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ASSOCIATION OF ANTHROPOMETRIC VARIABLES WITH SELECTED METABOLIC RISK FACTORS: A STUDY AMONG THE TRIBES OF WEST BENGAL

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Objective**:* To understand the risk and association of anthropometric measures with raised blood pressure, blood glucose and multiple metabolic risks among the males of Santal, Oraon with Kora tribes of Birbhum district of West Bengal. ***Methods: This Cross sectional study was undertaken among 349 randomly selected tribal males from Birbhum, West Bengal. Twelve anthropometric and metabolic variables were recorded for each subject. The selected anthropometric and metabolic variables were categorized into normal and risk groups as per their cut off levels. The association was analyzed. ***Results:*** Overall prevalence rates of raised SBP [33.81%,95% CI 30.86-47.85],DBP [31.51%,95%CI26.87-36.57], blood pressure [21.29%,95%CI17.24-25.79]and WHR [22.92%,95%CI18.82-27.61] were found high. Mean SBP (127.54±18.21) among Santals is close to prehypertensive (130mmHg) stage. High blood pressure (140/90mmHg) is prevalent among more than20per cent of each of the three population groups. High metabolic risk status was observed among 62.93% [95% CI 57.86-67.94] of the individuals in the category of low or normal BMI. Incidences of raised BMI [13.82%, 95% CI 8.81-21.02] and elevated blood glucose level [12.28%, 95% CI 7.59-19.89] were observed among Santals and Oraons respectively. A strong correlation was observed between most of anthropometric measures and metabolic variables indicating vulnerability to cardio- vascular health risks. ***Conclusion:*** Increased prevalence of metabolic risks with low or normal BMI indicates accumulation of intra-abdominal or visceral fat. WHtR is observed to be the best risk predictor for increasing prevalence of CVD risks among Indian tribes.

Keywords: WHR, WHtR, Cardiovascular Disease, ROC, Blood Glucose, Blood Pressure

Introduction

The major focus of various studies related to health issues among tribal populations of India has been on malnutrition or under nutrition (Kar et al. 2007, Radhakrishna and Ravi 2004, National institute of Nutrition Annual Report 1971, 2004, Census of India 2001, National institute of Nutrition Special Report 2000, Basu *et al.* 1990, Haque 1990, Mohapatra and Das 1990). However, it has become necessary to conceptualize such studies which lay emphasis on the assessment of the health status of various tribal groups with respect to obesity, metabolic measures, dietary profile and physical activity. Like all other developing countries, large scale urbanization/modernization has been taking place in India with effective changes in the lifestyles leading to appreciable increase in the prevalence of chronic metabolic conditions like cardio vascular diseases (CVD), diabetes, metabolic syndromes (Kamble *et al.* 2010, Mishra *et al.* 2009, Mohan *et al.* 2007, Ghosh

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2007, Zimmet and Alberti 2006, Sarkar 2006, Prabhakaran *et al.* 2005, Mishra and Khurana 2004, Ghosh *et al.* 2004, Mishra and Vikram 2002, Deepa *et al.* 2002, WHO 2000, WHO/IOTF/IASO. 2000, McKeigue *et al.* 1992). The benefits of development in education, health and income generation have resulted in a significant amount of mainstreaming of Indian tribes (Deshingkar 2005, Deshingkar and Grimm 2004, Deshingkar and Start 2003, Behura 1995). A number of tribal groups are capitalizing on economic opportunities that are available to them, with a desire to acquiring a better life style with modern life comforts (Dayal and Karan 2003, Karan 2003, Rogaly 2002).

Associations of waist–hip ratio or waist circumference with metabolic health risk factors among Indian tribal populations indicate the prevalence of undernutrition and its association with cardio-vascular health (Kapoor *et al.* 2012, Ramalingam S. *et al.* 2012. Meshram *et al.* 2012, Kerketta *et al.* 2009, Sachdev 2011, Manimunda SP *et al.* 2011, Mandani B. *et al.* 2011, Kusuma YS *et al.* 2008, Kusuma YS *et al.* 2001). It can further be said that many of the tribal populations are becoming susceptible to various life style risk factors (Rao *et al.* 2008). Therefore, it is worth investigating the anthropometric measures among the tribal population groups of India in order to predict metabolic health risk factors in a more meaningful way.

Strong association of anthropometric variables like Body Mass Index (BMI),Waist to Height ratio (WHtR), Waist Hip Ratio (WHR) and Hip to Height Ratio (HHtR) with metabolic risks have been found to be related with many complications like cardiovascular diseases, hypertension and obesity. Seidell (2010) emphasized the role of BMI, Waist Circumference (WC) and WHR in predicting health risk due to excess fat. As per the international diabetic federation criteria (adopted from Zimmet and Alberti 2006), the cut-off points for WC for South Asians are >90 cm and >80 cm for men and women respectively. However, BMI is accepted with same cut off values worldwide for various conditions of fat deposit. Different approaches with respect Receivor operating characteristics (ROC) curve are taken in order to determine the optimum cut off points for different anthropometric measures based on differences in population characteristics(Ghosh and Bandyopadhyay 2007, Welborn and Dhaliwal 2007, Mohan *et al.* 2007, Misra *et al.* 2005, Mirmiran 2004). Furthermore convincing results with respect to relationship between metabolic disorders and anthropometric measures like BMI, WC, WHR and WHtR have been obtained by many scholars (Lee *et al.* 2008, Huxley *et al.* 2008, Nyamdorj *et al.* 2008, Huxley *et al.* 2007). Associations of waist circumference or waist–hip ratio with metabolic health risk factors are indications of prevalence of undernutrition(Mendenhall *et al.* 2012, Ebrahim 2010). Studies are scanty and fragmentary in relation to association of anthropometric measures with metabolic risk factors among tribal groups of India. The present investigation was undertaken in 349 adult male subjects, among the tribes of the

Birbhum district of West Bengal to ascertain the association of anthropometric measures with metabolic health risk factors.

Materials and Methods

The present cross sectional study is the part of a large scale investigation on "Prevalence of metabolic and cardiovascular risk among selected Indian tribes" funded by Indian Council of Medical Research (ICMR). Indigenous tribal populations constitute 8.2 per cent of total population of India (Census of India 2001). These people are homogenous and culturally firm with well developed traditional health care system. They subsist in their own characteristic life style.

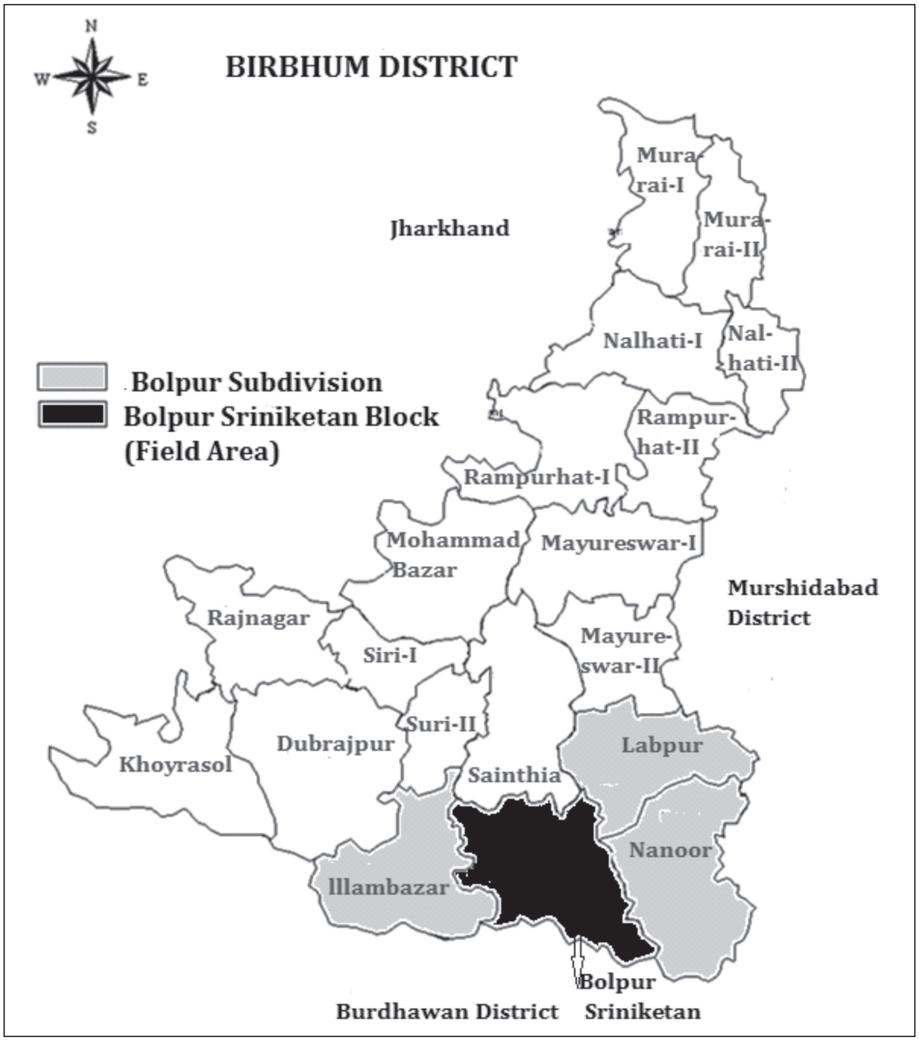
Area and People

The present study was conducted in the Bolpur-Sriniketan block in Birbhum District of West Bengal (Map I).West Bengal is a state in the eastern part of India. Tribal population constitutes 5.50 per cent of the total population of West Bengal with 38 types of tribal population groups (Census of India 2001). The studied Birbhum district is situated in the northern part of West Bengal. The district is dominated by tribal population groups and a part of the greater central Indian tribal population sphere. The population of Birbhum district is 3015422 out of which Schedule tribe population is 203127. The ST population in Birbhum district constitutes 6.74% of the district population and 4.61% of the state population (Census of India 2001). Literacy rate among all scheduled tribes is 43.4%. The selected three tribes in West Bengal- Santals, Oraons and Koras are the three major tribes of the state constituting 51.8 per cent, 14 per cent and 3.2 per cent of the total tribal population. Santals and Koras belong to Mundari language group of Austro-Asiatic language family while Oraons belong to Dravidian language family.

Study Design and Sample Size

The study was conducted among 349 tribal adult males from Santal, Kora and Oraon tribes belonging to 18 villages of Birbhum district of West Bengal. The sample size was estimated following the formula provided by WW Danial (1999). The prevalence rate for calculating sample size is based on the prevalence of obesity in Indian population (Misra and Khurana 2009). After calculating the total sample size it was further subdivided among the selected tribal groups. All the subjects were unrelated and were chosen randomly. Exclusion criteria include growth and developmental disorders, any severe health problems in last one year or any secondary cause of hypertension. Similarly self reported measurements were not recorded.

Informed written consents from the subjects participating in the study were obtained prior to actual commencement of the study.



Map I: Location of the Field Area

Anthropometric and Metabolic Variables

The basic information about the participating subjects like name of the tribe, age, sex, income and household information were collected from each individual by administering a structured schedule. All anthropometric measurements were taken following standard techniques (Lohman *et al.* 1988). Standing height and weight were measured to nearest of 0.1 cm and 0.1 kg respectively. The participants were encouraged to remove their shoes and heavy clothing before giving measurements.

WC was measured with standard, non stretchable tape at the level of midway between the lower rib margin and iliac crest to the nearest of 0.5 cm. Two trained anthropologists were involved in the process of data collection. In order to avoid measurement and data entry bias, all the measurements were taken by one anthropologist while all the data were entered to the datasheet by the other. Same instruments were used for all the participants during the study. BMI was calculated as weight in kilogram divided by height in meter square (kg/m^2). Individuals participating in height and weight measurements were only considered for BMI calculation. Blood pressures both systolic and diastolic were recorded by using a standard mercury sphygmomanometer on the right hand of the subjects with minimum 5 minutes rest before the measurement. Two measurements were taken at a time gap of at least 5 minutes and the average was recorded. Participants with SBP ≥130 mmHg and DBP ≥ 85 mmHg were considered as prehypertensive (Chobanian *et al.* 2003). In addition to prehypertensive SBP (SBP ≥ 130 mmHg) and prehypertensive DBP (DBP ≥ 85mmHg), high blood pressure (BP) was calculated for every participating individual subject if he or she showed both high SBP and high DBP. Subjects were also tested for random blood glucose with an automated analyzer by enzymatic method using commercial kits and ≥ 140 mg level was considered as risk status. Metabolic risk factors (MRFs) were calculated with respect to the presence of two or more risk factors including high SBP and high blood glucose according to the criteria by IDF (Alberti *et al.* 2005).

Statistical Analysis

After incorporating the data in Microsoft excel spread sheet 2007, further analysis was carried out using SPSS version 16.0 for Windows, Chicago IL, USA. Descriptive statistics such as mean and standard deviation (SD) were estimated for age, height, weight, WC, SBP, DBP, blood glucose level and for various indices like BMI, WHtR, WHR and HHtR. Independent sample t test and chi-square test for the selected measures were performed to calculate the significance of differences. One-way analysis of variance (ANOVA) test was carried out between anthropometric variables such as WC, BMI, WHtR, WHR and HHtR and metabolic variables such as SBP, blood glucose, blood pressure, two risk factors and multiple risk factor. Partial correlations were also estimated to find out the strength of the relationship between selected anthropometric variables and metabolic risks factors. Receivor operating characteristics (ROC) curve analysis was performed to find out the association of anthropometric variables with metabolic risk factors to determine the predictability of metabolic risk factors from anthropometric variables. Significance level is considered at <0.05 level while values between 0.05 to 0.09 levels are considered as suggestive (Hulleys and Cummings 1988).

RESULTS

Anthropometric characteristics of the study population are presented in Table I. The mean age of the studied population is 39.64 (±12.88) years. The mean values for Waist circumference, Waist hip ratio, Waist to height ratio and Hip to height ratio lie in the lower cut off ranges of respective indexes. Similarly, mean value of BMI for Santals [19.88 (±2.59) kg/m^2], Oraons [19.58 (±2.51) kg/m^2] and the total population [19.48 (±2.40) kg/m^2] lies close to lower cut off value of BMI (18.5 kg/m^2) while for Kora, this value is 18.94 (±1.97) kg/m^2. One way ANOVA test between the three population groups shows significant inter tribal group differences ($p<0.05$) for WC ($p = 0.002$) and BMI ($p = 0.009$) with WHR ($p = 0.075$), WHtR ($p = 0.053$) and HHtR ($p = 0.067$) at suggestive level. The mean value for SBP (127.54(±18.21) mmHg) for Santal population lies close to hypertension risk cut off i.e. 130mmHg.

TABLE I: DISTRIBUTION OF AGE, ANTHROPOMETRIC AND METABOLIC PARAMETERS AMONG THE STUDIED POPULATIONS (N = 349)

Variables	*Santal(n=123)*	*Kora(n=114)*	*Oraon(n=112)*	*Total(n=349)*	*p value**
Age	39.81 (±13.23)	40.05 (±12.86)	39.04 (±12.60)	39.64 (±12.88)	0.825
Height	161.48 (±6.51)	158.96(±6.94)	162.20 (±6.58)	160.89(±6.80)	0.001
Weight	52.24 (±8.57)	47.91 (±6.93)	51.22 (±8.36)	50.50 (±8.19)	0.001
WC	71.67 (±7.70)	68.24 (±6.29)	7 0.40 (±8.08)	70.14 (±7.51)	0.002
Blood glucose	118.12 (±48.26)	110.85 (±27.53)	111.99(±26.25)	113.78(±35.96)	0.244
SBP	127.54 (±18.21)	124.91 (±21.00)	124.10(±15.41)	125.58 (±18.37)	0.322
DBP	79.65 (±11.05)	80.32 (±11.50)	79.63 (±9.93)	79.87 (±10.83)	0.86
BMI	19.88 (±2.59)	18.94 (±1.97)	19.58 (±2.51)	19.48 (±2.40)	0.009
WHtR	0.44 (±0.04)	0.43 (±0.04)	0.43 (±0.05)	0.44 (±0.05)	0.053
WHR	0.87 (±0.07)	0.85 (±0.06)	0.85 (±0.07)	0.86 (±0.07)	0.075
HHtR	0.51 (±0.03)	0.50 (±0.03)	0.51 (±0.03)	0.51 (±0.03)	0.067

* 95% confidential level (CI).

Prevalence status of metabolic risk factors among the tribes of West Bengal is presented in Table II. It is observed that 39.02% and 30.08% of total studied Santal males show high levels of SBP and DBP respectively, and these values are higher in comparison to the corresponding values among Koras (27.19% and 21.05%) and Oraons (34.21% and 29.82%). Raised level of BMI (≥25 Kg/m^2) is observed to be among 13.82% studied Santals which is distinctly high than other two studied tribes. Prevalence of raised blood glucose level (≥140 mg/dl) is comparatively higher among Oraons (12.58%) than Santals (8.94%) and Koras (3.51%). But taking high blood pressure into account (elevated levels of both SBP and DBP), all the three tribes show more than 20% prevalence. Again, Santals show higher prevalence of more than two risks as well as high level of Waist Hip Ratio.

TABLE II: PREVALENCE OF ANTHROPOMETRIC AND METABOLIC RISK FACTORS IN THE STUDIED POPULATIONS

Tribes	*SBP ≥ 130 (mmHg) (%)*	*DBP≥85 (mmHg) (%)*	*Blood Glucose ≥ 140 (mg/dl) (%)*	*BMI ≥25 (%)*	*High Blood Pressure (%)*	*WHR (>90 cm) (%)*
Santal	39.02 (30.86-47.85)	30.08 (22.68-38.69)	8.94 (5.06-15.3)	13.82 (8.81-21.02)	21 (14.85-29.17)	26.82 (19.79-35.27)
Kora	27.19 (19.87-36.00)	34.21 (26.14-43.31)	3.51 (1.13-9.27)	1.75 (0.48-6.17)	21 (14.57-29.41)	22.80 (13.84-28.46)
Oraon	34.82 (26.63-44.01)	30.34 (22.61-39.41)	12.28 (7.59-19.89)	4.38 (1.92-10.02)	22 (15.6-30.88)	18.75 (12.6-26.97)
Total	33.81 (29.05-38.93)	31.51 (26.87-36.57)	10.31 (7.55-13.96)	8.02 (5.61-11.35)	21.29 (17.24-25.79)	22.92 (18.82-27.61)

Proportion is calculated and presented at 95% confidential level (CI) with lower limit and upper limit.

Clearly, these tribes show high level of SBP varying from 27.19% among Koras to 39.02% among Santals. Similarly, high DBP varies from 30.08% in Santals to 34.21% in Koras.

Prevalence of high blood pressure (both SBP and DBP at raised level) was found to be 22% in Oraons followed by both Santals and Koras (both 21%). Santals are with 26.82% of their population in the range of high level of WHR whereas corresponding values for Koras and Oraons were 22.80 % and 18.75% respectively.

One way analysis of variance was performed between anthropometric and metabolic indicators and the results are presented in Table III.

TABLE III: ONE WAY ANALYSIS OF VARIANCE (*F* VALUE) WITH *P* VALUES FOR ANTHROPOMETRIC MEASURES AND METABOLIC RISK FACTORS AMONG THE STUDIES POPULATION

	Blood Glucose	*SBP*	*Blood Pressure*	*2 risk (SBP+ Sugar)*	*Multiple Risk factors*
WC	1.094	28.075***	14.495***	9.431***	9.488***
BMI	.824	19.345***	5.575**	9.930***	6.988***
WHtR	1.267*	31.227***	16.922***	15.797***	10.361***
WHR	1.314**	22.555***	14.626***	7.352***	7.912***
HHtR	1.219	11.448***	4.592**	10.189***	4.376***

* p value lies between 0.05 to 0.09. ** p value is < 0.05. *** p value is ≤0.001.

It can be seen from the table that the variance (F) levels between normal and risk grades of metabolic variables are all significant with respect to anthropometric measures except for blood glucose.

Table IV shows the comparison of mean values of various anthropometric variables with normal and risk grades of selected metabolic factors like SBP, DBP, high blood pressure, blood glucose and multiple metabolic risks. Except blood glucose, the normal and risk categories of all metabolic variables showed significantly different ($p<0.05$) mean values for selected anthropometric measures. With BMI as anthropometric measure, 19 (SD±3) kg/m^2 is observed to be the approximate optimum mean for normal individuals. Similarly waist circumference at approximate 69 cm level was found to be optimum mean for normal individuals while 0.85, 0.42 and 0.50 have come out as the approximate optimum means for individuals with WHR, WHtR and HHtR at normal level.

TABLE IV: ASSOCIATION OF ANTHROPOMETRIC VARIABLES WITH DIFFERENT LEVELS OF METABOLIC RISK FACTORS

Metabolic Variables	*BMI*	*WC*	*WHR*	*WHtR*	*HHtR*
Systolic blood pressure					
<130 mmHg	19.08 (2.19)	68.68 (6.90)	0.85 (0.06)	0.42 (0.04)	0.50 (0.03)
≥130 mmHg	20.25 (2.62)	73.02 (7.86)	0.88 (0.06)	0.45 (0.05)	0.51 (0.03)
p value	< 0.001*	< 0.001*	<0.001*	<0.001*	=0.001*
Diastolic blood pressure					
<85 mmHg	19.34 (2.21)	69.35 (6.96)	0.85 (0.06)	0.43 (0.04)	0.50 (0.03)
≥ 85 mmHg	19.77 (2.77)	71.87 (8.37)	0.87 (0.07)	0.45 (0.05)	0.51 (0.03)
p value	0.118	=0.003*	=0.005*	=0.001*	=0.004*
High blood pressure					
Absent	19.32 (2.26)	69.36 (6.99)	0.85 (0.06)	0.43 (0.04)	0.50 (0.03)
Present	20.06 (2.79)	73.02 (8.65)	0.88 (0.07)	0.45 (0.05)	0.51 (0.03)
p value	=0.019*	<0.001*	<0.001*	<0.001*	0.033*
Blood Glucose					
<140	19.39 (2.5)	69.88 (6.73)	0.85 (.05)	0.43 (0.04)	0.50 (0.03)
≥ 140	19.58 (2.3)	70.46 (8.37)	0.87 (.08)	0.44 (0.05)	0.51 (0.03)
p value	0.48	0.45	0.06^	0.12	0.26
Multiple metabolic risk					
No risk factor	19.08 (2.19)	68.68 (6.90)	0.85 (.06)	0.427 (0.04)	0.50 (0.03)
One risk factor	20.59 (2.28)	73.02 (6.33)	0.88 (.05)	0.454 (0.04)	0.52 (0.02)
Two risk factors	20.18 (3.23)	73.59 (8.59)	0.89 (.07)	0.455 (0.05)	0.51 (0.04)
Three risk factors	19.92 (2.28)	72.39 (8.80)	0.88 (.07)	0.456 (0.05)	0.52 (0.03)
p value	<0.001*	<0.001*	<0.001*	<0.001*	=0.005*

*significant at 5% level.

Table V shows correlation coefficients between anthropometric and metabolic variables without taking age into consideration.

It is observed that all the anthropometric variables show statistically significant correlation coefficient values with respect to selected metabolic risk factors except blood glucose. Blood glucose shows significant correlation only with WC ($r = 0.32, \leq 0.05$) and BMI($r = 0.43, p \leq 0.05$).

TABLE V: CORRELATION (WITH AGE AS CONTROL VARIABLE) BETWEEN ANTHROPOMETRIC AND METABOLIC MEASURES

Selected Variables	*Blood Glucose*	*SBP*	*Blood pressure*	*Two metabolic risk*	*Multiple (Metabolic) Risk Factors*
WC	0.032**	0.259***	0.184***	0.150**	0.219***
BMI	0.043**	0.246***	0.140***	0.177***	0.189***
WHtR	0.091*	0.259***	0.184***	0.187***	0.230***
WHR	0.074*	0.216***	0.168***	0.119**	0.187***
HHtR	0.057*	0.169***	0.104**	0.162**	0.154**

*p values lies between 0.05 & 0.09 (suggestive). ** p value is < 0.05. *** p value is ≤ 0.001.

Receiver operating characteristics (ROC) curve analysis was performed to comprehend the role of selected anthropometric variables in explaining the identified metabolic risk factors. The Area Under Curve (AUC) with p value and the upper and lower bounds for each anthropometric variable with respect to selected metabolic risk measures have been presented in Table VI.

TABLE VI: ROC CURVE ANALYSIS FOR THE MEASURES OF OBESITY IN PREDICTING METABOLIC RISKS

	Area Under the Curve (95% Confidence Interval)				
Variable(s)	*Blood Glucose*	*SBP*	*High blood pressure*	*Two metabolic risk factors*	*Multiple Metabolic risk*
WC	0.525	0.655	0.617	0.612	0.638
	(.464-.586)	(.593-.717)***	(.540-.694)***	(.528-.696)***	(.556-.720)***
BMI	0.523	0.632	0.577	0.631	0.654
	(.463-.584)	(.571-.694)***	(.503-.652)*	(.555-.708)***	(.574-.733)***
WHtR	0.57	0.67	0.635	0.66	0.642
	(.510-.630)**	(.610-.730)***	(.561-.709)***	(.583-.737)***	(.562-.723)***
WHR	0.57	0.653	0.632	0.619	0.611
	(.510-.631)**	(.590-.716)***	(.556-.707)***	(.534-.704)***	(.522-.701)**
HHtR	0.546	0.609	0.569	0.64	0.618
	(.485-.607)	(.548-.671)***	(.495-.644)*	(.566-.714)***	(.540-.696)**

*p value is suggestive (0.05- o.09). ** p value is < 0.05. *** p value is ≤0.0001.

The AUC results are significant for WC, BMI, WHR, WHtR and HHtR with all the metabolic risks measures except for blood glucose, where it is significant only for WHR and WHtR.

But on overall, waist to height ratio (WHtR) shows better AUC results than waist to hip ratio (WHR).

Discussion

In India, cardiovascular disease and its causative health risk factors are emerging as important health problems particularly among urban rich, and paradoxically coexisting with undernutrition. Almost 30-65% of adult urban Indians are either overweight or obese (Misra and Khurana 2009).

The present study indicates the high prevalence of cardiovascular disease or such health risks among tribal populations. The results show that high SBP and high DBP risks are present among 33.81% [95% confidential interval (CI) 29.05-38.93] and 31.51% [95% confidential interval (CI) 26.87-36.57] of the studied population with a more than 20% of prevalence rate of high blood pressure (140/90 mmHg) among each of the three tribal population groups. Similarly increased incidences of raised BMI [13.82%, 95% confidential interval (CI) 8.81-21.02] and elevated blood glucose level [12.28%, 95% confidential interval (CI) 7.55-13.96] were observed among Santals and Oraons respectively. Our analysis also indicates the co-prevalence of high incidences of low BMI level and raised DBP risk among Koras, and highest prevalence of raised SBP risk among individuals with normal or raised BMI level among Santals. It also shows a strong correlation between various anthropometric measures and metabolic risk indicators.

The ROC analysis and subsequently the AUC results clearly indicate that all the anthropometric variables by and large show association with selected metabolic risk factors. Of the selected five anthropometric variables, hip to height ratio (HHtR) shows the least association with all the metabolic risks considered, while waist to height ratio (WHtR) demonstrates the highest association (table VI). In ROC analysis, the area under curve (AUC) shows that association of WHtR with raised blood glucose (AUC = 0.57, $p < 0.05$), high SBP (AUC = 0.67, $p < 0.001$) high blood pressure (AUC = 0.635, $p < 0.001$), two metabolic risk (AUC = 0.66, $p < 0.001$) and multiple metabolic risk (AUC = 0.654, $p < 0.001$) is more significant than other anthropometric markers (table VI). WHtR best explains the correlation with selected metabolic risk factors like SBP ($r = 0.259$, $p < 0.001$), blood pressure ($r = 0.184$, $p < 0.001$), two metabolic risk ($r = 0.187$, $p < 0.001$) and multiple metabolic risk ($r = 0.23$, $p < 0.001$) than other selected anthropometric variables (table V). It is important to note that WHtR shows a significance association with differentiated statuses (normal and selected risk categories) of SBP, DBP, BP and multiple risk factors with the clearly defined cut off ratio of 0.42 for normal individuals and 0.45 for individuals with raised WHtR status (table IV). So WHtR comes out as the best anthropometric index with possible risk predictability in the selected populations. The AUC analysis further shows that SBP is highly associated with selected anthropometric variables and therefore, maximum explained, while blood glucose is the least (table VI). Significant association of high BP with selected anthropometric variables is also observed. Taking two metabolic risk and multiple metabolic risk into account, the area under curve (AUC) for all the anthropometric variables like WC, BMI, WHR, WHtR, HHtR is significantly explained ($p < 0.001$).

The findings of the present study are in agreement with the results of the previous studies with respect to BMI and its predictability of risk among Asian populations. It has been found that People of South Asian origin (e.g. Indians) have more centralized obesity for a given level of BMI as compared to Caucasians (McKeigue *et al.* 1991). Among Asian populations, mortality and morbidity from chronic diseases (e.g. CHD) is occurring in people with lower body mass index and thus they tend to accumulate intra-abdominal or visceral fat without developing generalized obesity (Ghosh *et al.* 2004, WHO/IOTF/IASO 2000). So, Asian Indians are at a greater risk of developing obesity at lower levels of body mass index (BMI) and waist circumference (WC) (Misra and Khurana 2009). Similar trend is observed in the present study i.e. 62.93% (95% CI 57.86-67.94) of the individuals in the high metabolic risk category belong to low or normal BMI cut off range.

In the present study, the observed means of WC, BMI, WHR, WHtR and HHtR for normal and metabolic risk categories are distinctly different and at the same time, are bellow the respective accepted cut off points. WHO exports group has also found that people with a high risk of type 2 diabetes and cardiovascular disease is substantial at BMIs lower than the existing WHO cut-off point (WHO expert consultation group, 2004). So we strongly feel that this study may be replicated in larger size of population sample and cut off levels for various anthropometric variables be revised and redefined in the context of ethnic heterogeneity in India. And this we believe will help to predict high risk individuals at an early stage.

Studies with respect to CVD and its risks among tribal populations of India are scanty. But most of the earlier studies indicate a rising risk condition. Our findings with respect to increasing prevalence of CVD risks among tribal groups of India show that it is time to consider these unrepresented populations for large scale studies.

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