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No association between body height and metabolic risk factors in short Asian Indian tribal people

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Abstract

Background Asian Indians often get predisposed to non-communicable diseases for which the "thin-fat" or "hidden obese" Indian phenotype is usually regarded responsible. In Europe, America and in some low-middle-income countries (LMICs) short height is often associated with a high risk of metabolic syndrome (MetS). Indians and particularly tribal Indian people are relatively short.

Aim To assess the associations of height with MetS risk factors among tribal people of India.

Sample and methods This study was conducted among tribes of India under life-style transition. The height range was 163.2 cm to 156.5 cm (males) and 151.6 cm to 146.9 cm (females). The participants were 1066 men and 1090 women aged between 20 and 60 years. Anthropometric and metabolic markers included in the study were height, body mass index (BMI), waist circumference (WC), skinfolds (biceps, triceps, sub-scapular, and supra-iliacal), fasting blood glucose (FBG), blood pressure (systolic and diastolic) and pulse rate (PR).

Results The highest correlation existed between height and WC (male: 0.21; female: 0.15). Correlations of body composition variables (BMI, WC, skinfolds) with MetS risk factors (FBG, SBP, DBP, PR) were not reliable ($r < 0.30$) among both sexes. St. Nicolas House Analysis revealed WC among males and WC and sub-scapular skinfolds among females sharing more connections with other nodes variables.

Conclusions Unlike the people of the wealthy and often obese social strata of low-middle-income countries, and in Europe and North America, height of tribal Indian populations is not associated with metabolic risk factors, such as hypertension, elevated fasting blood sugar, and central obesity. Rather than linked to the phenotype, obesity appears to be associated with an obesogenic environment. Public health policy should focus on problems associated with obesogenic environments.

Take home message for students Short body height cannot predispose individuals to MetS risk factors in the absence of an obesogenic environment.

Introduction

Non-communicable diseases (NCDs), such as hypertension, diabetes, cardiovascular diseases and certain types of cancer are on the rise in India. One out of four Indians is at risk of death due to an NCD before reaching the age of 70 every year, which is alarming (National Health Portal Of India 2022). Changing life style and dietary habits have been made responsible for increasing NCDs among tribal people in India (Bhar et al. 2019; Ghosh-Jerath et al. 2021; Sajeev and Soman 2018; Sarkar et al. 2005; Shriraam et al. 2021; Soren et al. 2021). Common metabolic risk factors leading to NCDs are large waist circumference, a high triglyceride level, low HDL cholesterol, high blood pressure, and high fasting blood sugar (National Heart, Lung, and Blood Institute 2022). The simultaneous occurrence of three of these factors in an individual is called metabolic syndrome (MetS). The physical and emotional environment also increases susceptibility to MetS (Cornier et al. 2008; Huang 2009).

Indians have been observed to be at a higher risk of NCDs already at lower thresholds of body mass index and waist circumference than people of European ancestry (Hills et al. 2018; WHO/IASO/IOTF 2000). The reason often cited is the thin-fat Indian phenotype (Yajnik et al. 2003). This phenomenon is also observed in other populations, but was named differently, e.g. as "hidden obesity" or "TOFI" (Thin in the Outside, Fat in the Inside) (Zdrojewicz et al. 2017).

This is even more pronounced for marginalized tribes of India who are shorter and thinner than Europeans and the affluent population of India (Kshatriya and Acharya 2019; Mungreiphy et al. 2012). In the last 100 years height has increased by 1 cm per decade in different countries of Europe. This was different in Indians (NCD Risk Factor Collaboration 2016). The height of tribal people in India has remained fairly stable over the past 100 years. There is no change in the mean heights of Santal (161.48) and Oraon (162.13) males of the present study compared to heights of the same population reported by H. H. Risley more than 100 years ago (Risley 1891). For the present study sample, the population-specific mean heights of Santal and Oraon differ by 1.6 cm to 2.2 cm ($p < 0.001$) from the national mean height (NNMB III Repeat Rural Survey 2012). Even lower mean height was observed among Santals (160.5 ± 6.4), Oraon (161.8 ± 6.3), Bathudi (159.4 ± 6.4), Kora (158.9 ± 6.2), and Bhumij (159.8 ± 6.7) males of West Bengal and Odisha (Bose et al. 2006a, 2006c; Bose and Chakraborty 2005; Chakraborty et al. 2011). Short stature could result in a greater predisposition to NCDs already at lower waist circumference and body mass index.

The association of short height and the risk factors of MetS has commonly been reported from high-income countries and the wealthy social strata of Low and Middle-Income Countries (LMICs) (Islam et al. 2020; Janghorbani et al. 2012; Puchner et al. 2017; Stefan et al. 2016; Wittenbecher et al. 2019; Yuan et al. 2020). These studies suggest that tall people are less likely to be at risk of MetS than short people. Thus, as the average Indians are short, they may be more susceptibility to MetS than Europeans and North Americans. However, this has not been shown yet.

We hypothesize that short Asian Indian tribal people who currently undergo lifestyle transitions show an association between body height and metabolic risk factors. The present paper will assess this association, and the association of subcutaneous fat (skinfolds), height and metabolic disease risk factors.

Sample and Methods

This study is based on tribal people of India residing in the states of West Bengal, Odisha, and Gujarat. The majority of them lead a traditional way of life and rely on agriculture and forest products. Many of them work as manual laborer on farms, factories and construction sites (Kshatriya and Acharya 2016). They experience increasing economic dependency on influences from outside their community and life-style changes.

Participants and Design

The sample of the present study included people from Santal (245), Kora (235), and Oraon (238) of West Bengal; Santal (240), Bhumij (238), and Bathudi (240) of Odisha; and Dhodia (240), Kukna (239) and Chaudhari (241) of Gujarat. They differ in body height (Table 1). This study observed higher alcohol consumption among the tribes of West Bengal and Odisha, both in men and women than among the tribes of Gujarat. Similarly, the practice of tobacco chewing (not smoking) was found to be more prevalent among the tribes of Odisha than in West Bengal and Gujarat. Information related to entertainment, alcohol, and tobacco was collected in the course of the present study from each of the participating tribes.

Over the last years, community activities such as traditional folk singing and dancing practices, among the Santal, Dhodia, and Chaudhari, are being replaced by television and video shows. Similarly, modern entertainment media, such as television sets and radios are present in most households. People have access to basic amenities such as water, electricity, education, and health care; however, there are disparities in the availability of these facilities because of persisting social and economic inequities (Ghurye 1969; Saxena and Bhattacharya 2018). Traditionally, the tribes of West Bengal and Odisha mainly earn their livelihood from forest products, cultivation, and manual labor in farms. However, because of industrial growth and other developmental activities, several tribal people of West Bengal and Odisha are migrating and accept menial jobs. In contrast, the tribes of Gujarat are agriculturists and enjoy a relatively sedentary life. They are also involved in government jobs, cattle rearing, and manual labor. The tribes of Gujarat are the most affluent of all the tribes included in the present study.

The present cross-sectional study was conducted between January 2011 and December 2013 in five different phases to collect data on selected biomarkers. The study participants were selected using a multi-stage sampling method. In this process three states were selected from two different regions, two from the eastern region (West Bengal and Odisha) and one from the western region (Gujarat) of India. Three tribes were selected from each state based on their predominant distribution (Office of the Registrar General & Census Commissioner, India 2001). Again, four districts were chosen from three states which include two districts of Gujarat and one district each from West Bengal and Odisha. A total of 66 tribal villages from the selected four districts were chosen on the basis of comparative proximity to the 'urban centres' rather than to the typical countryside habitation, as the people in such areas are prone to lifestyle and dietary change. Village listings for each of the tribes were prepared on the basis of their population concentration. We first estimated the number of men and women in four 10-year age interval groups (20 – 60 years) across several villages with the preponderance of specific tribal inhabitants in the population. A sample size of 30 men and women from each of the four 10-year age interval groups was selected using systematic random sampling. The final sample size was 2156 adult tribal participants, with 1066 men and 1090 women (four less than the targeted sample size). Exclusion criteria used were as follows: growth and developmental disorders, severe health issues in the past year, existence of any secondary cause of hypertension, and pregnant women. The sample size for the present study was tested at a 5% level of significance, with a statistical power of 80%.

Ethical statement

Prior ethical clearance to conduct the research was obtained from the Institutional Review Committee of the Department of Anthropology, University of Delhi. Informed written consent from the participants of the study was obtained prior to the actual commencement of the study. Participants who avoided the sampling were excluded. The data were anonymized.

Measurement of anthropometric and metabolic variables

The primary information of the participants such as tribe affiliation, age and sex were recorded. Standard techniques were followed while taking all the anthropometric measurements (Lohman et al. 1988). The standing height and weight were measured to the nearest 0.1 cm and 0.1 kg respectively. Height vertex was measured using a portable anthropometer while the weight was measured by using body composition monitor (OmronKaradaScan HBF-375, Tokyo, Japan). The participants were measured in bare feet and with minimum clothing. Biceps (BSF), triceps (TSF), sub-scapular (SSSF), and supra-iliac (SISF) skinfolds were taken by Holtain skinfold calliper to the nearest 0.2 mm and used as proxy for body fat. Waist circumference (WC) was measured by standard technique and used as proxy for central obesity (Lohman et al. 1988). Central obesity or high waistline can be understood as excess intra-abdominal adipose tissue accumulation including dysfunctional subcutaneous adipose tissue expansion and ectopic triglyceride storage (Tchernof and

Table 1 Sex specific means ± standard deviations (SDs) of height (in cm) of the Asian Indian tribes using ANOVA are presented.

Indian states	Tribes	Male		Female		*F*-value
		N	Mean± SD	N	Mean± SD	
West Bengal	Santal	123	161.5±6.6	122	148.8±5.8	259.1*
	Oraon	114	162.1±6.6	124	148.3±5.1	328.7*
	Kora	114	159.0±6.9	121	147.0±5.2	225.6*
Odisha	Bhumij	116	160.9±6.1	122	149.9±5.4	215.6*
	Santal	121	161.6±6.8	119	149.8±5.9	205.3*
	Bathudi	119	156.5±6.2	121	146.9±6.2	143.2*
Gujarat	Dhodia	120	163.1±6.9	120	149.8±5.0	293.8*
	Kukna	119	162.3±6.0	120	150.1±4.7	310.2*
	Chaudhari	120	163.1±6.9	121	151.4±5.3	220.9*
Overall		1066	161.1±6.8	1090	149.1±5.6	2005.5*

* $p<0.01$; d.f.=1

Després 2013). Body mass index (BMI) was calculated by dividing weight (kg) by height (m^2), to assess weight status, such as underweight or overweight. Although used as proxy for obesity it does not discriminate between fat mass and fat free mass. Systolic and diastolic blood pressure (SBP and DBP respectively) were recorded twice using a standard mercury sphygmomanometer on the right arm of the participants. A minimum 15-minute rest before the measurement and a 5-minute interval between two measurements were ensured. The average of the two measurements was recorded. The pulse rate per minute (PR) was also recorded. Fasting bold glucose (FBG) was identified through finger prick by strip method with help of glucometer (Accu-Check Active, Mumbai, India). Participants were requested to participate in the morning before taking tea and breakfast. An overnight fasting of ~ 12 hours was maintained throughout the study. Other measurement related to body composition is not presented here as the focus of the present analysis is different.

The participation in the study was voluntary as villagers were informed before the commencement of the fieldwork. Data collection was supervised by one of the co-authors (GKK).

Criteria used for metabolic risks

Different FBG levels, such as ≤100mg/dl, 100 mg/dl – 125mg/dl, ≥ 126 mg/dl are recommended as normal, pre-diabetes, and diabetes, respectively (American Diabetes Association 2022; WHO 2022). In case an individual tested fell in the category of diabetes, the test should be conducted again to confirm it.

Blood pressure was classified into normal (SBP ≤ 120 mmHg and DBP ≤ 80 mmHg), pre-hypertension (SBP 120–139 mmHg and DBP 80–89 mmHg) and hypertension (SBP ≥ 140 mmHg and DBP ≥ 90 mmHg) (Weber et al. 2014). This classification is also recommended by the WHO (2022).

Central obesity for male and female, was defined using a waist circumference ≥ 90 cm and ≥80 cm, respectively (WHO 2008). According to the Asia-Pacific WHO guidelines, individuals with BMI <18.5 kg/m^2 were considered as underweight; >18.5 kg/m^2 but <23 kg/m^2 as normal; >23 kg/m^2 but <27.5kg/m^2 as overweight (high risk) and >27.5 kg/m^2 as obese (very high risk). The overweight and obese were combined for the purpose of the present study (WHO/IASO/IOTF 2000).

Statistical analysis

Statistical analysis were undertaken in R Gui (https://cran.r-project.org). Associations between variables were assessed using Pearson correlation, St. Nicolas' House Analysis (SNHA) with threshold value r > 0.01, and linear regression. The SNHA technique is a novel non-parametric statistical method that helps translating correlation matrices into network graphs by tracing "association chains". Series of coefficients of determinants that are characterized by the symmetry of ranks of R^2 both in forward and in backward direction are named "*association chains*". Thus, association chains formed are ranked according to magnitude of correlation coefficients (R^2), e.g., c[A*B], c[B*C], c[C*D], with the property c[A*B]>c[A*C]> c [A*D], and c[D*C] > c[D*B] > c[D*A]. Performance measures, the balanced classification rate and the F1-score showed that SNHA was superior to methods using sophisticated correlation value thresholds and methods based on partial correlations for analyzing bands and hubs (Groth et al. 2019; Hermanussen et al. 2021).

This technique is suitable for handling multiple correlations usually encountered in anthropometric and various socio-economic and socio-demographic variables (Groth et al. 2019). This new technique translates the correlation matrix into a network graph which is a useful visual aid and beneficial for data exploration. The SNHA is now started to be used by researchers to document the associations of various growth, socio-economic and socio-demographic variables in the form of a chain (Dorjee 2015; Martin et al. 2020). Essentially, St. Nicolas' house is a network, consisting of "nodes" and "edges". Edges direct from one node to the next one and have a topological ordering from earlier to later.

Results

The mean and standard deviation of BMI, WC, BSF, TSF, SISF, SSSF, FBG, SBP, DBP, and PR is given in Table 2. The overall prevalence of BMI based underweight (40.1%), and obesity (12.5%), central obesity using WC (15.8%), hypertension using SBP/DBP (11.3%), and FBG based diabetes (25.9%) is presented in Table 3. Correlation plot of the variables used is given in Figure 1. It is a visual presentation of correlations obtained in the present study. In the plot, color changes with direction of correlation, ellipses become tighter and color intensity increases with increasing coefficient. In the correlation plots of both sexes color intensity is low. The observed correlations of height with indices of metabolic risk factors such as BMI, WC, FBG, SBP, DBP, and PR were not relevant (r<0.30). Although negligible, the highest correlation of height was obtained with WC (male: 0.21; female: 0.15). Even correlations of body composition variables (BMI, WC, BSF, TSF, SISF, SSSF) with variables of MetS risk (FBG, SBP, DBP, PR) were negligible as the correlation coefficients were < 0.30 among both sexes.

Further using SNHA, we observed height had no direct connecting edges with SBP, DBP, PR, FBG and skinfolds among both men and women (Figure 2) indicating that the variable height is not directly associated with SBP, DBP, PR, FBG and skinfolds.

Table 2 Sex specific and combined means and standard deviations (±SDs) of metabolic risk factors with ANOVA result for sex differences of the present study population.

	Male (1066)	Female (1090)	Combined (2156)		
Metabolic Risk factors	Mean± SD	Mean± SD	Mean± SD	*F*-value	*p*-value
Age (Years)	40.5±12.9	40.1±11.9	40.3±12.4	0.5	0.49
Body Mass Index (kg/m^2)	19.9±2.8	19.2±3.1	19.5±3.0	30.5	0.01
Waist Circumference (cm)	74.8±9.7	66.5±7.6	70.6±9.7	469.9	0.01
Biceps Skinfolds (mm)	4.9±4.3	5.9±3.3	5.4±3.8	33.4	0.01
Triceps Skinfolds (mm)	7.0±3.5	10.6±6.5	8.8±5.5	255.0	0.01
Sub-scapular Skinfolds (mm)	12.4±6.9	13.4±5.7	12.9±6.4	11.9	0.01
Supra-iliac Skinfolds (mm)	7.2±4.5	9.0±5.4	8.1±5.0	45.3	0.01
Fasting glucose (mg/dl)	119.2±40.5	114.7±34.5	116.9±37.6	3.8	0.05
Systolic BP (mmHg)	126.4±19.0	127.6±21.3	127.0±20.2	2.1	0.15
Diastolic BP (mmHg)	77.5±11.8	81.9±13.1	79.7±12.7	64.7	0.01
Pulse Rate (per/min)	78.8±12.7	87.3±14.1	83.1±14.1	214.6	0.01

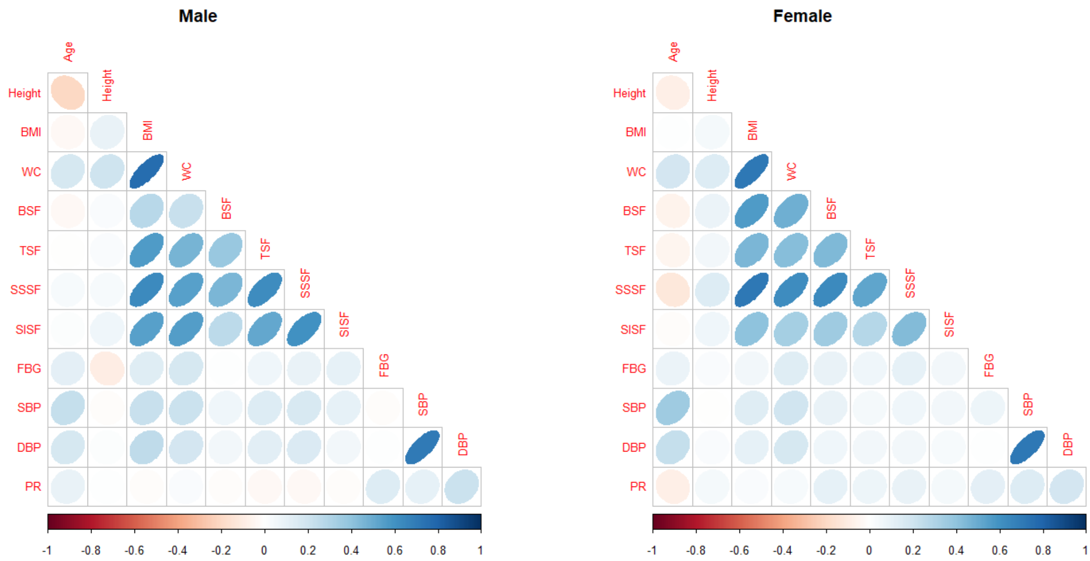

Figure 1 Pearson correlations presented as Corrplot for male and female individuals of variables Age, Height, BMI (body mass index), WC (waist circumference), BSF (biceps skinfolds), TSF (triceps skinfolds), SSSF (sub-scapular skinfolds), SISF (supra-iliac skinfolds), FBG (fasting blood glucose level), SBP (systolic blood pressure), DBP (diastolic blood pressure), and PR (pulse rate).

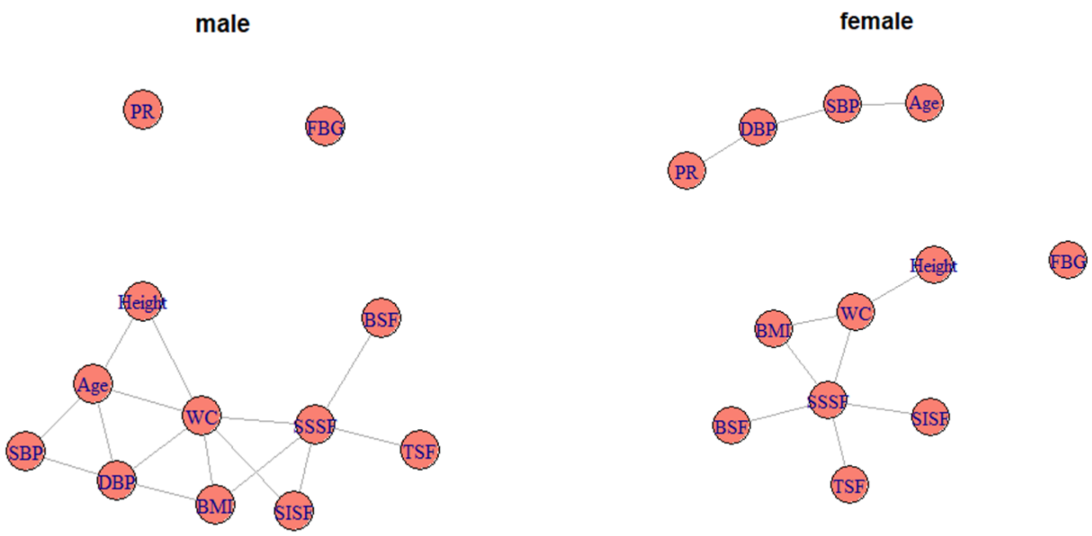

Figure 2 St. Nicolas House Analyses (SNHA), for male and female individuals, nodes represents variables Age, Height, BMI (body mass index), WC (waist circumference), BSF (biceps skinfolds), TSF (triceps skinfolds), SSSF (sub-scapular skinfolds), SISF (supra-iliac skinfolds), FBG (fasting blood glucose level), SBP (systolic blood pressure), DBP (diastolic blood pressure), and PR (pulse rate). An edge represents association between nodes.

Height is directly associated with WC in both sexes, and with age in adult males. The nodes of FBG and PR among males and node of FBG among females remain isolated indicating that FBG and PR are not associated with any other variable. Figure 1 shows that except for BMI, WC and skinfold, and SBP and DBP, all associations

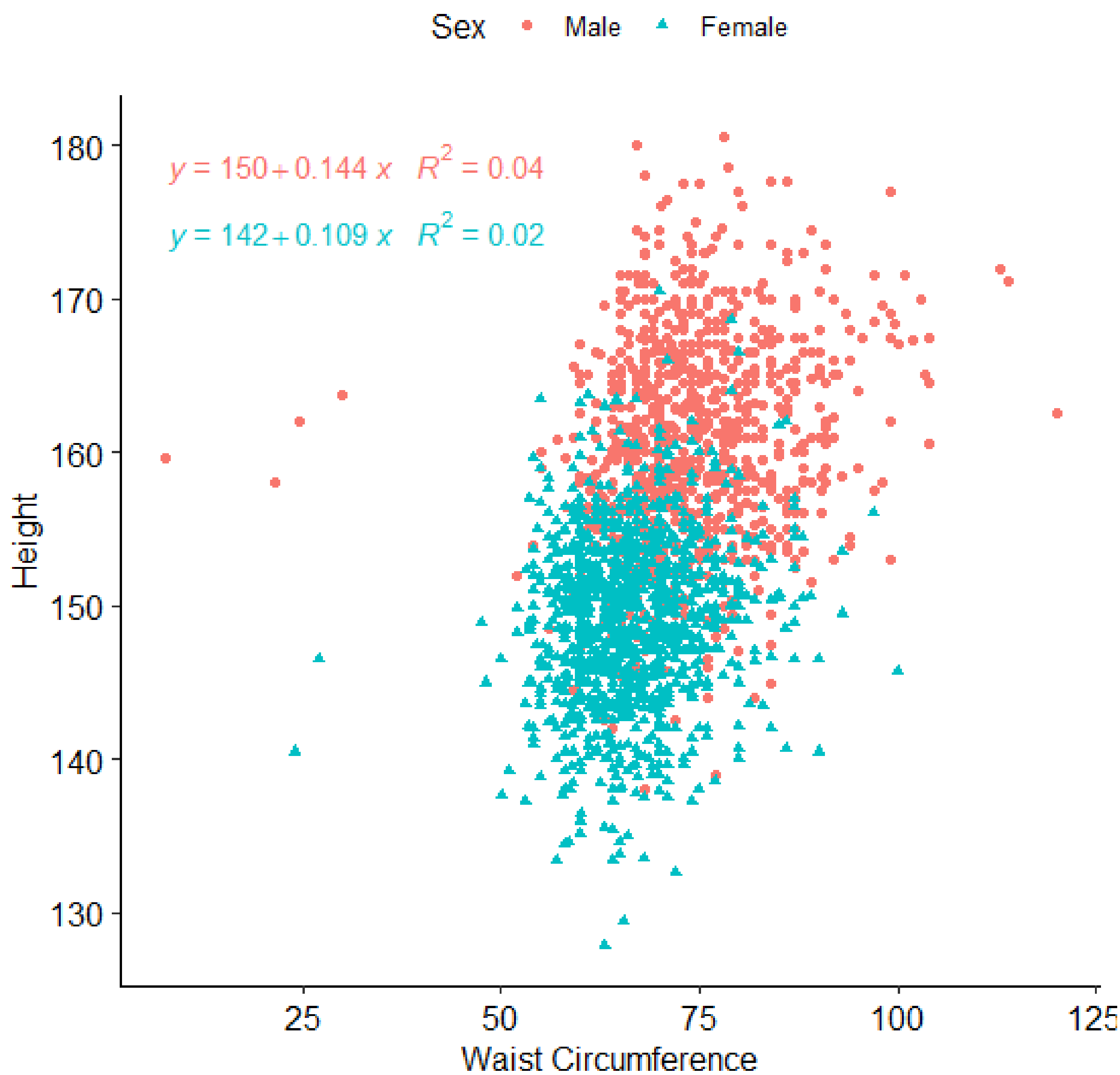

Figure 3 Regression plot of waist circumference (WC) on height of male and female individuals.

are very low with correlation coefficients < 0.30. Since WC has a central position in the SNHA plot and is considered a major MetS marker with an association with height, regression analysis was conducted to further explore this association. Linear regression confirmed that the effect size of height on WC was 4.0% and 2.0%, among male and female, respectively. Such an effect size is very small and may not be considered relevant in terms of risk assessment (Figure 3).

Discussion

The present study was an attempt to assess adult height and its relationship with metabolic risk factors among short height Asian Indian tribal people experiencing lifestyle transitions in India. The analysis obtained in the study population did not support the hypothesis that short Asian Indian tribal people who currently undergo lifestyle transitions show an association between body height and metabolic risk factors similar to what is observed in wealthy and often obese social strata of LMICs and the Western countries. Even though our population showed high metabolic risk factors with central obesity (15.8%), hypertension (11.3%), and diabetes (25.9%), the present study failed to indicate relevant correlations between the variables related with obesity (WC, BMI, and skinfolds), and FBG, SBP, DBP, and PR (all r < 0.30). The SNHA graph only shows one direct connecting edge between the variables height and WC; however the observed effect size of this association was not relevant (see Figure 3). Height was not directly linked with any indirect estimator of the nutritional status such as skinfold thickness (Figure 2). Our observations are in contrast to studies reported from other populations, but in line with studies conducted among children of Indonesia and India (Scheffler et al. 2020, 2018) that showed a similar lack of association between skinfold thickness and height. In our study skinfold thickness was not reliably associated with FBG. This is in line with previous observations showing that abdominal skinfolds were only associated with FBG among British European adult males, but that this association was absent among their Pakistani counterparts living in Britain (Bose and Mascie-Taylor 1995).

An association of blood pressure with height has been observed in European populations. One study observed the association of short height and leg length with increased SBP, but not with DBP, in middle-aged men and women (Langenberg et al. 2003). In another study, short height and leg length were observed with high blood pressure among men and women of England, Wales, and Scotland (Langenberg et al. 2005). Participants of these studies were individuals with diabetes, hypertension, and arthrosclerosis (Langenberg et al. 2005, 2003). Similarly, height was directly related with DBP in a study among the US American population with high serum cholesterol levels, chronic kidney disease, and diabetes mellitus (Gupta et al. 2021). This was different for females in Bangladesh. In this population, height was inversely associated with SBP and there was no such association with DBP. The prevalence of hypertension was 19.2% in the population of Bangladesh (Islam et al. 2020). Among Indian tribes the prevalence was 16.1% (Rizwan et al. 2014). The prevalence of hypertension in the present study was relatively low (11.3%) and an

Table 3 Sex specific and overall prevalence of diabetes, hypertension, central obesity, underweight, and overweight/obesity in the present study population.

Metabolic risk factors	Male	Female	Overall
Diabetes	298 (28.0)	260 (23.9)	558 (25.9)
Hypertension	88 (8.3)	156 (14.3)	244 (11.3)
Centrally Obese	280 (26.3)	60 (5.5)	340 (15.8)
Underweight	357 (33.5)	508 (46.6)	865 (40.1)
Normal weight	561 (52.6)	461(42.3)	1022 (47.4)
Overweight/obese	148 (13.9)	121 (11.1)	269 (12.5)

Numbers in the braces are percentages. Diabetes was defined using fasting blood glucose level ≥ 126 mg/dl; Hypertension was defined using systolic and diastolic blood pressure ≥ 140/90 mmHg; Central obesity was defined by waist circumference ≥ 90 cm for males and ≥ 80 cm for females. BMI was used to defined underweight (< 18.5 kg/m^2), normal weight (18.5 – 22.9 kg/m^2) and overweight/obese (≥ 23 kg/m^2)

association of blood pressure with height in the present study was absent.

Studies on the association of height with risk of diabetes have reported inverse association of height with diabetes (Janghorbani et al. 2012). Usually greater height was related with lower diabetes risk (Wittenbecher et al. 2019). Short height was associated with undesired changes in glucose metabolism and predicts an increase in the risk of type 2 diabetes and cardiovascular events (Vangipurapu et al. 2017). These studies were conducted among American and European people. Similar associations with height were also observed among Mexican women (Puchner et al. 2017). Height was inversely associated with diabetes risk in a nationwide study of Korean adults (Rhee et al. 2019). An association of height with MetS was reported from Peru as well (Toro-Huamanchumo et al. 2020). Similarly, an association between height components, leg length, ratio of leg length-to-height and adiposity, insulin resistance, and glucose intolerance was observed by several authors (Asao et al. 2006; Lawlor et al. 2002). FBG as a marker of diabetes was used by Rhee et al. and Vangipurapu et al (Rhee et al. 2019; Vangipurapu et al. 2017). As mentioned earlier, in the present study the association of height with FBG was not relevant due to its small effect size in spite of 25.9% prevalence of diabetes based on FBG level.

The variation of SBP and DBP, explained by height was 16.0% and 4.0% respectively in the Tromso Heart Study (Førde and Thelle 1980). The publication based on the Tromso Heart Study cited here excluded individuals with diabetes, hypertension, and arthrosclerosis. In spite of being short and thin, the present study population has prevalence of central obesity, hypertension, and diabetes. Further, the people of the South Asian Indian biocultural feature do have cardiovascular disease (CVD) risks due to high fat mass and lower muscle mass which increases with affluence (Kshatriya et al. 2021). Also the populations of the present study were at risk of MetS and CVDs. But we found that height is a poor predictor of metabolic risk and not associated with WC, FBG, SBP, DBP, and PR.

An environment which promotes weight gain and less physical activity within the home or the workplace has been defined as an obesogenic environment (Swinburn et al. 1999). An obesogenic environment has been described in short adults (145 cm – 166 cm) working on educational institutes of Lima, Peru. This environment can promote weight gain due to the lack of enough physical activity. Yet in contrast with this study our study population consisted of people who performed manual labor and still lead a relatively traditional way of life (Toro-Huamanchumo et al. 2020). Increasing modernization, asscess to globalized foods and adaptation to urban lifestyle have been made responsible for the increasing prevalence of obesity in rural areas (Kirchengast and Hagmann 2021). This indicates that changes in lifestyle and obesogenic environments are responsible for the increase of metabolic risks. This also applies for Asian Indian tribal people, but merely being of short height does not predispose to metabolic disorders.

Conclusions

Unlike the people of the wealthy and often obese social strata of low-middle-income countries, and in Europe and North America, height of tribal Indian populations is not associated with metabolic risk factors, such as hypertension, elevated fasting blood sugar, and central obesity. Rather than being linked to the phenotype, obesity appears to be associated with an obesogenic environment. Public health policy should focus on problems associated with obesogenic environments.

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