal (<80 cm)	15.2	81.3	0.32 (NS)
	Risk (≥ 80 cm)	0.7	2.7	

(Abbreviations- BMI- body mass index; WHtR-waist height ratio; VF- Visceral fat; PBF-percentage body fat; WHR-waist hip ratio; MWC-minimum waist circumference).
 ***p < 0.001, **p < 0.01, *p < 0.05.

Table 4

Univariate analysis between hypertension and anthropometric indicators (n = 1431).

Anthropometric indicators	Hypertensive (Mean \pm SD)	Normotensive (Mean \pm SD)	p-value
PBF	25.8 \pm 7.03	21.4 \pm 7.37	<0.001
MWC (cm)	70.7 \pm 8.94	69.4 \pm 8.18	0.57
BMI(kg/m ²)	19.89 \pm 3.29	19.27 \pm 2.87	0.01
WHR	0.85 \pm 0.064	0.85 \pm 0.65	0.79
WHtR	0.46 \pm 0.04	0.45 \pm 0.48	0.001
SF4 (mm)	34.8 \pm 14.4	33.7 \pm 16.36	0.37
Visceral fat	4.26 \pm 3.06	3.49 \pm 2.65	<0.001

(Abbreviations- PBF-percentage body fat; MWC-minimum waist circumference; BMI- body mass index; WHR-waist hip ratio; WHtR-waist height ratio; SF4- sum of four skinfold thickness; SD- standard deviation).

p-value is significant at 0.05 level.

Bathudi women followed by Oraon and Santal of West Bengal (40.0%), Bhumij and Kora (30.0%), Santal of Odisha (20.0%). In the male context, Santals of Odisha were observed with the highest percentage (17.6%) of hypertension followed by Santal of West Bengal and Kora (17.4%), Bhumij (17.2%), Bathudi (14.8%) and Oraon (13.3%).

Overall, the tribal females were found to be more vulnerable to elevated blood pressure (>40% as hypertensive) in comparison to the males. The rate of increase in hypertension due to age among Bhumij, Kora, and Santal of West Bengal was higher as compared to three tribes of Bathudi, Oraon and Santal of Odisha.

Table 3 shows the sex disaggregated distribution of hypertensive and normotensive individuals among the selected categories of anthropometric indicators. Significant differences between hypertensive and normotensive individuals were observed among normal and risk categories of the anthropometric indicators like BMI, WHtR, PBF, VF and WHR.

The Univariate analysis in Table 4 indicates four anthropometric indicators- PBF, BMI, WHtR and VF to be significantly associated with hypertension.

Table 5 presents the discriminant function analysis for hypertension in males, females, and the total population. It is observed from the Table, that standardized function coefficients (SFCs) among the males, and females combined show three variables -PBF (0.889), VF (0.737) and MWC (0.448) as the most powerful discriminators of hypertension than normotension and overall, the model correctly classified 66.7% of the participants in the study.

Among males, the SFCs show that VF (1.464) and PBF (0.356) are

the most powerful discriminators of hypertension and overall, 71.5% of the participants were classified correctly. Similarly, among females, the SFCs reveal PBF (0.761) and VF (0.581) as the most powerful discriminator for hypertension and overall, the model correctly classified 67.2% of the participants in the study.

Table 6 presents the discriminant function analysis for high SBP and DBP for males and females. It is observed from the Table, that standardized function coefficients (SFCs) among males show two variables-VF (1.385) and WHtR (0.673) as the most powerful discriminators of high systolic blood pressure (SBP) than normal SBP. Overall the model correctly classified 64.4% of the sample whereas among females, SFCs reveal VF (0.953), PBF (0.683), and MWC (0.666) as the powerful discriminators of high SBP and overall, the model correctly classified 68.9% of the participants in the study.

Similarly, for high diastolic blood pressure (DBP), SFCs (standardized function coefficients) reveal VF (0.625), WHtR (0.471) and PBF (0.466) as the powerful discriminators among males; overall, the model correctly classified 68.7% of the sample. In females, SFCs reveal MWC (1.632) and PBF (0.971) as the most powerful discriminator for high DBP and overall, the model correctly classified 60.5% of the participants in the study.

4. Discussion

Trends in the increasing prevalence of hypertension and pre-hypertension among the tribal populations (Fig. 2), particularly in the context of the highly prevalent chronic undernutrition (reported elsewhere) are the significant findings of the present study.

Table 5
Discriminant function coefficients and structure coefficients of hypertension in males, females and total of the studied populations.

Variables	Wilks' Lambda	F statistics	p-value	Standardized function coefficients	Structure coefficients	Correctly classified
Males and Females combined (n = 1431)						
PBF	0.961	57.548	0.000	0.889	0.827	66.7%
MWC (cm)	0.997	3.630	0.057	0.448	0.208	
BMI (kg/m ²)	0.996	6.272	0.012	-0.637	0.273	
WHR	1.000	0.068	0.794	-0.526	-0.028	
WHtR	0.993	10.159	0.001	0.272	0.348	
SF4 (mm)	0.999	0.783	0.376	-0.550	0.096	
Visceral fat	0.991	12.905	0.000	0.737	0.392	
Males (n = 705)						
PBF	0.974	19.106	0.000	0.356	0.699	71.5%
MWC (cm)	0.981	13.304	0.000	0.070	0.583	
BMI (kg/m ²)	0.983	12.304	0.000	-0.627	0.561	
WHR	0.986	10.269	0.001	0.197	0.513	
WHtR	0.979	15.097	0.000	-0.019	0.622	
SF4 (mm)	0.998	1.386	0.239	-0.616	0.188	
Visceral fat	0.970	21.612	0.000	1.464	0.744	
Females (n = 726)						
PBF	0.970	22.581	0.000	0.761	0.690	67.2%
MWC (cm)	0.994	4.238	0.040	0.262	0.299	
BMI(kg/m ²)	0.997	2.158	0.142	-0.826	0.213	
WHR	0.999	0.409	0.523	-0.604	-0.093	
WHtR	0.997	2.304	0.129	-0.415	0.220	
SF4 (mm)	1.000	0.161	0.689	-0.669	-0.058	
Visceral fat	0.987	9.507	0.002	0.581	0.448	

(Abbreviations- PBF-percentage body fat; MWC-minimum waist circumference; BMI- body mass index; WHR-waist hip ratio; WHtR-waist height ratio; SF4- sum of four skinfold thickness).

p-value is significant at 0.05 level.

Table 6
Discriminant function coefficients and structure coefficients of high SBP and DBP among adult tribal males and females of the studied populations.

Variables	Wilks' Lambda	F statistics	p-value	Standardized function coefficients	Structure coefficients	Correctly classified
High SBP (Males, n = 705)						
PBF	0.983	12.144	0.001	0.123	0.600	64.4%
MWC (cm)	0.979	15.185	0.000	-0.616	0.671	
BMI (kg/m ²)	0.983	11.868	0.001	-0.734	0.593	
WHR	0.978	16.065	0.000	0.347	0.690	
WHtR	0.970	21.970	0.000	0.673	0.807	
SF4 (mm)	0.992	5.955	0.015	-0.234	0.420	
Visceral fat (%)	0.971	20.882	0.000	1.385	0.800	
High SBP (Females, n = 726)						
PBF	0.947	40.604	0.000	0.683	0.707	68.9%
MWC (cm)	0.988	9.198	0.003	0.666	0.336	
BMI (kg/m ²)	0.995	3.305	0.069	-1.242	0.202	
WHR	1.000	0.026	0.872	-0.548	0.018	
WHtR	0.987	9.446	0.002	0.212	0.341	
SF4 (mm)	1.000	0.051	0.822	-0.503	0.025	
Visceral fat	0.971	21.780	0.000	0.953	0.518	
High DBP (Males, n = 705)						
PBF	0.967	23.746	0.000	0.466	0.728	68.7%
MWC (cm)	0.971	21.041	0.000	-0.039	0.685	
BMI (kg/m ²)	0.972	20.076	0.000	0.006	0.669	
WHR	0.981	13.643	0.000	-0.008	0.552	
WHtR	0.966	24.823	0.000	0.471	0.744	
SF4 (mm)	0.995	3.355	0.067	-0.553	0.274	
Visceral fat	0.963	27.325	0.000	0.625	0.781	
High DBP (Females, n = 726)						
PBF	0.979	15.349	0.000	0.971	0.657	60.5%
MWC (cm)	0.997	2.445	0.118	1.632	0.262	
BMI (kg/m ²)	1.000	0.172	0.678	-0.679	0.070	
WHR	1.000	0.001	0.981	-0.385	0.004	
WHtR	0.999	0.584	0.445	-0.949	0.128	
SF4 (mm)	0.999	0.466	0.495	-0.596	-0.115	
Visceral fat	0.997	2.133	0.145	0.147	0.245	

(Abbreviations- PBF-percentage body fat; MWC-minimum waist circumference; BMI- body mass index; WHR-waist hip ratio; WHtR-waist height ratio; SF4- sum of four skinfold thickness).

p-value is significant at 0.05 level.

Most importantly, the findings of the present study, reporting the internal fat deposition indicators as significant indicators of elevated blood pressure categories is an important observation (Tables 5 and 6). It indicates an increasing trend in physio-

metabolic health adversities, lifestyle changes, and the associated epidemiological transition among the Indian tribes. It further indicates the adversities due to undernutrition on the physiological and metabolic processes of the indigenous population, in the form

of fat intolerance. Therefore, the present study carries a lot of significance in the absence of systematic analysis of the various anthropometric tools to evaluate and compare their ability to predict hypertension in the context of the Indian indigenous population. It is important to note here, that the prevalence of hypertension in the present study was found to be 12.6% (Table 2). The highest prevalence was observed at 43.3% among the Bathudi women and 17.6% among the Santal men of Odisha. While due to age, the highest prevalence rate was observed among Bhumij, Kora and Santal of West Bengal. It is also worth mentioning here that isolated hypertensive SBP has been identified as an independent cardiac risk [55,56]. In this context, more than 20% (hypertensive plus isolated hypertensive SBP) of the Indian tribal population fall into such risk bracket which is a serious health concern. It is also important to note that Gopalan (1992) reported a 2–3% overweight among the Indian tribes. A recent study has reported that among the tribes of India more than 10% are overweight and 2–3% obese along with a high prevalence of undernourishment [5]. Therefore, in the context of such an increasingly alarming situation, it is necessary to evaluate the efficacy and the predictability of the indicators for hypertension for future measurements and evaluation.

The present study of the six major tribes from India is also important as it examines and compares the significance of anthropometric variables towards predicting hypertension among adult males, females and the total population.

In the previous studies, anthropometric indicators like BMI [18,27,57–60], WHR [3,59–63], MWC [20,59,64–66] and WHtR [25,26,67,68] have been considered as better predictors of hypertension for the Indian population. Kesavachandran, Bihari & Mathur (2012) reported that under normal BMI limit, higher PBF was present as a risk factor for type-2-diabetes/hypertension among male residents of Lucknow city, North India [50]. Few studies have also shown association of skinfold thickness with blood pressure among Punjabi community of Amritsar [69] and Delhi [58] and adult tribal males of India [70]; similar association was also observed with body fat percentage in Indian populations [50,58,71]. However, in terms of predictability of hypertension with SF4 and PBF, it lacks extensive investigation; and among the tribal groups of India, it is absent. Similarly, VF is also a less explored indicator in the Indian context. Moreover, it can be said that there is a limited availability of literature evaluating the ability of various anthropometric indicators in predicting hypertension and similar risks (raised SBP and DBP) among the Indian tribal populations. Thus, it becomes important to evaluate such risk factors; additionally, Indian tribes have a tendency to preferentially acquire increased subcutaneous adiposity than general obesity [5].

In the present study, the tribal females were found to be more hypertensive than males and the hypertension prevalence rate was found to be synchronous with the increase in the age among selected groups than others (Fig. 2). The findings also reported significant differences among the different categories of selected anthropometric indicators with hypertensive and normotensive individuals. Univariate analysis showed four anthropometric indicators – PBF, BMI, WHtR and VF, significantly associated with hypertension.

In the present study, we performed a discriminant analysis to identify and compare the better predictors for discriminating between hypertensive and normotensive groups in the selected six tribes of West Bengal and Odisha. By employing a discriminant analysis, PBF and VF along with MWC were found to be the most powerful discriminators of hypertension and other raised blood pressure conditions (raised SBP and DBP) and its risks in the total pooled population. Overall, the model correctly classified 67.2% of the hypertensive and 66.6% of the normotensive participants in the study. Similarly, in males, PBF and VF were found to be the most

powerful discriminators of hypertension where 71.9% of hypertensive and 71.5% of normotensive participants were classified correctly. In females, PBF and VF along with MWC were found to be the most powerful discriminators of hypertension and similar risks (raised SBP and DBP) where 68.1% of the hypertensive and 67.0% of normotensive subjects were classified correctly. For high SBP, VF and WHtR were found to be the better predictors in males while PBF, VF along with MWC were found to be the effective predictors of high SBP in females. Similarly, for high DBP and PBF, VF along with WHtR were found to be the more appropriate predictors of high DBP in adult males; while PBF along with MWC were found to be the better predictors of high DBP risk in females.

Overall, PBF and VF were found to be good predictors for identifying hypertension and similar risks among men and women; similar findings have been reported in previous studies [72,73]. Few studies have reported that PBF could accurately reflect body composition than BMI, though both BMI and PBF have been widely used for the evaluation of human health risks like CVD [74–76] and hypertension. Chakraborty et al. (2009) reported that increased PBF among adult Bengalee male slum dwellers in West Bengal, India put them at 2.6 times higher risk for hypertension [77]. VF is considered as a unique, pathogenic fat depot [36] and responsible for higher prevalence of hypertension [78–80] & metabolic risk [81–83]. Since VF is not externally visible and remains unnoticed, it is supposed to be closely linked to increased fat level in the bloodstream and may lead to harmful effects on health [84,85]. Kuk et al. (2006) reported VF as an independent predictor of all-cause mortality in men [86]. However, Zeng et al. (2012) showed PBF as a stronger predictor of CVD risk than BMI in the Chinese population [76]. PBF consists of two types of fat in our body – essential fat and storage fat, that helps in storing energy and protecting internal organs, while too much fat and too little fat may be unhealthy and responsible for negative health implications [76,87]. Here, it may be mentioned from the studies around the world that VF and PBF are strongly associated with higher risks of hypertension and prehypertension [36,72,79,88,89]. Furthermore, these two fat indicators are the better substitutes for BMI. Although BMI is the most widely used predictor of cardio-metabolic risks, it does not indicate the central fat distribution and could not differentiate between fat and lean body mass [33] among the populations like Indian tribes affected by the double burden of malnutrition. Therefore, in the context of the widely used various anthropometric indices i.e. BMI, MWC, WHR, and, WHtR in determining hypertension in various urban and rural Indian populations [1,20,25,30,31,58,64,65,90–95], the predictive ability of PBF and VF will be of added advantage in better screening and management of the cardio-metabolic risks.

The present findings become significant as PBF and VF are being reported for the first time as more effective discriminants of hypertensive risk in Indian tribes. Here it is important to mention that PBF and VF are independent of BMI. Thus, it becomes all the more important in the context of the tribal populations of India to further investigate such risk factors among large and extensive Indian tribal populations.

The present study has several other implications for public health and epidemiological perspectives. The study in the context of fat indicators i.e. PBF and VF have emerged as major classifiers of hypertension and highlights the possibility of a potential epidemiological transition among the Indian tribal populations. Such a state of health might be experienced in two different ways. Previous studies have reported lifestyle and behavioral changes among Indian indigenous people that are mostly foreign to their long practiced indigenous patterns [5,96,97]; accumulation of excessive fat as a major outcome of dietary changes by adopting cheaply available non-traditional modern food is one major aspect and a

serious concern. Secondly, chronic undernutrition during gestation, infancy, adolescent and post-adolescent phases leads to fat intolerance in the body during adulthood of such individuals, causing extra deposition of fat. This, as a consequence, leads to issues like hypertension, obesity and other CVD risks. Therefore, in the context of the above high prevalent morbid conditions, proper screening of the risk along with consistent surveillance comes out as the priorities. PBF and VF may be further examined in different tribal populations to study their ability to evaluate the cardio-metabolic risks.

Limitations of the study

The present findings of the study do not fully represent the diverse Indian tribal population landscape and therefore, needs to be replicated among other tribes in the different geographic and cultural setups in other parts of India. The prevalence of hypertension may increase if specific cut-off values for hypertension are generated separately for the tribal population. The increased prevalence of high undernutrition associated hypertension needs investigation.

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Conflicts of interest

The authors declare that there is no conflict of interest.

Authors' contributions

GKK, AK and SKA designed the study. AK analyzed the data, AK and SKA drafted the manuscript. GKK provided necessary logistic support. SKA edited the manuscript.

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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.2018.11.038>.

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