Predictors of hypertension among adult tribal males of India

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Abstract

Background: Cardiovascular diseases (CVD) have increased worldwide equally burdening people from different ethnic and socio-economic groups. Hypertension is an eminent modifiable risk factor for CVD and relates to body adiposity, which can be evaluated by various anthropometric measurements.

Objective: The present study reports prevalence of under nutrition and hypertension, potential predictors of hypertension and new cutoff values for various disease associated adiposity markers in six tribal populations inhabiting different states in India.

Methods: Cross sectional sample of 910 adult males aged 46.98 ±17.17 years was studied. Anthropometric measurement (height, body weight, body circumferences, skinfold thicknesses), blood pressure and socio-demographic characteristics were ascertained. General and regional adiposity indices, muscle diameter and fat % were derived. Descriptive, multivariate regression analyses were performed. Receiver operating characteristics (ROC) was used to determine optimal cutoffs values.

Results: Underweight (45.3%) and hypertension [Systolic blood pressure (SBP) - 15.2%, Diastolic blood pressure (DBP)-25.5%] co-exist in the tribal population under study. General adiposity measures were better predictors of hypertension. Body mass index (BMI), fat% (negatively associated), age and mid upper arm circumference (positively associated) were independent risk factor for hypertension. Out of all reported cut offs, the new BMI cutoff values (20.12 kg/m^2 and 18.98 kg/m^2) and for mid upper arm circumference (MUAC) (21.44cm and 21.95cm) for predicting SBP and DBP respectively corresponding nearly to earlier reported standards by World health Organization (WHO).

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Conclusion: The inverse association of general adiposity markers with blood pressure among the present subjects indicates that CVD is not only prevalent among the affluents but is also affecting the socio-economically and nutritionally deprived groups. Population specific cutoffs for the anthropometric markers are needed to identify individuals with different body compositions at risk. Long term treatment expenses and health burden further depletes the limited economic resources of these vulnerable groups creating a vicious cycle of CVD and undernutrition.

Keywords: Hypertension, under nutrition, tribe, India.

Introduction

Cardiovascular disease (CVD) is a primary cause of mortality**,** worldwide. India is facing epidemic of CVD with estimated 3 million deaths per year (WHO, 2005) affecting both urban (Reddy et al., 2005) and rural adult population (Joshi et al., 2006). It is expected that by 2025 nearly 213.5 million men and women in India will be hypertensive (Kearney et al., 2005). Several studies have shown association of overnutrition with hypertension and determined cut off values of BMI above which there is increased CVD risk (Lin et al., 2002;Wildman et al., 2005). Increased abdominal fat accumulation assessed by waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) has been extensively documented as independent risk factor across different ethnic groups (Ducimetiere et al., 1986; Ho et al., 2001; Kawad, 2002; Hsieh et al., 2005) Pattern of body fat distribution being age, sex and population specific (Mungreiphy et al., 2010) is reported as more important determinant of CVD than body mass index (BMI) (Pi-Sunyer, 2000).

Asian Indians have higher fat% and central adiposity despite their lean BMI and tends to develop chronic diseases at a lower BMI compared to white populations (Tuan et al., 2009; Wang et al., 1994). Although WHO has defined BMI, WC and WHR cutoff points for different ethnic populations (WHO, 1998), these cannot be readily applied to all populations (Okosun et al., 2000). Mean BMI of healthy Indians is much lower than WHO international cutoff (25kg/m^2) leading to new BMI cutoffs (23kg/m^2) for Asians. But these Asians do not truly represent the variability in a country like India due to its multi-caste and multi-cultural composition. Anthropometric cutoffs are needed to identify health risks associated with different body compositions (WHO, 2004).

Current health and demographic transition in India has led to multiple chronic disease risks of dual nutrition burden and hypertension. Lower income groups and traditional societies undergoing socio-economic and nutrition transition are at higher risk. Prevalence of hypertension has increased in traditional populations undergoing modernization (Kapoor et al., 2010) and undernutrition has been reported as its risk factor (Longo-Mbenza et al., 2007). The prevalence of malnutrition is on rise, and CVD being an important cause of morbidity and mortality, its risk factors and their measurements warrant further study among high risk population. Several studies have determined prevalence and risk factors of hypertension in

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urban areas, slums and villages however not many have reported the disease risk in Tribal groups which constitute about 8 % of Indian population (Census of India, 2001).

The published literature assessing the multiple adiposity measures and hypertension in multi-tribal population of India is meager. In the present study we assessed the associations of regional and general adiposity measures to hypertension risk and to determine optimal cutoff values using receiver operating characteristic (ROC) analysis for various anthropometric indices as predictors of hypertension, among adult males of different tribal population in India.

Methods

Indian mainland comprises numerous socio-culturally distinct caste groups, ethnic and tribal communities. Tribal people inhabit various ecological and geo-climatic conditions ranging from plains, forest, hills and less accessible areas. During 1999-2001, cross sectional sample of 910 adult males aged 46.98 ±17.17 years was studied from six tribal populations inhabiting different villages – CarNicobarese (Nicobar Islands), Saharia (MadhyaPradesh), Tadvi (Gujarat), Bhotias (Uttarakhand), Minas (Rajasthan) and DesiaKhond (Orissa). Age was recalled among elderly. All groups belonged to lower socio-economic scale, had low literacy level and traditionally high consumption of alcohol and beetle leaves. They lived in traditional mud houses with no toilets and used pond, well or hand pumps as source of water supply. All, but Car-Nicobarese had nuclear families. While all others were mainly agriculturalists, semi-skilled laborers, Bhotias followed semi-nomadism and transhumance and practiced some trading. Car-Nicobarese were mainly horticulturist, but also practiced animal rearing, hunting, fishing and practiced barter with neighboring communities. Availability and accessibility of PHC varied across different villages studied. All of them had high physical activity levels either due to their occupation or geographical locations.

Study purpose was explained to all volunteers before seeking their written consent. The study protocol was duly approved by the Ethical committee of Department of Anthropology, University of Delhi. Subjects were asked questions about their daily habitual activity and lifestyle using a pretested proforma. Anthropometric measurement (height, body weight, body circumferences, skinfold thicknesses) were taken by trained anthropologist using standard procedures (Weiner & Lourie, 1969). Height, body weight, circumferences (minimum waist, maximum hip. mid upperarm), skinfold thicknesses (biceps, triceps, subscapular, suprailiac and calf posterior) were recoreded to the nearest 0.1cm, 0.5kg, 0.1cm and 0.2mm respectively. Body circumferences were measured using flexible steel tape while skinfold thicknesses by using Harpenden skinfold caliper which exerted a constant pressure of 10gm/mm^2 on the contact surface.

Blood pressure (systolic and diastolic phase V of Korotoff) were measured twice in the right arm in sitting position, at an interval of 5minutes, using a standard mercury sphygmomanometer and stethoscope. Subjects were asked to take rest before taking measurements on them. Body mass index (BMI) was computed as weight (kg)/ height (m^2).Waist hip ratio (WHR) and waist height ration (WHtR) was calculated. Grand mean thickness (GMT) was calculated as mean of the skinfold thicknesses taken over different sites. Durnin’s age specific equations (1974) were used to calculate the body density which was in turn was used in Siri's equation (1961) to determine the total body fat.

$$\text{Body fat \%} = (4.95/D - 4.50) \times 100.$$

Adult BMI of <18.5 kg/m^2 has been used to diagnose chronic energy deficiency (CED) (WHO, 2003; Shetty et al., 1994). As CED represents undernutrition, in the present study CED I (17.00 - 18.49 kg/m^2), II (16.00 - 16.99 kg/m^2) and III (<15.99 kg/m^2) categories have been clubbed together as undernourished. Hypertension was defined according to the VII report of the joint National Committee (JNC, 2003). The normal blood pressure was taken as <120mmHg (Systolic) and <80mmHg (Diastolic). Subjects with blood pressure value of 120-139 mmHg (Systolic) and 80-89mmHg (Diastolic) were categorized as pre-hypertensives and those with blood pressure value above 140mmHg (systolic) and above 90 mmHg (Diastolic) were classified as hypertensives..

Statistical analysis

Data was analyzed for each tribe separately and then combined. Results are presented as the mean ±SD, or percentage, where appropriate. Pearson’s chi square was used to test the difference in proportions. Analysis of variance (ANOVA) and post hoc tests were used to test mean differences in variables, between different tribal groups. Pearson’s correlation coefficient(r) was calculated for measures of blood pressure, anthropometric variables and indices. Univariate and multivariate regression models were fitted to identify the independent risk factors.

ROC analysis which evaluates accuracy of a diagnostic test was used to find out the optimal cut-off values for various anthropometric variables and indices and the overall performance of ROC test was quantified by computing area under the curve (AUC). In the context of the present study, this diagnostic accuracy refers to the ability of the anthropometric variables to discriminate between hypertensive and normotensive. Individual cutoffs were defined as that point on the curve where the sum of sensitivity and specificity was highest. All statistical inference was based on 95% confidence interval (CI) and 5% p values. Data was analyzed using PASW (version 18.0,Chicago, IL, USA).

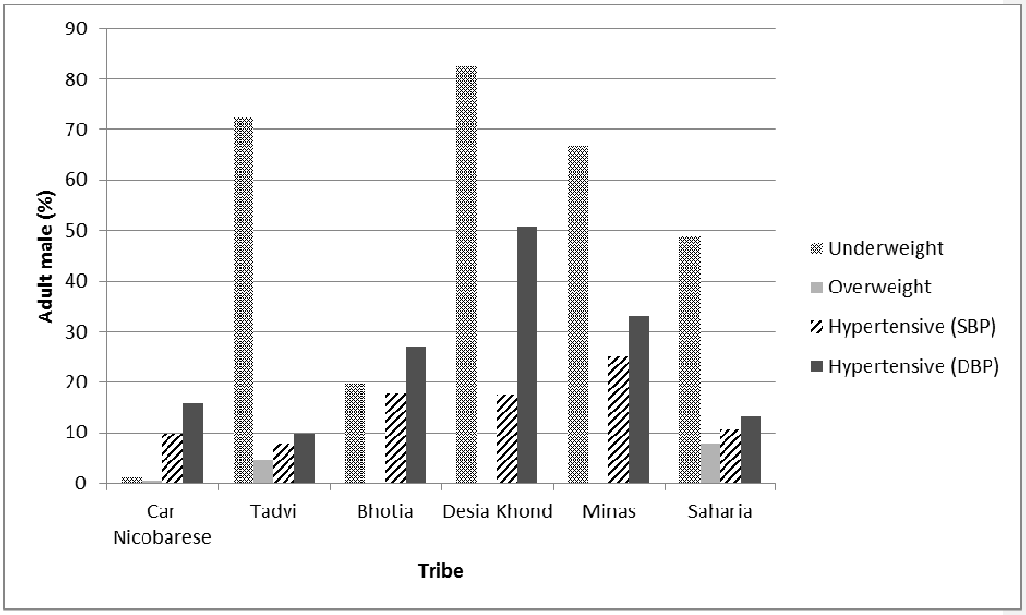
Results

Table 1 summarizes basic characteristics of subjects. ANOVA suggested significant differences between the groups for various anthropometric and physiological variables. Mean BMI showed that Tadvis, DesiaKhond and Minas were undernourished while Saharias, Car-Nicobarese and Bhotias were marginally normal nourished. GMT and fat % showed greater variation between the groups. Fig. 1 shows tribe wise prevalence of under nutrition and hypertension. The overall prevalence of underweight was 45.3% and overweight was 2%. As per systolic blood pressure (SBP), 66.9 % and 15.16% and as per diastolic blood pressure (DBP), 53.6% and 25.4% subjects were categorized as pre-hypertensive and hypertensive respectively. Considering SBP, 62.8% of underweight subjects were at risk of hypertension and 17.96% were hypertensive while DBP discerned 47.57% and 33.5% of underweight subjects to be pre-hypertensive and hypertensive respectively. Prevalence of under nutrition and hypertension increased with age (data not shown).

Table 1: Basic data of subjects from different tribes

Tribe		Age	Height	Weight	BMI	GMT	Fat %	MUAC	Triceps SFT	WC	WHR	WhtR	SBP	DBP
	n	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Car Nicobarese	165	52.18 (16.86)	158.72 (4.10)	55.3 (3.41)	21.98 (1.48)	5.60 (0.61)	9.57 (1.86)	25.73 (0.86)	4.70 (0.60)	70.19 (2.60)	0.86 (0.04)	0.44 (0.02)	126.3 8.14)	83.43 (6.61)
Tadavi	91	41.87 (17.82)	158.39 (5.74)	45.59 (9.39)	18.13 (3.52)	6.31 (2.19)	11.48 (4.34)	23.64 (2.53)	3.80 (2.87)	67.98 (5.32)	0.87 (0.05)	0.43 (0.04)	123.9 (8.44)	81.44 (6.49)
Bhotia	182	52.87 (16.37)	159.14 (3.30)	49.38 (4.50)	19.48 (1.52)	7.03 (1.47)	14.37 (4.23)	24.62 (2.44)	6.40 (1.68)	73.58 (3.95)	0.88 (.05)	0.46 (0.02)	129.37 (13.89)	85.99 (8.64)
Desia Khond	144	51.11 (16.56)	158.71 (1.96)	44.4 (2.41)	17.63 (0.95)	4.11 (0.97)	5.37 (2.21)	20.68 (1.22)	3.56 (0.44)	65.53 (2.25)	0.87 (0.03)	0.41 (0.01)	127.93 (9.87)	88.35 (8.55)
Minas	160	49.13 (15.59)	159.85 (5.18)	44.75 (4.76)	17.55 (2.06)	5.70 (1.09)	10.58 (3.22)	23.11 (1.83)	4.49 (1.57)	67.61 (5.78)	0.85 (0.08)	0.42 (0.04)	130.02 (13.23)	85.01 (10.75)
Saharia	168	32.72 (19.11)	165.02 (6.17)	52.05 (7.49)	19.11 (2.56)	8.29 (3.18)	13.80 (5.10)	22.72 (2.74)	6.62 (2.78)	69.55 (5.95)	0.85 (0.04)	0.42 (0.04)	120.32 (11.55)	79.68 (8.53)
All	910	46.99 (17.17)	160.13 (5.14)	48.96 (6.84)	19.10 (2.57)	6.24 (2.22)	11.01 (4.76)	23.48 (2.59)	5.09 (2.18)	69.34 (5.20)	0.86 (0.05)	0.43 (0.03)	126.48 (11.83)	84.10 (8.95)
	F	41.95[a]	48.84[a]	100.12[a]	103.22[a]	99.01[a]	123.66[a]	111.29[a]	77.16[a]	60.11[a]	8.96[a]	58.27[a]	16.80[a]	20.41[a]

Fig 1. Prevelance of Undernutrition and Hypertension in Adult males of different tribes



To check whether these tribes were under the risk of CED or were actually lean ie having less fat % but relatively higher muscle mass, than other groups, we calculated the muscle diameter using mid upper arm circumference formula (Osborne et al., 1959). The size of the muscle mass is an indirect indicator of protein reserve (WHO, 1995). This value was corrected for fat content by subtracting bicep and triceps skinfold thicknesses. The mean value of muscle mass for all 6 tribe was significantly different p<0.001 (ANOVA). Post hoc analysis revealed that mean muscle mass of Saharia, Tadvis and Minas were not statistically different, hence the 3 tribes were combined for further analysis. Bhotia, Car-Nicobarese and DesiaKhond were taken separately, thus comparing 4 groups of relatively lower, medium and higher muscle mass.

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Table 2 shows arm diameter, muscle diameter [corrected], general and regional adiposity measures, and hypertension levels in these groups. Across the table, from group 1 to 4 the mean of muscle diameter decreased simultaneously with a decrease in BMI irrespective of fat% which indicates the populations to be undernourished.

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Table 2: Arm diameter, muscle diameter, general and regional adiposity markers among different ethnic groups

\	Group 1 (Car Nicobarese)		Group 2 (Bhotia)		Group 3 (Saharia,Mina,Tadvi)		Group 4 (Desia Khond)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MUAC	25.73	0.86	24.62	2.44	23.0	2.39	20.68	1.22
Arm Diameter	8.19	0.27	7.84	0.78	7.34	0.76	6.58	0.38
Muscle diameter (Corrected)	7.77	0.27	7.32	0.68	6.77	0.75	6.26	0.38
BMI	21.98	1.49	19.48	1.52	18.30	2.72	17.62	0.95
GMT	5.60	0.61	7.03	1.47	6.87	3.63	4.10	0.97
Triceps SKFT	4.71	0.61	6.40	1.68	5.21	2.70	3.56	0.44
Fat %	9.57	1.86	14.37	4.23	12.06	4.53	5.37	2.21
WC	70.19	2.60	73.58	3.95	68.46	5.81	65.5	2.25
WHR	0.86	0.04	0.88	0.05	0.85	0.6	0.87	0.3
WHtR	0.44	0.02	0.46	0.03	0.42	0.3	0.41	0.1
SBP Prehypertensive %)	80.6		71.4		75.8		70.1	
Hypertensive (%)	9.7		17.6		13.8		17.4	
DBP Prehypertensive (%)	66.1		60.4		63.1		45.8	
Hypertensive (%)	15.8		26.9		21.6		50.7	

Correlation and linear regression model for blood pressure and anthropometric parameters are presented in Table 3. The anthropometric variables showed a significant correlation with SBP and DBP. Blood pressure (SBP and DBP) showed significant negative association with BMI, GMT, triceps skinfold thickness and positive association with WHR, WHtR and age. DBP correlated negatively with fat% also. There was significant association between all

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anthropometric indices except WHR as shown by the age adjusted partial correlation coefficients (data not shown). Simple linear regression models were run using SBP and DBP as a dependent variable and age and all anthropometric parameters as predictor variables and the regression coefficients with 95% confidence interval are presented in Table 3.

Table 3: Simple linear regression of blood pressure on different adiposity markers

	DBP											
	B value	β	95% CI		r	p	B value	β	95% CI		r	p
			Lower	Upper					Lower	Upper		
BMI	-0.319	-0.069	-0.618	-0.019	-0.069	0.037[a]	-0.477	-0.137	-0.703	-0.252	-0.137	0.001[c]
GMT	-0.746	-0.140	-1.089	-0.403	-0.140	0.001[b]	-0.866	-0.215	-1.122	-0.610	-0.215	0.001[c]
Fat %	-0.071	-0.029	-0.233	0.091	-0.029	0.387	-0.226	-0.120	-0.348	-0.104	-0.120	0.001[c]
MUAC	0.275	0.060	-0.022	0.572	0.060	0.070	-0.201	-0.058	-0.425	0.024	-0.058	0.080
TSF	-0.508	-0.094	-0.860	-0.157	-0.094	0.005[b]	-0.506	-0.123	-0.771	-0.241	-0.123	0.001[c]
WC	0.076	0.033	-0.072	0.224	0.033	0.314	0.007	0.004	-0.105	0.119	0.004	0.904
WHR	33.038	0.148	18.702	47.374	0.148	0.001[c]	31.531	0.187	20.751	42.310	0.187	0.001[c]
WHtR	41.558	0.122	19.611	63.505	0.122	0.001[c]	19.289	0.075	2.597	35.980	0.075	0.024[a]
Age	0.289	0.419	0.248	0.329	0.419	0.001[c]	0.209	0.400	0.178	0.240	0.400	0.001[c]

[a]$p < 0.05$, [b]$p < 0.01$, [c]$p < 0.001$

The independent association of anthropometric indices with risk factors was further examined using stepwise multiple linear regression models. Table 4 shows multiple linear regression coefficients using SBP and DBP as dependent variables while age, BMI, MUAC and fat% as independent risk factors. Age and tribe adjusted models showed negative linear association of BMI and fat % with both SBP and DBP. On an average, each unit decrease in BMI and fat % was associated with 0.6 and 0.4 unit increase in SBP, 0.5 units and 0.3 unit increase in DBP respectively. Systolic blood pressure was positively related to mid upper arm circumference, an indicator of nutritional status and the association remained statistically significant after adjustment for confounders such as age and obesity indices. The proportion of the variance (R^2) in the blood pressure explained by the base model of age and tribe was 17%. Subsequently adiposity indicators were included in the model, the difference in the R^2 for the base model and the model that included the adiposity indices indicated the degree to which the adiposity index explained an additional proportion of the variance SBP and DBP as a risk factor. Table 4 shows that age, MUAC and BMI contributed to 19% of variance in SBP whereas for DBP, 17.9% of variance was explained by age, BMI and fat%.

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Table 4: Stepwise multiple linear regressions using systolic blood pressure and diastolic blood pressure as a dependent variable

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Variables	SBP						DBP					
	B	β	95% CI		R^2	p	B	β	95% CI		R^2	p
			Lower	Upper					Lower	Upper		
Base model **Age & tribe**	0.322	0.028	0.266	0.378	0.176	0.001[c]	0.209	0.402	0.167	0.252	0.160	0.001[c]
BMI	-0.677	-0.147	-1.060	-0.293	0.180	0.001[c]	-0.511	-0.146	-0.803	-0.218	0.174	0.001[c]
Fat %	-0.441	-0.177	-0.796	-0.085	-	0.015[a]	-0.391	-0.207	-0.662	-0.120	0.179	0.005[b]
MUAC	0.903	0.198	0.508	1.299	0.191	0.001[c]	0.267	0.077	-0.035	0.569	-	0.083
GMT	0.525	0.099	-0.257	1.306	-	0.188	0.097	0.024	-0.499	0.694	-	0.749
TSF	-0.019	-0.003	-0.547	0.509	-	0.944	0.362	0.088	-0.041	0.764	-	0.078
WC	-0.039	-0.017	-0.232	0.154	-	0.694	-0.022	-0.013	-0.169	0.125	-	0.768
WHR	-15.956	-0.072	-35.307	3.395	-	0.106	0.207	0.001	-14.555	14.969	-	0.978
WHtR	24.377	0.072	-16.091	64.846	-	0.237	14.527	0.057	-16.344	45.399	-	0.356

Table 5 summarizes the AUCs of ROC analyses and cut off values of various anthropometric indices showing how each adiposity measures predict systolic and diastolic blood pressure. An AUC of one indicates perfect separation between affected and non-affected subjects, while an AUC of 0.5 indicates no discriminative value of test used. Cutoffs for various anthropometric indices were determined using ROC analysis, for subjects, whose SBP or DBP were >120mmHg and >80 mmHg respectively. AUC of BMI, GMT, fat %, MUAC, WC and WHR were statistically significant for SBP and AUCs for BMI and WHtR were statistically significant for DBP. Considering SBP, the optimal cut off values were 20.12 kg/m^2 for BMI, 3.48mm for GMT, 8.91% for fat, 21.45cm for MUAC, 65.65cm for WC, 0.85 for WHR and 0.43 for WHtR. In disparity, for DBP the cutoffs were 20.44 kg/m^2 for BMI, 21.95 cm for MUAC and 0.42 for WHtR.

Table 5: Cutoff points of anthropometric parameters for hypertension in tribal males

	SBP					DBP				
	AUC	(95% CI)		Cutoff value	p	AUC	(95% CI)		Cutoff value	p
BMI	0.568	0.529	0.607	20.12	0.001[c]	0.569	0.532	0.606	18.98	0.001[c]
GMT	0.452	0.411	0.493	3.475	0.01[b]	0.532	0.494	0.570	4.15	0.09
Fat %	0.497	0.457	0.538	8.91	0.89	0.549	0.511	0.587	7.09	0.01[b]
MUAC	0.568	0.528	0.608	21.45	0.001[c]	0.566	0.528	0.603	21.95	0.001[c]
TSF	0.469	0.427	0.510	3.35	0.12	0.530	0.492	0.568	4.15	0.14
WC	0.540	0.499	0.581	65.65	0.04[a]	0.522	0.484	0.560	65.35	0.25
WHR	0.575	0.536	0.614	0.85	0.001[c]	0.511	0.474	0.549	0.85	0.55
WHtR	0.576	0.537	0.616	0.43	0.001[c]	0.549	0.512	0.587	0.42	0.01[b]

Discussion

When most of the world is combating with debacle of obesity, India is struggling to overcome dual burden of malnutrition and rising health burden of CVD at both ends of nutritional spectrum.

Underweight and hypertension co-exist in the study sample increasing the morbidity of the population. High prevalence of under nutrition (45.3%) and hypertension (27.5%) among the tribal population under study, while that of obesity-39% and hypertension- 38.5% reported among urban adults (Prasad et al. 2010) conform to U shaped association of BMI and mortality (Shetty et al., 1994). This indicate that rather than a linear relationship between hypertension and obesity, there exists a U-curved association in which both underweight and overweight people are at risk compared to people with a normal weight. Earlier studies have also reported high prevalence of underweight (Kapoor et al., 2009a,b) and prevalence of hypertension (Kusuma et al., 2004; 2008) among tribal population. The present day challenge is to combat the dual problem of CED and hypertension in socio-economically disadvantaged populations (Kusuma et al., 2004).

Tribes in India are closed isolated groups with traditionally distinct culture, beliefs and practices. Since independence various programmes have been introduced by the Government of India for tribal development. With reservations they are getting better jobs and getting assimilated into the mainstream population. At one end globalisation and industrialization are influencing lifestyle in big cities while at the other end the traditional populations are giving up their age old occupations. Such a shift has lead to increased biological risks in the entire population. Although some of tribal groups have become more advanced and moved to cities, study subjects were from the villages living in the areas of hardships. Hypertension, although common is inadequately detected and treated in India (Reddy et al., 2005). Situation is more complex among villagers living in hard to reach geographical location. The differences in nutritional status between different tribes can be attributed to their SES. DesiaKhond, Saharias and Tadvis belong to the weakest SES group and live in economic hardships often working as daily wage laborers and supplementing their diet by gathering edible roots, leaves and tubers, fishing in hill stream and water logged paddy fields. Other groups like Car-Nicobarese are relatively better in terms of their diet and occupation. They consume animal based product and protein rich diet.

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None of the subjects studied were taking antihypertensive medicine. Majority of them were not aware about their hypertension status but reported prolonged weakness and tiredness. During our fieldwork among Saharia, subjects always demanded for saline drips which they understood as the only treatment for all sorts of ailments pertaining to weakness and lethargy. Some of them preferred traditional healing system over modern medicine. Accessibility and acceptability of medical services was also limited in most of these areas. Hard work to earn every day meal, poor health awareness, and traditional belief system, hard to reach pockets limits their knowledge about hypertension. Subjects with severe hypertension were advised to visit nearest primary health centers.

Measurements of subcutaneous fat among populations characterized by a low degree of fatness may not be a sensitive indicator of nutritional status and growth (Frisancho, 1974).The ability of BMI alone to predict cardiovascular risk has been challenged by many as it does not distinguish overweight due to excess fat mass or due to excess lean mass. MUAC is another effective tool for the determination of malnutrition among adults in developing countries (James et al., 1994). Direct measurements for estimation of body constituents may not be possible on all individuals in all settings. Relative measurements and indices are the best possible alternatives. So, we calculated arm diameter and corrected it for biceps and triceps skinfold thickness in order to see whether subjects with such high prevalence of underweight as per BMI were chronic energy deficient or had lean BMI. Our results showed that DesiaKhond suffered CED with nearly 5% body fat which is just bare minimum for human survival and any further nutritional stress would cost upon protein depletion depicted as muscle depletion, reducing the immunity level (Castaneda, 2002; Hickson, 2006) and may lead to increased blood pressure (de Belchior et al. 2012). This signifies that reduction in general adiposity measure (BMI, fat% and GMT) below a certain point is detrimental to health and a major risk factor for hypertension. Prevalence of both SBP and DBP dependent hypertension decreased with increase adiposity measures. However, interpreting the blood pressure–BMI relationship is further complicated beyond a threshold effect below which there appears to be no correlation between the blood pressure and BMI (Bunker et al., 1995; Thorogood et al., 2003). A diminution of the slope between these two variables is apparent below the threshold ranging from as high as 27 kg/m^{2}10 to as low as 20 kg/m^{2}, (Willett et al., 1995; Kaufman et al., 1997; Rosengren et al., 1999). BMI itself is a very important tool and its utility cannot be underestimated. A combination of central adiposity indices and fat

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distribution profile may perform well in predicting disease risk associated with overweight and obesity where the relative fat content is important; however, in CED population BMI combined with MUAC and other general adiposity markers can be the simplest tool to assess the risk of hypertension.

Several studies have reported associations of hypertension with various anthropometric, body-composition measurements and derived indices, however, it is still controversial whether absolute (general adiposity) or relative body fat (central adiposity) is a better predictor of risk for hypertension (Spiegelman et al., 1992). BMI, WC (Wildman et al., 2005; Obesity in Asia Collaboration, 2008; Decoda Study Group, 2008), WHR and WHtR were broadly similar at discrimination of hypertension in Asians (Obesity in Asia Collaboration, 2008; Decoda Study Group, 2008). Others found BMI as non- (Amato et al., 2010) or poor discriminator while WHtR was the best discriminator for hypertension (Lee et al., 2008; Herrera et al., 2009). The present study demonstrated that conventional risk factors of hypertension are not same for entire spectrum of BMI. The significant negative association of BMI with SBP and DBP persisted after controlling for potential confounders and other predictors. MUAC and fat% were also independent predictors of disease risk. Kaufman et al. (1997) found that BMI <21 kg/m^2 was linearly related to BP and emphasized that obesity per se is not required for this association to get manifested. Our results favor the use of combination of anthropometric indices of general adiposity over abdominal adiposity markers in lean, undernourished population for determining hypertension risk.

The relationship between anthropometric measures of central obesity and disease risk varies with age sex, race and ethnic group (Mungreiphy et al., 2010). WHO has proposed different BMI cut off values for Asians due to their being at high risk of CVD at low BMI (Mckeigue et al., 1991). Others have recommended lower values of WC and WSR for Asians. However same cut off values are not applicable to all Asians. Although this paper does not attempt any sort of racial classification however, it is important to note that the sample constituted groups from different racial strains (Risley, 1915), differing in origin and are homogenous in their respective marital exchange. Car-Nicobarese and Bhotia belonged to Mongoloid, DesiaKhond to Dravidian stock, Saharia and Meena to Proto-Dravidian stock and Tadavai to Non-Dravidian. The new WHO classification for Asians does not truly represent all ethnic groups cohabiting in the region. With this concern we have used the international standards of BMI classification.

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In populations, measures of central obesity and disease risk vary at different BMI levels. Studies have highlighted that the prevalence of hypertension increase gradually with increasing BMI however our results show that incidence of hypertension can increase even below certain lower value for BMI, GMT and fat%. Thus, both extremely high and extremely low value of these adiposity markers can predict hypertension. It is important to know what value of adiposity measures marks the lower cut off point to identify high risk individuals with poor nutritional status. So, we determined the cutoffs for various general and regional adiposity markers in the study group. The new BMI cutoff values were 20.12 and 18.98 for predicting SBP and DBP respectively, later value corresponding nearly to international standards for undernutrition (WHO, 2003). Cut off values for MUAC (21.44 and 21.95 for SBP and DBP respectively) were also nearly equal to widely accepted value of 22cm (James et al., 1998). Single cut off for a given index to indicate central obesity for entire range of BMI is problematic. We also report present sample based cut off values for WC, WHR and WSR.

Limitations of the study

It is noteworthy that the present data is not representative of entire tribal population or the villages in which the study was conducted as each village was multiethnic with both tribes and caste groups neighboring each other. The data is mainly limited to those men who worked in agricultural fields as others who worked outside the villages went early for work; we could expect varying results had we sampled rural adults from other occupational stratum. Dyslipidemia and highly sensitive C-reactive protein (hs-CRP) could provide a much broader picture of the cardiovascular health. However concerning the limitation of resources in developing countries like India, we have focused on easy and non-invasive anthropometric methods of risk assessment. The present study reports 19% of variance in SBP whereas 17.9% in DBP as explained by the age, anthropometric markers of nutritional status and obesity. It is nonetheless possible that underlying metabolic, genetic or environmental influences could explain the residual confounding of hypertension.

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Conclusion

Our study reports high prevalence of undernutrition and hypertension and identified the potential predictors of hypertension in Indian tribal population. Cutoffs values for hypertension associated adiposity markers have been proposed. The inverse relation of general adiposity markers with blood pressure indicates that cardiovascular diseases not only affect the affluent, but also the socio-economically and nutritionally deprived groups. High prevalence of under nutrition and hypertension calls for health programmes that incorporate elements of awareness and disease prevention in the less privileged populations. Hence, further studies focusing at both end of nutrition spectrum that is, under- and overnutrition are desired to understand the disparities in CVD risk across various population. Population specific cutoffs for the anthropometric markers are needed to identify individuals with different body compositions at risk. These should also consider socio-cultural norms of the target population for effective implementation of nutritional and health programs.

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Author's contribution

AKK and SK conceptualized the study and contributed to the acquisition of data. KS and DV performed the statistical analysis and are responsible for interpretation of data. The article was drafted by AKK, SK, KS and DV. The manuscript was revised critically and finally approved for publication by AKK and SK.

References

World Health Organization. (2005). Preventing chronic diseases: a vital investment. Geneva: World Health Organization, 5-12.

Reddy, K.S., Shah, B., Varghese, C., Ramadoss, A. (2005). Responding to the threat of chronic diseases in India. Lancet, 366(9498), 1744–1749.

Joshi, R., Cardona, M., Iyengar, S., Sukumar, A., Raju, C. R., Raju, K.R., Raju, K., K Reddy, S., Lopez, A. Neal, B. (2006). Chronic diseases now a leading cause of death in rural India–mortality data from the Andhra Pradesh Rural Health Initiative. Int J Epidemiol, 35, 1522-1529.

Kearney, P.M., Whelton, M., Reynolds, K., Muntner, P., Whelton, P.K., He, J. (2005) Global burden of hypertension: analysis of worldwide data. Lancet, 365(9455), 217-223.

Lin, W.Y., Lee, L.T., Chen, C.Y., Lo, H., Hsia, H.H., Liu, I.L., Lin, R.S., Shau, W.Y., Huang, K.C. (2002). Optimal cutoff values for obesity using simple anthropometric indices to predict cardiovascular risk factors in Taiwan. Int J Obes Relat Metab Disord, 26, 1232-1238.

Wildman, R.P., Gu, D., Reynolds, K., Duan, X., Wu, X., He, J. (2005). Are waist circumference and body mass index independentlyassociated with cardiovascular disease risk in Chinese adults? Am J Clin Nutr, 82(6), 1195–1202.

Ducimetiere, P., Richard, J., Cambien, F. (1986). The pattern of subcutaneous fat distribution in middle-aged men and the risk of coronary heart disease: the Paris Prospective Study. Int J Obes, 10, 229–240.

Ho, S.C., Chen, Y.M., Woo, J.L.F., Leung, S.S.F., Lam, T.H., Janus, E.D. (2001) Association between simple anthropometric indices and cardiovascular risk factors. Int J Obes, 25, 1689– 1697.

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Kawad, T. (2002). Body mass index is a good predictor of hypertension and hyperlipemia in a rural Japanese population. Int J Obes, 26, 725–729.

Hsieh, S.D., Muto, T. (2005). The superiority of weight-to-height ratio as an anthropometric index to evaluate clustering of coronary risk factors among non-obese men and women. Prev. Med, 40, 216–220.

Mungreiphy, N.K., Kapoor, S. (2010). Socio economic changes as covariates of overweight and obesity among Tangkhul Naga tribal women of Manipur, North- East India. J Biosoc Sci, 42, 289–305.

Pi-Sunyer, F.X. (2000). Obesity: criteria and classification. Proc Nutr Soc, 59, 505–509.

Tuan, N.T., Adair, L.S., Suchindran, C.M., Ka, H., Popkin, B.M. (2009). The association between body mass index and hypertension is different between East and Southeast Asians. Am J Clin Nutr, 89(6), 1905-1912.

Wang, J., Thornton, J.C., Russell, M., Burastero, S., Heymsfield, S., Pierson, R.N. (1994). Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr, 60, 23-28.

World Health Organization.Obesity. (1998). Preventing and managing the global epidemic. WHO technical report series 894, Geneva: World Health Organization.

Okosun, I.S., Liao, Y., Rotimi, C.N., Choi, S., Cooper, R.S. (2000). Predictive values of waist circumference for dyslipidaemia, type 2 diabetes and hypertension in overweight White, Black, and Hispanic American adults. J Clin Epidemiol, 53, 401-408.

WHO expert consultation. (2004). Appropriate body-mass index for Asian population and its implication for policy and intervention strategies. Lancet, 363, 157-163.

Kapoor, S., Tyagi, R., Saluja K, Chaturvedi, A., Kapoor, A.K. (2010). Emerging health threats among a primitive tribal group of Central India. J Public Health Epidemiol, 2(2), 13-19.

Longo-Mbenza, B., Lukoki-Luila, E., M'Buyamba-Kabangu, J.R. (2007). Nutritional status, socio-economic status, heart rate, and blood pressure in African school children and adolescents. Int J Cardiol, 121, 171–177.

Census of India. (2001). Office of Registrar General and Census Commissioner, India.

Weiner, J.S. and Lourie, J.A. (1969). Human Biology: A guide to field methods, Oxford Blackwell Scientific Publications(s).

Durnin, J.V., Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutr, 32(1), 77-79.

Siri, W.E. (1961). Body composition from fluid spaces and density: Analysis of methods, in Brozek, J. and Henschel, A. (Eds.), Technique for measuring Body composition (Washington DC; National Academy of science- National Research Council), pp. 223-24.

WHO Diet, nutrition and prevention of chronic disease. (2003). Report of a joint WHO/ FAO expert consultation, Technical series no.916.

Shetty, P.S., James, W.P.T. (1994). Body mass index: A measure of chronic energy deficiency in adults. Food and nutrition paper Rome FAO, 56.

Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. (2003). The Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. JAMA, 289, 2560–2572.

Osborne, R.H., De George, F.V. (1959). Genetic basis of morphological variation: An evaluation and application of the twin study method. Harvard University press Cambridge, Massachusetts.

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Field Code Changed

Field Code Changed

Field Code Changed

WHO. (1995). Physical status: the use and interpretation of anthropometry. Geneva, World Health Organization.

Prasad, D.S., Kabir, Z., Dash, A.K., Das, BC. (2010). Coronary risk factors in South Asians: A prevalence study in an urban populace of Eastern India. CVD prevention and control, 5(4), 125-132.

Kapoor, S., Tyagi, R., Saluja, K., Chaturvedi, A., Kapoor, A.K. (2009). Nutritional Profile and Socio-Economic Status of Saharia, a Primitive Tribe of India. Open Anthropol J, 2, 58-63.

Kapoor, A.K., Tyagi, R., Kapoor, S. (2009). Nutritional status and cardio-respiratory functions among adult Raji males, a hunter and gatherer tribe of the Indian Himalayas. Anthropol Sci, 117(1), 1-7.

Kusuma, Y.S., Babu, B.V., Naidu, J.M. (2004). Prevalence of hypertension among a few cross-cultural populations of Visakhapatnam district, Andhra Pradesh, India. Ethnic Dis, 14, 250-259.

Kusuma, Y.S., Das, P.K. (2008). Hypertension in Orissa, India: a cross sectional study among some tribal, rural and urban population. Public Health, 122, 1120-1123.

Frisancho, A.R. (1974). Triceps skin fold and upper arm muscle size norms for assessment of nutritional status. Am J Clin Nutr, 27, 1052-1058.

James, W.P., Mascie-Taylor, G.C., Norgan, N.G., Bistrian, B.R., Shetty, P.S., Ferro-Luzzi, A. (1994). The value of arm circumference measurements in assessing chronic energy deficiency in Third World adults. Eur J Clin Nutr, 48(12), 883-894.

Field Code Changed

Castaneda, C. (2002). Muscle wasting and protein metabolism. J Anim Sci, 80, 98-105.

Hickson, M. (2006). Malnutrition and ageing. Postgrad Med J, 2006, 82(963), 2–8.

de Belchior, A.C.S., Angeli, J.K., de O. Faria, T., Siman, .F.D.M., Silveira, E.A., et al. (2012) Post-Weaning Protein Malnutrition Increases Blood Pressure and Induces Endothelial Dysfunctions in Rats. PLoS ONE, 7(4), 34876. doi:10.1371/journal.pone.0034876.

Bunker, C.H., Ukoli, F.A., Matthews, K.A., Kriska, A.M., Huston, S.L., Kuller, L.H. (1995). Weight threshold and blood pressure in a lean black population. Hypertension, 26,616–623.

Thorogood, M., Appleby, P.N., Key, T.J., Mann, J. (2003). Relation between body mass index and mortality in an unusually slim cohort. J Epidemiol Community Health, 57, 130–33.

Willett, W.C., Manson ,J.E., Stampfer, M. J., Colditz, G.A., Rosner, B., Speizer, F.E., Hennekens, C.H. (1995). Weight, weight change, and coronary heart disease in women. Risk within the 'normal' weight range. JAMA , 273,461–65.

Kaufman, J.S., Asuzu, M.C., Mufunda, J., Forrester, T., Wilks, R., Luke, A., Long, A.E., Cooper, R.S. (1997). Relationship between blood pressure and body mass index in lean populations. Hypertension. 30(6), 1511-1516.

Spiegelman, D., Israel, R.G., Bouchard, C., Willett, W.C. (1992). Absolute fat mass, percent body fat and body-fat distribution: which is the real determinant of blood pressure and serum glucose? Am J Clin Nutr, 55, 1033-1044.

Obesity in Asia Collaboration. (2008). Is central obesity a better discriminator of the risk of hypertension than body mass index inethnically diverse populations? J Hypertens, 26, 169–177.

Decoda Study Group. (2008). BMI compared with central obesity indicators in relation to diabetes and hypertension in Asians. Obesity, 16 (7), 1622–1635.

Amato, M.C., Giordano, C., Galia, M., Criscimanna, A., Vitabile, S., Midiri, M., Galluzzo, A.; AlkaMeSy Study Group. (2010). Visceral Adiposity Index: a reliable indicator of visceral fat function associated with cardiometabolic risk. Diabetes Care, 33(4), 920–922.

Lee, C.M.Y., Huxley, R.R., Wildman, R.P., Woodward, M. (2008). Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol, 61(7), 646–653.

Field Code Changed

Herrera, V.M., Casas, J.P., Miranda, J.J., Perel, P., Pichardo, R., González, A. et al. (2009). Interethnic differences in the accuracy of anthropometric indicators of obesity in screening for high risk of coronary heart disease. Int J Obes, 33(5), 568–576.

Mungreiphy, N.K., Kapoor, S. (2010). Socioeconomic changes as covariates of overweight and obesity among Tangkhul Naga tribal women of Manipur, north-east India. J Biosoc Sci, 42(3), 289-305.

Mckeigue, P.M., Shah, B., Marmott, M.G. (1991). Relationship of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. Lancet, 337, 382-86.

Risley, H.H. (1915). The People of India. (Ed. Crooke, W.). Oriental book reprint corporation, New Delhi, 1969.

James, W.P.T., Ferro-Luzzi, A., Waterlow, JC. (1988). Definition of chronic energy deficiency in adults. Report of a Working Party of the International Dietary Energy Consultative Group. Eur J Clin Nutr, 42, 969-981.

Appendix

Anthropometric measurements	Instrument used	
Height (0.1 cm)*	Anthropometer	
Body weight (0.5 kg)*	Weighing scale	
Circumferences (minimum waist, maximum hip , mid upper arm) 0.1 cm*	Flexible steel tape	
Skinfold thicknesses (biceps, triceps, subscapular, suprailliac and calf posterior) 0.2 mm*	Harpenden skinfold caliper exerting constant pressure of 10gm/mm² on the contact surface	
Blood pressure (systolic and diastolic phase V of Korotkoff)	Measured twice on the right arm in sitting position, at 5 minutes interval using mercury sphygmomanometer and stethoscope	
Indices	**Formula**	
Body mass index (BMI)	Weight (kg)/height (m²).	
Waist hip ratio (WHR)	Waist circumeference(cm) / Hip circumference(cm)	
Waist height ratio (WhtR)	Waist circumference (cm)/height (cm)	
Grand mean thickness	Mean of all skinfold thicknesses (mm)	
Body Fat percentage	Fat % = (4.95/D - 4.50) x 100)	
Muscle diameter	{MUAC (cm) / π} – {biceps (cm)/2} – {triceps (cm)/2}	
Diagnostic criteria		
BMI	CED III	<15.9 kg/m^2
	CED II	16.0-16.9 kg/m^2
	CED I	17.0-18.4 kg/m^2
	Underweight	$\leq$ 18.4 kg/m^2;
	Normal	18.5 kg/m^2– 24.9 kg/m^2
	Overweight/obese	$\geq$25 kg/m^2

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Hypertension	**Systolic** <120 mmHg (Normal) 120-139mmHg (Pre hypertensive) >140 mmHg (Hypertensive) **Diastolic** <80 mmHg (Normal) 80-89 (Pre hypertensive) >90mmHg (Hypertensive)