# Ethnicity, obesity and health pattern among Indian population

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## Abstract

**Objective:** To study the relationship of ethnicity with overweight/obesity, variation in adiposity levels, regional distribution of fat and its impact on cardio-respiratory health among selected ethnic groups. **Materials and methods:** A cross-sectional study was carried out among 300 young adults of three ethnic groups from different geographical regions of India ranging in age from 20 to 30 years. Stature, weight, circumferences, body fat percentage, and skinfold thicknesses were measured. Obesity indices like body mass index (BMI), grand mean thickness (GMT), waist hip ratio (WHR), waist height ratio (WHtR), and conicity index (CI) were computed. Cardio-respiratory health indicators such as lung functions including forced expiratory volume in 1 s ($FEV_{1.0}$), forced vital capacity (FVC), forced expiratory ratio (FER), peak expiratory flow rate (PEFR), breath holding time (BHT), and systolic and diastolic BP (blood pressure) were taken and associated with obesity indices. **Results:** General body fat deposition, assessed by BMI, GMT, and fat percentage, was found to be the highest among Delhi females and males. However, central adiposity as assessed from WHR, WHtR, and CI was found to be significantly higher among the Manipur subjects signifying a relatively more androidal pattern of fat deposition. Most of the inter-group differences for adiposity indices were significant; however, it was not so in the case of blood pressure among different ethnic groups. On the other hand, the respiratory efficiency varied significantly between different ethnic groups. Ethnicity, adiposity, and cardio-respiratory health were found to be interrelated. **Conclusions:** Subjects belonging to three ethnic groups showed marked differences in different body dimension, adiposity indices, and cardio-respiratory health. Central obesity has been found to be a better pointer for cardiovascular health risk. There were ethnic and gender differences with respect to adiposity measures and cardio-respiratory health indicators

**Key words:** Cardio-respiratory health, ethnicity, obesity

## INTRODUCTION

Obesity as a health risk needs no introduction in the present global scenario. What is much needed is finding the environmental trigger and its prevention. Ethnicity and socioeconomic status have been found to be two separate independent factors influencing BMI in men and women.[1] People with part ancestry in high-risk groups have an intermediate risk for obesity.[2]

Response to environmental triggers of obesity may vary among individuals, but the rise in obesity in both developed and developing countries, and the lower levels of obesity and related chronic diseases among African populations in West Africa than in the Caribbean and the US, suggest that environmental rather than genetic factors are the major drivers for ethnic differences in obesity.[3] An understanding of the prevalence of obesity and overweight in populations is important since some ethnic groups may be particularly vulnerable to the adverse health effects associated with obesity.[4]

The association of ethnicity and obesity has been documented in a number of studies mainly in the US and UK, with a higher risk of obesity being consistently reported among black women, compared with Whites.[5,6] Asian-Americans in US were found to be having lower rates of obesity than other Americans,[7] whereas Pacific Islanders were found to have the highest rates.[8]

South Asians generally have a higher level of fat per unit of BMI compared to Whites.[9] Stephanie *et al*.[4] showed that the 'epidemic' of childhood obesity observed in UK involves adolescents from all ethnic groups, although there are some differences between ethnic groups in the prevalence of overweight. Indian males were at higher risk of being overweight than white British males. The prevalence of obesity and overweight was similar in white British and Bangladeshi males.

India is a multiethnic country, but ethnic differences in adiposity or the influence of lifestyle and ethnicity on obesity and cardio-respiratory health has been less explored in spite of India's diversity in terms of biological as well as socio-cultural backgrounds. The present research aims to study the relationship of ethnicity with overweight and obesity among different ethnic groups from different geographical regions of India. Variations in adiposity levels and regional distribution of fat and its effect on cardio respiratory health among three different ethnic groups were comprehended.

## MATERIALS AND METHODS

A cross-sectional study was carried out among 360 young adults of three different ethnic groups of India ranging in age from 20 to 30 years. Sixty subjects were excluded from the sample as they did not fit into the inclusion criteria. The inclusion criteria were: subjects not related by blood, product of inter-caste marriage, age between 20 and 30 years, no physical deformity. After exclusion, the subjects comprised of 50 males and 50 females each from Manipur, Delhi, and Kerala. The purpose of the study and techniques to be used were explained to each subject. Those who volunteered and gave written consent were studied.

### Anthropometric and physiological measurements
Each subject was measured for stature, weight, circumferences at waist and hip, skinfold thickness at biceps, triceps, suprailiac, subscapular, and calf posterior sites. Anthropometric measurements were taken using standard protocols given by Weiner and Lourie.[10] Stature was taken with the help of anthropometer in the standard arm hanging position; body weight was measured by using spring balance with minimum clothing; minimum waist

circumference and maximum hip circumference were measured with a flexible steel tape. Skin fold thicknesses were taken with Holtain's skinfold caliper which exerted a constant pressure of $10 \text{ g/mm}^2$ over the contact surface. Measurements were conducted by trained anthropologists.

Body fat percentage was measured using bioelectric impedance technique (Tanita body composition analyser). Lung functions including forced expiratory volume in first second ($FEV_{1.0}$), forced vital capacity (FVC), forced expiratory ratio (FER), and peak expiratory flow rate (PEFR) were recorded with single breath using a micro-spirometer. Breath holding time (BHT) was assessed using a stop watch. Systolic (SBP) and diastolic (DBP) blood pressures were taken with the help of sphygmomanometer and stethoscope. Body fat percentage and BHT were taken for Manipur and Delhi subjects only.

Obesity indices which include body mass index (BMI), grand mean thickness (GMT), waist–hip ratio (WHR), waist–height ratio (WHtR), and conicity index (CI) were computed statistically. BMI was classified according to WHO,[11] BMI less than 18.5 as underweight and more than 24.9 as overweight/obese. WHR cut-off points followed for males was 0.95 and for females was 0.80.[12] WHtR cut-off points taken for both females and males was 0.50.[13] Conicity index (CI) was calculated as 'waist circumference $(m)/[0.109 \ X\sqrt{} \ \{body \ weight \ (kg)/ \ height \ (m)\}]$'. Conicity index cut-off points taken for females was 1.18 and for males it was 1.25.[14]

The subjects were classified in different blood pressure group categories according to JNC VII.[15] In this study, subjects were divided into three categories: normotensive, prehypertensive (120–139 mmHg systolic; 80–89 mmHg diastolic), and hypertensive (≥140/90 mmHg). To determine lung efficiency, forced expiratory ratio (FER) was assessed with 80% as the cutoff point for normal value.[16]

### Statistical analysis
The data was analyzed using SPSS 16.0 version. For group comparisons, one-way ANOVA and '*t*' test were applied. Pearson's correlation (two-tailed) was used to evaluate the strength and direction of linear relationship between obesity indices and cardio-respiratory health indicators for each of the populations.

### Subjects and area
The studied groups comprise of males and females belonging to Khatri from Delhi, tribal population from Manipur and Ezhava from Kerala. The majority of the subjects were either in services or students. Delhi is situated between the Himalayas and Aravalis range in the

heart of the Indian sub-continent. It is the plain area. The Khatris follow caste endogamy and clan exogamy. It is a patriarchal and patrilineal society. Females helped in household activities besides their own work. Males were mostly sedentary. The staple food is wheat and eating out habit is prevalent among them. They usually take fat-rich diet and lot of sweets.

Manipur ethnic groups racially and linguistically belong to the Tibeto-Burman group. Manipur, the easternmost part of India, is a mountainous region, isolated from the neighboring states by a chain of hill ranges. North East India in the context of India occupies a distinctive place due to its geographical, historical, social, cultural, and political features. The tribal populations follow endogamous, patriarchal, and patrilineal system. All the subjects were actively engaged in household chores and other physical activities besides their own work. Their staple food was rice and most of them were non-vegetarian, but they usually take less sweets, oily foods, and milk products.

The third group studied comprised of Ezhava of Amboori village of Thiruvananthapuram district, Kerala. Kerala is a state on the south-west tropical Malabar Coast of India.

Ezhava is Other Backward Caste (OBC) group of Kerala. They do not own large areas of agricultural land, but quite a few were involved in agricultural practices mainly as laborers. Females in addition also helped in household activities. Most of them were non-vegetarian. Rice constituted the staple food and fish was taken regularly. The Ezhava followed community endogamy and clan exogamy, patrilineal, and patriarchael system.

## RESULTS

Table 1 shows mean, standard deviation, and *F*-value for various anthropometric and physiological measurements and different obesity indices of young Indian females and males belonging to three different ethnic groups. Delhi females were found to be tallest (156.5 ± 6.64) and heaviest (52.0 ± 9.51) whereas Manipur females were shortest (153.0 ± 5.62) and Kerala females were lightest (47.5 ± 8.16) of all. The inter-group differences were found to be significant ($P < 0.001$) for both stature and body weight. Manipur females had the maximum waist circumference, and Delhi females had the maximum hip circumference. The inter-ethnic group differences were statistically significant ($P < 0.001$) for both the circumferences.

### Table 1: Basic characteristic of the female and male subjects

| Variables | Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|---|
| | Delhi | Manipur | Kerala | F value | Delhi | Manipur | Kerala | F value |
| Stature (cm) | 156.5 ± 6.64 | 153.0 ± 5.62 | 155.9 ± 5.32 | **5.03** | 167.2 ± 7.16 | 164.8 ±5 .72 | 170.6 ± 5.95 | **10.62** |
| Weight (kg) | 52.0 ± 9.52 | 49.6 ± 7.47 | 47.5 ± 8.16 | **3.60** | 61.5 ± 13.63 | 59.1 ± 8.38 | 56.9 ± 10.39 | 2.23 |
| Waist circumference (cm) | 67.3 ± 8.00 | 69.7 ± 7.27 | 62.5 ± 6.40 | **12.85** | 76.3 ± 8.51 | 72.2 ± 8.70 | 68.0 ± 7.02 | **12.83** |
| Hip circumference (cm) | 91.0 ± 7.36 | 89.4 ± 5.55 | 84.0 ± 5.39 | **17.58** | 90.3 ± 7.74 | 89.8 ± 4.20 | 85.1 ± 6.83 | **9.91** |
| Body mass index (kg/m²) | 21.2 ± 3.66 | 21.1 ± 2.26 | 19.5 ± 2.72 | **5.55** | 21.9 ± 3.96 | 21.7 ± 2.66 | 19.5 ± 3 .05 | **8.47** |
| Grand mean thickness (mm) | 14.4 ± 5.09 | 13.4 ± 3.78 | 14.3 ± 3.52 | 0.88 | 10.4 ± 5.18 | 9.86 ± 4.46 | 10.1 ± 3.71 | 0.15 |
| Fat percentage (%) | 19.6 ± 5.66 | 16.4 ± 7.29 | – | 2.92 | 17.8 ± 5.99 | 11.4 ± 4.11 | – | **19.94** |
| Waist–hip ratio | 0.74 ± 0.05 | 0.78 ± 0.07 | 0.74 ± 0.06 | **6.88** | 0.84 ± 0.05 | 0.80 ± 0.07 | 0.79 ± 0.06 | **7.85** |
| Waist height ratio | 0.43 ± 0.05 | 0.45 ± 0.04 | 0.40 ± 0.04 | **17.73** | 0.45 ± 0.05 | 0.43 ± 0.04 | 0.39 ± 0.04 | **18.06** |
| Conicity index | 1.07 ± 0.07 | 1.13 ± 0.10 | 1.08 ± 0.08 | **16.09** | 1.16 ± 0.07 | 1.11 ± 0.10 | 1.08 ± 0.08 | **10.37** |
| Systolic blood pressure (mmHg) | 104.1 ± 9.17 | 106.7 ± 9.73 | 107.5 ± 10.20 | 1.75 | 119.7 ± 9.32 | 121.2 ± 12.84 | 121.1 ± 10.2 | 0.29 |
| Diastolic blood pressure (mmHg) | 70.7 ± 6.93 | 70.2 ± 8.26 | 72.3 ± 10.30 | 0.81 | 83.4 ± 9.39 | 75.4 ± 10.02 | 81.6 ± 8.8 | **9.95** |
| Forced expiratory volume$_{1.0}$ (l) | 2.10 ± 0.45 | 2.15 ± 0.45 | 1.62 ± 0.61 | **15.65** | 2.45 ± 0.97 | 3.07 ± 0.65 | 2.36 ± 0.77 | **11.23** |
| Forced vital capacity(lit.) | 2.38 ± 0.46 | 2.31 ± 0.49 | 1.73 ± 0.66 | **20.86** | 2.95 ± 0.96 | 3.39 ± 0.71 | 2.49 ± 0.82 | **14.29** |
| Forced expiratory ratio(%) | 87.6 ± 10.29 | 92.5 ± 5.42 | 89.0 ± 19.59 | 1.69 | 85.6 ± 14.48 | 90.2 ± 1 0.04 | 94.6 ± 5.83 | **8.45** |
| Peak expiratory flow rate(lit/min) | 215.5 ± 87.94 | 253.7 ± 83.87 | 172.1 ± 83.62 | **11.27** | 261.7 ± 141.0 | 363.2 ± 133.2 | 296.9 ± 1 22.2 | **7.56** |
| Breath holding time(seconds) | 37.9 ± 14.55 | 27.2 ± 13.11 | – | **9.77** | 42.9 ± 11.67 | 39.3 ± 15.62 | – | 0.89 |

*F value in bold letters shows significant values.

General obesity as assessed from BMI, GMT, and fat percentage was found to be highest among Delhi females. Whereas central obesity assessed from WHR, WHtR and CI were found to be maximum among Manipur females. Although WHtR was more among Delhi females as compared to Kerala females, the latter had a higher value of CI. With the exception of GMT and fat percentage, statistically significant differences were observed between different ethnic groups for other indices.

Although the differences for blood pressure were not statistically significant, Kerala females had a highest value of both systolic and diastolic blood pressure followed by Manipur females and Delhi females. Respiratory efficiency as assessed by $FEV_{1.0}$, FER, and PEFR were found maximum among Manipur females followed by Delhi and Kerala females. Ethnic differences for $FEV_{1.0}$, FVC, PEFR and BHT were found statistically significant.

Kerala males were found to be significantly taller (170.6 ± 5.95), and Manipur males were shortest (164.8 ± 5.72) while Delhi males were heaviest (61.5 ± 13.6), although the differences between different ethnic groups for body weight were statistically non-significant. Delhi males had largest waist and hip circumferences followed by Manipur and Kerala males. Inter-ethnic group differences for both the circumferences were statistically significant ($P < 0.001$). The differences between groups were statistically significant with the exception of GMT. The central obesity was relatively higher among Delhi males followed by Manipur males and was lowest among Kerala males. The inter-group differences for all the regional adiposity indices were statistically significant.

Systolic blood pressure was highest among Manipur males followed by Kerala and Delhi males although the differences between groups were not statistically significant. The inter-group differences for diastolic blood pressure were statistically significant with the highest value among Delhi males and minimum among Manipur males. Respiratory efficiency as assessed by $FEV_{1.0}$, FVC, and PEFR was found to be highest among Manipur males followed by Delhi males. The differences for various respiratory functions were statistically significant among different ethnic groups with the exception of breath holding time.

Comparison of different populations for general and regional obesity and cardio-respiratory health indicators has been displayed in Table 2. The mean differences for BMI were statistically significant for Delhi–Kerala and Kerala–Manipur males ($P < 0.001$) and females ($P < 0.01$) whereas none of the differences were found to be statistically significant for GMT. Both Delhi–Manipur males and females were significantly different ($P < 0.01$)

from each other for WHR along with Delhi–Kerala males ($P < 0.001$) and Kerala–Manipur females ($P < 0.01$). The females of all the three groups were significantly different from each other with respect to WHtR as also Delhi–Kerala and Kerala–Manipur males. The CI varied significantly between females of Delhi–Manipur, Delhi–Kerala, and Kerala–Manipur groups. The Delhi–Manipur and Delhi–Kerala males were also significantly different from each other.

The differences for systolic and diastolic blood pressure and forced expiratory ratio were statistically nonsignificant for females in any of the population groups. The Delhi–Manipur, Kerala–Manipur males differ significantly ($P < 0.001$) from each other with reference to diastolic blood pressure whereas the Delhi–Manipur females, Delhi–Kerala males, and Kerala–Manipur males differ significantly with respect to FER.

Prevalence of overweight/obesity, hypertension, and FER risk groups among Delhi, Manipur, and Kerala females and males are given in Table 3. The prevalence of overweight/obesity as assessed from BMI was found to be maximum in Delhi subjects among both males and females. Kerala had a maximum number of underweight subjects in both males and females. Manipur males and females displayed a maximum number of normal weight subjects. On the basis of WHR, maximum numbers of Manipur females were in the risk category followed by Delhi and Kerala females but among males except for 4% of Delhi males none of them were in the risk category. On the other hand, WHtR gave a different picture with 20% Manipur females and 16% Delhi females to be in the risk category though all the Kerala females were in the normal category. Among males, 22% from Delhi, 16% from Manipur, and 2% Kerala were in the risk category.

90% of Delhi females were in the normotensive category as against 42% among Delhi males. The 14% of both Manipur and Kerala females were in the prehypertensive category whereas none of the females in any of the three population groups were hypertensive with respect to SBP. However, 10% males from Manipur and 4% from Delhi were hypertensive on the basis of SBP. Maximum number of Delhi females (92%) had normal DBP. 20% Manipur females were prehypertensive followed by Kerala females, whereas 6% Kerala females and 2% Manipur females were hypertensive. Among males, maximum from Manipur (58%) were normotensive but from Kerala were prehypertensive (40%). Maximum males (36%) from Delhi were hypertensive followed by Kerala males (20%) with respect to diastolic BP. Maximum males from Delhi (22%) were found to be in the risk category followed by Delhi females (18%) with respect to PEFR.

**Table 2: Comparison of different populations for general and regional obesity and cardio-respiratory health indicators**

| Dependent variables | Groups | 't' value with level of significance | |
|---|---|---|---|
| | | **Females** | **Males** |
| General and regional obesity | | | |
| Body mass index (kg/m²) | Delhi–Manipur | 0.18 | 0.24 |
| | Delhi–Kerala | 2.71** | 3.41*** |
| | Kerala–Manipur | 3.28** | 3.92*** |
| Grand mean thickness (mm) | Delhi–Manipur | 1.09 | 0.52 |
| | Delhi–Kerala | 0.08 | 0.27 |
| | Kerala–Manipur | 1.24 | 0.32 |
| Waist–hip ratio | Delhi–Manipur | 3.30** | 2.86** |
| | Delhi–Kerala | 0.43 | 4.88*** |
| | Kerala–Manipur | 2.78** | 0.33 |
| Waist–height ratio | Delhi–Manipur | 2.44** | 1.72 |
| | Delhi–Kerala | 3.26** | 6.40*** |
| | Kerala–Manipur | 6.64*** | 4.01*** |
| Conicity index | Delhi–Manipur | 2.98** | 2.57** |
| | Delhi–Kerala | 2.95** | 7.01*** |
| | Kerala–Manipur | 5.32*** | 1.34 |
| Cardio-respiratory health indicators | | | |
| Systolic blood pressure | Delhi–Manipur | 1.40 | 0.68 |
| | Delhi–Kerala | 1.79 | 0.69 |
| | Kerala–Manipur | 0.42 | 0.07 |
| Diastolic blood pressure | Delhi–Manipur | 0.33 | 4.12*** |
| | Delhi–Kerala | 0.91 | 0.95 |
| | Kerala–Manipur | 1.12 | 3.31** |
| Forced expiratory ratio | Delhi–Manipur | 2.99** | 1.84 |
| | Delhi–Kerala | 0.55 | 3.78*** |
| | Kerala–Manipur | 1.09 | 2.31* |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4 displays correlation between regional and central obesity indices and cardio-respiratory health indicators among Delhi, Manipur, and Kerala females and males. Among Delhi females, SBP had significant ($P < 0.01$) positive correlation with BMI, GMT, WHR, and WHtR. Among Manipur females, systolic BP showed significant positive correlation with WHtR and WHR. DBP was significantly correlated with BMI ($P < 0.01$), GMT ($P < 0.01$), and WHtR ($P < 0.05$). Among Kerala females, none of the correlations between cardio-respiratory health indicators and adiposity indices were significant as was the case among Delhi and Manipur males. Among Kerala subjects, both systolic and diastolic BP showed significant correlation with BMI ($P < 0.01$), WHtR ($P < 0.01$), and GMT ($P < 0.05$). WHR showed statistically significant correlation only with diastolic BP ($P < 0.05$).

## DISCUSSION

General body fat deposition, assessed by BMI, GMT and fat percentage, was found to be highest among Delhi females and males. Overweight/obesity was most prevalent among Delhi subjects and underweight among Kerala subjects. However, central adiposity as assessed from WHR, WHtR, and CI was found to be significantly higher among the Manipur females signifying a relatively more androidal pattern of fat deposition, whereas among males Delhi subjects had higher central adiposity. More trunkal fat has been found to be independently related to cardio-vascular health problems[17] thereby indicating more cardiovascular health consequences among Manipur and Delhi subjects than Kerala subjects. Satwanti *et al*.[18] and Kapoor *et al*.[19] also observed an ethnic variation in the pattern of fat stored subcutaneously and internally. The ethnic differences in adiposity, and the intermediate values in admixed individuals, may stem from both genetic and environmental sources.[20] However, Luke *et al*.[3] suggested that environmental rather than genetic factors are the major drivers for ethnic differences in obesity.

**Table 3: Prevalence of overweight, obesity, hypertension and forced expiratory ratio risk groups in the percentage among Delhi, Manipur and Kerala females and males**

| Obesity Indices and physiological measurements | Females | | | Males | | |
|---|---|---|---|---|---|---|
| | Delhi | Manipur | Kerala | Delhi | Manipur | Kerala |
| Body mass index | | | | | | |
| Underweight | 30 | 10 | 36 | 22 | 08 | 34 |
| Normal | 54 | 86 | 60 | 54 | 82 | 58 |
| Overweight/obesity | 16 | 04 | 04 | 24 | 10 | 08 |
| Waist–hip ratio | | | | | | |
| Normal | 88 | 58 | 88 | 96 | 100 | 100 |
| Risk | 12 | 42 | 12 | 04 | – | – |
| Waist–height ratio | | | | | | |
| Normal | 84 | 80 | 100 | 78 | 84 | 98 |
| Risk | 16 | 20 | – | 22 | 16 | 02 |
| Systolic blood pressure | | | | | | |
| Normotensive | 90 | 86 | 86 | 42 | 36 | 42 |
| Prehypertensive | 10 | 14 | 14 | 54 | 54 | 58 |
| Hypertensive | – | – | – | 04 | 10 | – |
| Diatolic blood pressure | | | | | | |
| Normotensive | 92 | 78 | 84 | 34 | 58 | 40 |
| Prehypertensive | 08 | 20 | 10 | 30 | 30 | 40 |
| Hypertensive | – | 02 | 06 | 36 | 12 | 20 |
| Forced expiratory ratio | | | | | | |
| Normal | 82 | 98 | 88 | 78 | 92 | 100 |
| Risk | 18 | 02 | 12 | 22 | 08 | – |

**Table 4: Correlation between regional and central obesity indices and cardio-respiratory health indicators among females and males**

| | Females | | | | | Males | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Body mass index | Grand mean thickness | Waist hip ratio | Waist height ratio | Conicity index | Body mass index | Grand mean thickness | Waist–hip ratio | Waist–height ratio | Conicity index |
| Delhi | | | | | | | | | | |
| Systolic blood pressure | 0.52** | 0.48** | 0.39** | 0.51** | 0.27 | 0.12 | 0.03 | –0.16 | 0.02 | -0.12 |
| Diastolic blood pressure | –0.02 | 0.13 | 0.05 | 0.03 | 0.14 | –0.22 | –0.15 | –0.08 | –0.15 | 0.05 |
| Forced expiratory ratio | 0.10 | 0.22 | –0.13 | 0.03 | –0.07 | 0.01 | –0.07 | –0.34 | –0.10 | -0.19 |
| Manipur | | | | | | | | | | |
| Systolic blood pressure | 0.19 | 0.12 | 0.29* | 0.33* | 0.26 | 0.03 | –0.08 | 0.18 | 0.17 | 0.17 |
| Diastolic blood pressure | 0.51** | 0.44** | 0.13 | 0.30* | 0.01 | 0.12 | –0.03 | 0.17 | 0.20 | 0.14 |
| Forced expiratory ratio | –0.13 | –0.18 | 0.05 | –0.03 | 0.05 | –0.14 | –0.12 | –0.06 | –0.12 | -0.05 |
| Kerala | | | | | | | | | | |
| Systolic blood pressure | 0.20 | 0.11 | 0.17 | 0.22 | 0.24 | 0.41** | 0.29* | 0.25 | 0.39** | 0.23 |
| Diastolic blood pressure | 0.21 | 0.14 | 0.09 | 0.11 | –0.04 | 0.45** | 0.33* | 0.34* | 0.48** | 0.24 |
| Forced expiratory ratio | –0.05 | –0.02 | 0.10 | –0.05 | 0.005 | –0.01 | –0.18 | –0.23 | –0.13 | -0.22 |

*$P < 0.05$, **$P < 0.01$.

The prevalence of prehypertension as assessed from SBP was highest among Manipur and Kerala females. On the basis of DBP, more Manipur females were prehypertensive followed by Kerala females, but prevalence of hypertension was highest among Kerala females. Prehypertension was maximum among Kerala males and hypertension among Delhi males. A relatively lesser number of females were found to be prehypertensive/hypertensive than their male counterparts in all the three groups. Although the central obesity was predominant among Manipur males and

females despite them having less fat mass, the association between hypertension and pattern of fat deposition was clearer among Manipur females than males thus putting them to a greater risk of cardiovascular health problems.

All the lung functions were found to be more efficient among the Manipur males and females indicating a better respiratory efficiency and an adaptive role of higher physical activity at hilly terrains among Manipur males and females than their counterparts from plains.

Most of the inter-group differences for adiposity indices were significant, but not in the case of blood pressure in different ethnic groups. On the other hand, respiratory efficiency varied significantly between different ethnic groups. Respiratory efficiency is influenced by physical activity, blood pressure is a function of age and lifestyle, and body composition is due to differences in energy intake and physical activity, besides the differences in the genetic composition. These findings strengthen the association between the adiposity and physical activity level on one hand and that of respiratory efficiency and physical activity on the other. Prehypertension/hypertension was almost absent in a significant proportion in any of the groups, but the prevalence was relatively higher among Manipur males and females, which shows an independent relationship between central obesity and cardiovascular health risk. Body composition (i.e. fat *vs*. muscle, abdominal visceral fat *vs*. abdominal subcutaneous fat) may differ between ethnic groups due to genetic differences, or differences in energy intake and levels of physical activity. Due to this, the consequent risk of chronic diseases may not be the same in different ethnic groups.[21] Studies have demonstrated that social and economic factors are associated with CVD,[22] and because these factors are distributed unequally by sex and ethnicity, they may help to explain 'apparent' sex and ethnic differences in CVD distribution.[22]

In this study, WHtR has been found to be a better indicator for cardiovascular health among males and females as shown in the association between central obesity and blood pressure. Systolic blood pressure showed positive and significant association with most of the indices of adiposity among females of Delhi and Manipur. However, diastolic blood pressure showed positive and significant association among Kerala males only. Gender differences in the relationship of adiposity measures and blood pressure was also reported by Gerber *et al*.[23] Suman and Kapoor[24] reported a similar positive and significant association between BMI and blood pressure.

The North Indian (Delhi) subjects were found to be more obese, with highest general obesity and relatively poor lung functions, which can be attributed to their metropolitan city lifestyle, characterized by a relatively faster life, irregular food habits, more consumption of fast food, and lower physical activity. When macrostructural processes favor sedentarism and consumption of energy-dense food,[25] social disadvantage is associated with fewer resources for individuals opting for healthier lifestyles regarding dietary and physical activity patterns.[26] Ethnicity, an overlooked dimension of the obesity epidemic was related to different socioeconomic trajectories, thus representing one of the axes of social adversity associated with the weight change.[27]

Most subjects from Kerala were underweight according to BMI categories. Manipur subjects were characterized by higher central adiposity despite having lesser general obesity levels and best respiratory efficiency than rest of the subjects. Manipur subjects were more predisposed to prehypertension and hypertension along with having higher central adiposity, and also may be due to perpetual tension and questionable future because of insurgencies in the state. The remarkable variation in the prevalence of across populations suggests that social, economic and environmental factors have important influences on the epidemic, although it may be also true that genetic differences across populations play equally important role.[28]

Lifestyle indicators, socioeconomic status, and dietary habits influences the obesity level and health inference. It explains the existence of different levels of body mass index and other obesity indices in the same population. Obesity is more common among people of the higher socioeconomic status and those living in urban areas. Urbanization and economic development bring about improvement in the socio-economic status, nutritional transition, and sedentary lifestyle, which contributed to the increasing prevalence of overweight and obesity and associated health problems especially in urban areas.

The three groups studied comprise of Indo-Aryan (North Indian), Mongoloid (North East Indian), and Dravidian (South Indian) populations which comprise most of the main ethnic groups of India. These ethnic groups are further subdivided into numerous subgroups, castes, and tribes in India. Although the populations studied here belonged to the three different ethnic groups, they do not represent all the regions and ethnic populations of India, which is the main limitation of the study.

Ethnicity is a complex construct of assured biology, but also cultural, language, religion, and importantly for epidemiologist, distinct health beliefs, and health behavior. The study of ethnic groups is of crucial value

in determining the role of different exposures to disease risk, which could not be delivered by the sole study of a single ethnic group, and is an easy way of providing etiological clues. Further, the demonstration of variation in the ethnic group susceptibility to various diseases is of importance in directing public health interventions and health care resources.[29] Ethnic differences could be clearly seen in this study among the South Indians, North Indians, and North East Indians in general and regional obesity and its association with cardio-respiratory health. However, a larger sample size study would be of much help to make the ethnic specific cutoffs for indices of general and regional adiposity.

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