2022 | Anthropo-Indialogs Vol. 2, No. 1, pp. 1-20

ISSN: 2583-1070 • *URL: www.arfjournals.com*
https://doi.org/10.47509 /AI.2022.v02i01.01

Effects of Gender, Residence, and Ethnicity on Anthropometric Parameters in three Endogamous Populations of Andhra Pradesh

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Abstract: Gender and urban-rural (residence) differences of anthropometric variables are known in endogamous populations. It is not known whether gender and urban-rural differences are same or different across the endogamous population. Ethnic variation of anthropometric variables was studied using few anthropometric variables only. Only difference of anthropometric variables are reported, it is to be known whether gender, residence and ethnicity have any effect in contributing variation in anthropometric variable alone or in combination. In this study an attempt was made to study the gender and residence differences as well variation of 38 anthropometric variables/indices across the endogamous populations and the effect of gender, residence and ethnicity in contributing variation alone or in combination. A total of 900 participants representing three endogamous populations namely Reddy, Golla and Madiga of Chittoor district of Andhra Pradesh were recruited. In each endogamous group 75 sample each in gender and residence were enrolled for the study. Gender and residence differences in anthropometric variables were not found to be endogamous population specific. Significant mean differences were observed in anthropometric variables between endogamous population. Effect of gender, ethnicity and residence on anthropometric parameters/indices was evaluated using two way multivariate analysis of variance**.** Gender was shown to influence anthropometric variables/ indices to the extent of 1.2%-65.9, residence and ethnicity to the tune of 1%-11.5% and 1.8%-14.3% respectively. Further analyses showed that gender, ethnicity and residence variables in combination also influence the anthropometric variables/indices contributing 0.9% to 5.7% variation in anthropometric variables/ indices.

Keywords: Anthropometric variables, gender, ethnicity, residence, two way multivariate analysis of variance

Received : 28 March 2022
Revised : 14 April 2022
Accepted : 24 April 2022
Published : 30 June 2022

TO CITE THIS ARTICLE:

Venkatramana, P., Latheef, S.A.A., & Annaiah, P. (2022). Effects of Gender, Residence, and Ethnicity on Anthropometric Parameters in three Endogamous Population of Andhra Pradesh, *Anthropo-Indialogs,* 2: 1, pp. 1-20. *doi.org/10.47509 /AI.2022.v02i01.01*

Introduction

Measurement of human body consisting of bones, muscles and adipose tissues by recording lengths, widths, heights or diameters is termed as anthropometry (NHNESIII 1988). These measurements are useful to estimate size, composition, and proportion of the human body (Latheef *et al.* 2018). Gender (Kamran *et al.*2020; Reddy *et al.*2019; Karmegam *et al.* 2011; Reddy, 1998) and residence (urban-rural) (Reddy *et al.*2019; Maken and Varte, 2016; Roy *et al.*2015; Venkatramana and Reddy, 2002; Reddy, 1998) differences of anthropometric variables were reported in endogamous populations. It is not known whether difference of gender and residence are same or different across endogamous populations. Studies on ethnic variation in anthropometric variables reported using few variables such as stature, weight, body mass index, circumference of waist and hip, waist-hip ratio, body surface area, lean body mass and middle upper arm circumference (Kamran *et al.* 2020; Karmegam *et al.*2011; Banik *et al.* 2009; Reddy, 1998). Data on anthropometric parameters in general and on large number of variables in particular from endogamous populations are scarce (Banik *et al.*2009). The objectives of the present study are (1) whether gender and residence differences are same or not across three endogamous populations (2) to bring out information on the variation on the anthropometric variables across endogamous population and (3) to investigate the effect of the gender, residence, and ethnicity in contributing variation to the anthropometric variable alone or in combination using multivariate techniques.

Material and Methods

A total of 900 participants from Reddy, Golla and Madiga Caste populations belonging to the urban and rural areas were drawn from Chittoor District of Andhra Pradesh. In each caste population, 75 participants of each sex (total=150) from either urban or rural were recruited for the study. The data for the urban sample were collected from Tirupati city of Chittoor District while the rural samples were drawn from eight villages of Chittoor District namely Ramapuram, Nadimuru, Diguvaramapuram, Diguvaramapuram Harijanawada, KammapalliHarijanawada, Gollapalli, Venkataramapuram, and Panakam.

A Brief Description on the Investigated Endogamous Populations

Reddy: The Reddy is one of the forward Castes in Andhra Pradesh. They are also called as 'Kapu' in Rayalaseema. A total of 88 sub-castes are reported in this Caste. The

dominant Sub-Castes of Reddis are Panta, Pedakanti, Akuthota, Pokanati, Desuri, Kodithe, Motati, Bhumanchi, Morasu and Palle. For the present study, the data were collected from Akuthota Reddy only. They Speak and write Telugu language. Consanguineous marriages are common among the Reddis. Occupationally they are engaged in agriculture, business, government jobs, animal husbandry and cattle rearing.

Madiga: They are one of the largest Scheduled Caste groups in India. The Madiga are known as 'Mang' in Maharashtra; the 'Chakkaliya' in Tamil Nadu and the 'Matang' in North India. In Ancient times they were engaged in hunting and gathering and presently involved in leather works, and as agricultural labours. About 25 sub-Castes in Madigas are reported and among the predominant Sub-Castes are Dappu Madiga, Mashti Madiga, Jogi Madiga, Penda Madiga, Telugu Madiga, Arava Madiga and Periki Madiga. In the present study data on the Telugu Madiga were included. They speak and write Telugu language. In this Caste also consanguineous marriage are common.

Golla: The Golla is a pastoral and Backward community. This Caste population is distributed throughout India and know by different names. The Gollas of Andhra Pradesh speak and write Telugu language. The Sub-Castes of Gollas includes Erra, Ala, Pooja, Gangeddu, Gauda, Karma, Pakanati, Racha, Peddeti and Krishna. Each Sub Caste is strictly an endogamous unit. The present study has been carried out on Krishna Gollas. The Gollas were traditionally sheep and cattle herders and involved in dairy activities. Now they are engaged in agriculture, government jobs and business.

Variables included in the study: The list of variables included, instruments, landmarks, formulae, and procedures used for the measurement of anthropometric variables and indices in participants are described in Table 1.

Statistical analyses: Continuous variables were presented in mean and standard error of mean. Means of the groups were compared with student *'t'* test and one way analysis of variance. Effect of gender, ethnicity and residence as well as their interactions on anthropometric variables/indices were investigated using two way multivariate analysis of variance.

Results

The descriptive statistics of Anthropometric variables are described below in terms of gender, residence, and ethnicity.

Gender: Comparison of the means of anthropometric parameters between sexes revealed that differences were not ethnic group specific. In all endogamous

Table 1: List of variables, instruments, landmarks, formulae and reference followed for measurement of anthropometric variable/indices

Anthropometric variable	*Instrument used/ Landmark / formula*	*Reference*
Height	Anthropometer	Lohman *et al.* 1988
Weight	Weighing machine	Lohman *et al.* 1988
Waist circumference	Non-elastic tape, minimum circumference between umbilicus-xiphoid Non-elastic tape	Lohman *et al.* 1988
Hip circumference	Non-elastic tape, maximum Circumference around the buttocks posteriorly and the symphysis pubis anteriorly	Lohman *et al.* 1988
Upper arm circumference	Non-elastic tape, proximal part of the forearm perpendicular to its long axis	Lohman *et al.* 1988
Abdominal circumference	Non-elastic tape, at the level of the greatest anterior extension of the abdomen	Lohman *et al.* 1988
Chest circumference	Non-elastic tape, at the union of the 3rd and 4th stern brae, right angles to the axis of the body and at the end of normal expiration	Lohman *et al.* 1988
Calf circumference	Non-elastic tape, maximum circumference in a plane perpendicular to the long axis of the calf	Lohman *et al.* 1988
Biacromial diameter	Anthropometer, base of the neck outwards to the tips of the shoulder	Lohman *et al.* 1988
Biilliac diameter	Anthropometer, maximum breadth of iliac crest	Lohman *et al.* 1988
Knee diameter	Sliding caliper, distance between the most medial and most lateral aspect of the femoral condyles	Lohman *et al.* 1988
Ankle diameter	Sliding caliper, maximum diameter of ankle	Lohman *et al.* 1988
Elbow diameter	Sliding caliper, distance between the epicondyles of the humerus	Lohman *et al.* 1988
Wrist diameter	Spreading caliper, ulnar to radial styloid	Lohman *et al.* 1988
Triceps skinfold	Lange skin fold calliper, midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna.	Lohman *et al.* 1988

Anthropometric variable	*Instrument used/ Landmark / formula*	*Reference*
Biceps skinfold	Lange skin fold calliper, anterior aspect of the arm, over the belly of the biceps muscle	Lohman *et al.* 1988
Subscapular skinfold	Lange skin fold calliper, below the inferior angle of the scapula	Lohman *et al.* 1988
Suprailiac skinfold	Lange skin fold calliper, just above the iliac crest in the midaxillary line.	Lohman *et al.* 1988
Abdomen skinfold	Lange skin fold calliper, a horizontal fold of skin 1 cm below the umbilicus and 3 cm laterally (to the right)	Lohman *et al.* 1988
Calf skinfold	Lange skin fold calliper, maximum circumference at the medial (inner) aspect of the calf.	Lohman *et al.* 1988
Body mass index (BMI)	Weight (Kg)/height (m^2)	
Waist-hip ratio (WHR)	Waist circumference/hip circumference	Tanphaichitr et al (1990)
Sum of the three trunk skin folds (TSF3)	Abdominal skinfold + sub scapular skinfold+ suprailiac skinfold	Hasstedt et al (1989)
Sum of the six skin folds (SF6)	Abdominal skin fold+ sub scapular skin fold+ suprailiac skin fold + calf skinfold + triceps skin fold + biceps skin fold	Hasstedt et al (1989)
the ratio of the sum of the trunk to the sum of the extremity skin folds (TE ratio)	TSF3 / (calf + triceps + biceps)	Hasstedt et al (1989)
Relative fat pattern index (RFPI)	Sub scapular / (sub scapular + suprailiac)	Hasstedt et al (1989)
Height index	Sitting height/height	
Arm muscle circumference (AMC)	Ca – (π×St); Ca = Upper arm circumference; St= Triceps skin fold thickness	
Arm muscle area (AMA)	$\frac{Ca-(\pi \times St)^2}{4\pi}$ Ca = Upper arm circumference; St= Triceps skin fold thickness	
Ponderal Index (PI)	$height/\sqrt[3]{Weight}$	

Anthropometric variable	*Instrument used/ Landmark / formula*	*Reference*
Body Density (BD)	$Y = 1.1631 - 0.0632 \log_{10} SSFT$ Y= Predicted body density SSFT= Sum of four skinfolds (Σ BST, TST, SST, SIST) BST=Biceps skinfold thickness; TST=Triceps skin fold thickness; SST=Subscapular skin fold thickness; SIST=Suprailiac Skin fold thickness	Durnin and Rahman (1967)
Percent body fat (% Bd Fat)	$\left(\frac{4.95}{Bodydensity} - 4.5\right)$	Siri's (1956)
Fat Free Weight (FFW)	(Actual body weight)- $\frac{\%bodyfat}{100} \times Actual\ body\ weight$	
Bone Mineral Content (BMC)	$3.9 \times T^2 \times H \times 10^{-4}$ T = Average of elbow, Wrist, Knee and ankle diameters (cm) H = Stature (cm)	
Total Body Water (TBW)	$0.784 \times (Lean\ body\ mass - Bone\ mineral)$	Allen *et al.* (1959)
Body Fat (BF)	$\left(\frac{4.95}{Body\ density} - 4.50\right) \times Body\ Weight$	Siri (1961)

populations common observations were made with reference to gender. In all endogamous populations, significantly higher averages of height, weight, sitting height, diameters of biacromial, elbow, wrist and ankle, circumferences of waist, forearm, upper arm and abdominal, WHR, PI, FFW, BMC, TBW, HWR, AMC, AMA were observed against women (Table 2). In women significantly higher averages of skinfolds of biceps, triceps, subscapular, abdominal and calf, hip circumference, TSF3, TSF6, RFPI and %BF were observed when compared to the men (Table 2).

Residence: Anthropometric variable differences in urban-rural participants among endogamous populations were not unique to endogamous populations. In all three endogamous populations common urban-rural differences were observed.

These included higher averages of skinfolds of biceps, triceps, calf ($p<0.01$) subscapular and suprailliac ($p<0.05$), biacromial diameter, circumferences of hip and calf, TSF3, TSF6, BMI, %BF, FFW, HWR, TBW ($p<0.01$) and BF($p<0.05$) were significantly different in urban when compared to the rural men. In contrast averages of elbow and knee diameter, fore arm circumference, AMC, AMA, RFPI and PI ($p<0.01$) were significantly higher in rural against urban men. Significantly higher averages of weight, skin folds of biceps, triceps, subscapular, suprailliac and abdominal, hip circumference, billiac diameter, BMI, TSF3, TSF6, HWR, %BF ($p<0.01$), TE ratio, FFW, BF and TBW ($p<0.05$) were observed in urban against rural women. In contrast averages of height, sitting height, RFPI, PI, ankle diameter ($p<0.01$), AMA and forearm circumference ($p<0.05$) were significantly higher in rural when compared to the urban women (Table 2).

Ethnicity: We have pooled urban-rural participants of each endogamous group and performed one way analyses of variance (one way ANOVA) for each gender separately to investigate significant differences in the mean values of anthropometric variables across the endogamous populations. In men, Madiga participants showed significant difference in mean against Reddy and Golla Caste populations in anthropometric variables such as weight, sitting height, skinfolds of biceps, triceps, subscapular and supralilaic, diameters of biacromial, knee and ankle, circumferences of hip, waist, upper arm, forearm, chest and abdominal, BMI, height index, TSF3, SF6, TE ratio, AMC, HWR, PI, body density, % of body fat, FFW, BMC, TBW and body fat ($p<0.01$). In variables such as height, skinfolds of biceps and calf, diameters of biacromial, billiac and elbow, circumference of upper arm, forearm and calf, TE ratio and AMC Significant mean difference was observed between Golla and Reddy Men($p<0.01$), in contrast in variables like biacromial diameter, calf skinfold and % BF, significant mean differences were observed between Golla and Madiga men ($p<0.01$).

In women, significant mean differences were observed in anthropometric variables such as weight, knee diameter, circumferences of hip, waist forearm, chest, abdomen and calf, BMI, AMC, HWR, PI, FFW and TBW in Madiga when compared to Reddy and Golla ($p<0.01$). In variables like sitting height, skin folds of triceps and subscapular and calf, diameters of biacromial and elbow, upper arm circumference, SF6,AMA and BMC significant mean differences were observed between Reddy and Golla women($p<0.01$). Significant mean difference in variables such as diameters of wrist, elbow and biacromial diameter and upper arm circumference were observed between Golla and Madiga women ($p<0.01$).

Table 2: Mean and standard error of mean of anthropometric parameters among participants of ethnic groups

Variable	*Reddy*				*Golla*				*Madiga*			
	Urban		*Rural*		*Urban*		*Rural*		*Urban*		*Rural*	
	Male (n=75)	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*
Age(years)	39.84 ± 1.31	46.30 ± 1.70**	37.69 ± 1.43	39.46 ± 1.28	42.40 ± 1.27	42.33 ± 1.27	40.12 ± 1.37	38.60 ± 1.19	34.56 ± 1.45	34.80 ±1.38	38.06 ± 1.44	37.26 ± 1.18
Weight(kg)	62.30 ±1.17	56.20 ± 1.21**	60.48 ± 0.99	50.78 ± 0.95**	63.16 ± 0.90	54.25 ± 0.87**	59.94 ± 0.86	51.36 ± 0.79**	57.46 ± 1.09	48.53 ± 1.22**	51.20 ± 0.88	47.18 ± 0.84**
Height(cm)	166.99 ± 5.83	151.63 ± 6.79**	167.39 ± 0.66	152.0.65 ±0.60**	165.76 ± 0.47	150.31 ±0.58**	165.65 ± 0.61	152.93 ±0.51**	165.32 ± 0.71	151.93 ± 0.45**	164.61 ± 0.44	152.57 ± 0.57**
Sitting Height	86.50 ± 0.43	78.63 ± 0.37**	85.38± 0.36	79.70± 0.40**	85.28 ± 0.28	76.79 ± 0.29**	85.04 ± 0.33	78.47 ± 0.25**	85.20 ± 0.42	77.88 ± 0.30**	82.75 ± 0.30	78.00 ± 0.36**
Biceps SF (mm)	4.36 ± 0.26	8.05 ± 0.41**	3.22 ±0.20	5.33 ± 0.25**	4.66 ± 0.22	6.42 ± 0.40**	4.28 ± 0.17	5.49 ± 0.22**	4.49 ± 0.32	6.38 ± 0.40**	2.36 ± 0.13	4.54 ± 0.23**
Triceps SF (mm)	13.50 ± 0.48	21.09 ± 0.79**	11.14 ± 0.49	15.24 ± 0.49**	13.52 ± 0.43	16.09 ±0.64**	12.57 ± 0.34	14.89 ± 0.35**	13.29 ± 0.51	18.38 ± 0.75**	8.88 ± 0.44	14.26 ± 0.51**
Subscapular SF (mm)	16.84 ± 0.59	22.40 ± 0.77**	15.65 ± 0.67	18.01± 0.58**	17.40 ± 0.53	19.29 ± 0.61*	15.72 ± 0.54	17.69 ± 0.41*	16.93 ± 0.64	18.86± 0.86	11.70 ± 0.55	16.97 ± 0.48**
Suprailiac SF(mm)	21.12 ± 0.77	24.04 ± 0.79**	18.58 ± 0.87	18.65 ± 0.62	20.02 ± 0.57	21.64 ± 0.66	17.97 ± 0.63	18.73 ± 0.42	21.32 ± 0.76	20.45 ± 0.79	12.61± 0.74	18.73 ± 0.47**
Abdominal SF (mm)	22.72 ± 0.80	25.81 ± 0.79**	20.61 ±0.92	19.94 ±0.71	21.69 ± 0.65	23.34 ± 0.69	20.22 ± 0.73	20.42 ± 0.46	22.94 ± 0.82	21.16 ± 0.85	14.30 ± 0.77	20.30 ± 0.56**
Calf SF (mm)	14.50 ± 0.41	15.53 ± 0.51	11.49± 0.45	15.92± 0.35**	14.74 ± 0.35	15.21 ± 0.37	13.46 ± 0.32	14.64 ± 0.24*	14.25 ± 0.46	16.33 ± 0.50**	10.18 ± 0.45	13.61 ± 0.34**
Biacromial Dia (cm).	37.60 ± 0.24	33.14 ± 0.18**	35.91 ± 0.28	33.26 ± 0.22**	37.68 ± 0.20	34.00 ± 0.20**	37.33 ± 0.13	33.56 ± 0.20**	37.47 ± 0.21	32.75 ± 0.17**	36.05 ± 0.19	33.17 ± 0.28**
BiiliacDia (cm).	31.66 ±0.22	31.63 ± 0.24	30.00 ± 0.20	30.07 ± 0.24	31.94 ± 0.20	31.41 ± 0.24	31.64 ± 0.14	30.39 ± 0.17**	30.32 ± 0.21	30.32 ± 0.24	29.82 ± 0.18	29.57 ± 0.18
Wrist Dia (cm).	5.23 ±0.31	4.79 ± 0.03**	5.36 ±0.03	4.85 ± 0.02**	5.28 ± 0.03	4.85 ± 0.03**	5.33 ± 0.27	4.87 ± 0.02**	5.22 ± 0.03	4.77 ± 0.02**	5.31 ± 0.03	4.79 ± 0.02**
Elbow Dia (cm).	6.30±0.04	5.89 ±0.04**	6.57± 0.06	5.76 ± 0.03**	6.15 ± 0.05	5.54 ± 0.05**	6.43 ± 0.04	5.58 ± 0.03**	6.37 ± 0.04	5.89 ± 0.04	6.30 ± 0.03	5.66 ± 0.03**

Variable	*Reddy*				*Golla*				*Madiga*			
	Urban		*Rural*		*Urban*		*Rural*		*Urban*		*Rural*	
	Male (n=75)	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*
Knee Dia (cm).	9.80 ± 0.07	9.83 ± 0.06	9.75 ±0.07	9.57 ± 0.07	9.91 ± 0.05	9.60 ± 0.06	9.64 ± 0.05	9.46 ± 0.05*	9.47 ± 0.08	8.93 ± 0.11**	9.23 ± 0.07	9.00 ± 0.06*
Ankle Dia (cm).	6.48 ± 0.03	6.02 ± 0.04**	6.72 ±0.05	5.98 ± 0.03**	6.57 ± 0.04	5.84 ± 0.04**	6.70 ±0.04	6.03 ± 0.02**	6.51 ± 0.04	5.97 ± 0.03**	6.41 ± 0.03	6.00 ± 0.03**
Waist Cir (cm).	80.13 ± 0.94	78.08 ± 0.93	80.38 ± 0.99	76.73 ± 0.79**	81.21 ± 0.79	76.07 ± 1.68**	79.64 ± 0.94	75.93 ± 0.75**	77.56 ± 1.06	72.64 ± 1.08**	73.18 ± 0.75	72.21 ± 0.89
Hip Cir (cm).	92.06 ± 0.92	97.34 ± 0.99**	90.75 ± 0.84	92.45 ± 0.92	93.19 ± 0.66	96.54 ± 0.92**	90.49 ± 0.78	92.80 ± 0.74**	89.09 ± 0.77	90.43 ± 1.09	84.07 ± 0.69	88.60 ± 0.85**
Upper arm Cir (cm).	26.83 ± 0.26	27.19 ± 0.30	27.24 ± 0.31	26.44 ± 0.33	27.94 ± 0.28	26.41 ± 0.33**	28.58 ± 0.22	25.83 ± 0.25**	26.53 ±0.26	25.50 ± 0.37*	25.43 ± 0.21	24.72 ± 0.25*
Forearm Cir(cm)	25.70 ± 0.16	24.13 ± 0.25**	26.70 ± 0.24	24.59± 0.23**	26.40 ± 0.19	23.70 ± 0.21**	27.12 ± 0.19	24.39 ± 0.16**	25.77 ± 0.21	23.61 ± 0.28**	25.18 ± 0.16	23.31 ± 0.15**
Chest Cir(cm).	87.41 ±0.74	87.36 ± 0.99	87.71 ± 0.73	85.79± 0.80	87.61 ±0.56	87.24 ± 0.76	86.25 ± 0.72	84.25 ± 0.77	86.70 ± 0.83	82.86 ± 0.96**	81.78 ±0.61	80.89 ± 0.82
Abdominal Cir(cm).	84.31 ±1.13	81.98 ± 1.11	84.99 ± 1.10	80.22 ± 1.13**	86.72 ± 1.08	82.40 ± 0.99**	83.76 ± 1.15	79.69 ± 0.97**	81.84 ± 1.30	77.32 ± 1.28*	75.72 ± 0.96	76.08 ± 1.11
Calf Cir(cm).	33.42 ± 0.32	34.45 ± 0.30*	33.65 ± 0.29	32.22 ±0.31**	32.85 ± 0.28	32.76 ± 0.27	31.70 ± 0.22	33.08 ± 0.20**	32.72 ± 0.28	31.40 ± 0.37**	30.41 ± 0.22	30.95 ± 0.30
BMI(Kg/m2)	22.32 ±0.36	24.41 ± 0.48**	21.58 ±0.33	21.72 ± 0.33	22.96 ± 0.28	24.03 ± 0.39*	21.82 ± 0.28	21.93 ± 0.29	21.03 ± 0.38	20.99 ± 0.49	18.85 ± 0.28	20.26 ± 0.34**
WHR	0.87 ± 0.005	0.80 ± 0.006**	0.88 ±0.00	0.83 ± 0.00**	0.87 ± 0.00	0.80 ± 0.00**	0.87 ± 0.01	0.81 ± 0.00**	0.86 ± 0.00	0.80 ± 0.05**	0.87 ± 0.00	0.81 ± 0.00**
Height Index	0.51 ± 0.001	0.51± 0.001	0.51 ±0.00	0.52 ± 0.00**	0.51 ± 0.00	0.51 ± 0.00	0.51 ± 0.00	0.51 ± 0.00	0.51 ± 0.00	0.51 ± 0.00	0.50 ± 0.00	0.51 ± 0.00**
TSF3	60.68 ± 2.05	72.25 ± 2.27**	54.85 ± 2.34	56.61 ±1.85	59.12 ± 1.66	64.28 ± 1.91*	53.92 ± 1.86	56.85 ± 1.23	61.20 ± 2.02	60.48 ± 2.41	38.62 ± 2.01	56.01 ± 1.42**
TSF6	93.06 ±2.94	116.93 ± 3.60**	80.72 ± 3.25	93.10 ± 2.70**	92.05 ± 2.37	102.01 ± 3.04**	84.24 ± 2.54	91.80 ± 1.81*	93.24 ± 2.96	101.59 ± 3.76	60.00 ± 2.80	88.44 ± 2.22**
TE Ratio	1.88 ± 0.03	1.65 ±0.03**	2.16 ± 0.06	1.55 ± 0.028	1.80 ± 0.03	1.73 ± 0.03	1.76 ± 0.03	1.63 ± 0.02	1.94 ± 0.04	1.48 ± 0.03**	1.80 ± 0.04	1.76 ± 0.03

Variable	*Reddy*				*Golla*				*Madiga*			
	Urban		*Rural*		*Urban*		*Rural*		*Urban*		*Rural*	
	Male (n=75)	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*	*Male (n=75)*	*Female (n=75)*
RFPI	0.44 ± 0.006	0.48 ± 0.005**	0.46 ± 0.00	0.49 ± 0.00**	0.46 ± 0.00	0.47 ± 0.00	0.46 ± 0.00	0.48 ± 0.00**	0.44 ± 0.00	0.47 ±0.00**	0.49 ± 0.00	0.47 ± 0.00*
AMC	22.58 ± 0.19	20.56 ±0.26**	23.74 ± 0.24	21.65 ± 0.26**	23.69 ± 0.23	21.35 ± 0.28**	24.63 ± 0.20	21.15 ± 0.22**	22.35 ± 0.22	19.72 ± 0.26**	22.64 ± 0.17	20.24 ± 0.22**
AMA	0.56 ± 0.09	1.69 ±0.24**	1.04 ± 0.07	0.13 ± 0.11**	0.67 ± 0.07	0.17 ± 0.67**	0.96 ± 0.066	0.24 ± 0.08**	0.56 ± 0.11	0.95 ±0.21**	1.29 ± 0.05	0.21± 0.13**
H W Ratio	0.37 ± 0.006	0.37 ± 0.007	0.36 ± 0.00	0.33 ± 0.00**	0.38 ± 0.00	0.36 ± 0.00**	0.36 ± 0.00	0.33 ± 0.00**	0.34 ± 0.00	0.31 ± 0.00**	0.31 ± 0.00	0.30 ± 0.00
Ponderal Index	42.31 ± 0.23	39.85 ± 0.26**	42.81 ± 0.24	41.42 ± 0.21**	41.74 ± 0.18	39.86 ± 0.23**	42.44 ± 0.18	41.27 ± 0.18**	43.06 ± 0.27	42.03 ± 0.31*	44.52 ± 0.21	42.44 ± 0.24**
Body Density	1.05 ±0.00	1.04 ±0.00**	1.05 ±0.00	1.05 ± 0.00	1.05 ± 0.00	1.05 ± 0.00	1.05 ± 0.00	1.05 ± 0.00	1.05 ± 0.00	1.05 ± 0.00	1.06 ± 0.00	1.05 ± 0.00**
%B F	19.70 ± 0.43	23.29 ± 0.55**	17.60 ± 0.60	20.07 ± 0.40**	19.74 ± 0.41	21.30 ± 0.42**	18.58 ± 0.38	20.23 ± 0.26**	19.72 ± 0.44	21.13 ± 0.54*	13.76 ± 0.58	19.62 ± 0.32**
FFW	49.77 ± 0.72	42.79 ± 0.76**	49.52 ± 0.62	40.42 ± 0.66**	50.52 ± 0.60	42.48 ± 0.54**	48.63 ± 0.58	40.87 ± 0.55**	45.85 ± 0.69	37.91 ± 0.76**	43.85 ± 0.54	37.78 ± 0.58**
Bone Mineral content	3.16 ± 0.04	2.61 ±0.03**	3.31 ± 0.04	2.55 ± 0.03**	3.16 ± 0.03	2.45 ± 0.03**	3.20 ± 0.03	2.51 ± 0.02**	3.07 ± 0.04	2.43 ± 0.03**	2.98 ± 0.02	2.41 ± 0.02**
TBW	36.54 ±0.54	31.49 ± 0.58**	36.23 ± 0.46	29.68 ± 0.50**	37.13 ± 0.45	31.38 ± 0.41**	35.61± 0.43	30.07 ± 0.42**	33.53 ± 0.52	27.81 ± 0.58**	32.03 ± 0.41	27.72 ± 0.44**
Body Fat	12.58 ± 0.48	13.40 ± 0.50	10.95 ± 0.48	10.35 ± 0.34	12.64 ± 0.37	11.44 ± 0.43*	11.30 ±0.36	10.49 ± 0.27	11.60 ± 0.44	10.62 ± 0.49	7.35 ± 0.40	9.39 ± 0.29**

SF: Skinfold ; TE: trunk extremity ratio; AMC: Arm-muscle circumference; AMA: Arm-muscle area; HW ratio:Height-Weight ratio;%BF: Percent of body fat; TBW: Total body water; C: Cholesterol; FFW: Fat free weight

**p<0.01 *p<0.05

Effect of Gender, Ethnicity, and Residence on Anthropometric Variables

To investigate the effect of gender, residence and ethnicity on anthropometric variables, the data of all participants were pooled and two way multivariate analyses were performed. Effect of gender was observed on all anthropometric parameters except calf circumference and body fat and demonstrated that gender is a significant variable that influences most of the anthropometric variables/indices. The effect of gender was higher on height (65.9) followed by sitting height (55.8%), bone mineral content (52%), diameters of biacromial (49.4%), wrist (42.1%) and ankle (41.8%), FFW (32.4%), TBW (30.1%) forearm circumference (26.6%), AMC (27.2%), WHR (22.8%) and AMA (22.4%). The effect of gender on anthropometric variables/indices ranges from 1.2%-65.9. Except RFPI and WHR, ethnicity showed significant effect on all anthropometric parameters/indices in the investigated populations and ranged from 1.8%-14.3%, the highest on knee diameter and lowest on biceps skin fold was observed. Compared to gender, effect of ethnicity was found to be lesser on anthropometric parameters/indices. Residence showed no effect on sitting height, elbow diameter, TE ratio and BMC. Effect of residence on anthropometric variables/indices ranged from 1%-11.5% the highest effect on AMA (11.5%) and least effect on sitting height (1%). Among the studied variables of gender, ethnicity and residence, the effect of gender was found to be highest followed by ethnicity and residence (Table 3).

Discussion

Gender: Significantly higher mean height, weight (Kamran *et al.* 2020; Karmegam *et al.* 2011; Reddy *et al.* 2019) waist circumference and WHR (Reddy *et al.* 2019) were observed in men against women, whereas, significantly higher averages of hip circumference and RFPI (Karmegam *et al.* 2011; Reddy *et al.* 2019; Reddy, 1998) were observed in women when compared to men participants in earlier studies among endogamous populations and in agreement with findings of the present study. The gender differences in anthropometric variables were attributed to the variations in anatomy, hormones, physical activity, body composition, nutritional status, fat distribution, , and functions associated with reproduction roles (Obeidat *et al.* 2015; Josilathi *et al.* 1999).

Residence: Studies conducted on urban-rural differences in endogamous population revealed significantly higher mean of height, weight, waist circumference and BMI in urban men against rural men(Venkatramana and Reddy,2002), in contrast significantly lower mean height and weight were observed in urban against

Table 3: Influence of gender, residence and ethnicity on anthropometric parameters analysed bytwo way multivariate analysis of variance

Variable	*Gender*			*Ethnicity*			*Residence*		
	F value	*P Value*	*Partial Eta²*	*F value*	*P Value*	*Partial Eta²*	*F value*	*P Value*	*Partial Eta²*
Weight(kg)	180.117	0.000	0.169	52.142	0.000	0.105	37.124	0.000	0.040
Height(cm)	171.93	0.000	0.659	4.179	0.016	0.009	3.641	0.057	0.004
Sitting Height	112.13	0.000	0.558	22.128	0.000	0.000	0.606	0.437	0.001
Biceps SFT (mm)	166.161	0.000	0.158	9.883	0.000	0.022	84.144	0.000	0.087
Triceps SFT(mm)	208.929	0.000	0.190	8.366	0.000	0.018	102.145	0.000	0.103
Subscapular SFT (mm)	78.709	0.000	0.081	12.604	0.000	0.026	55.708	0.000	0.059
Suprailiac SFT(mm)	19.619	0.000	0.022	11.315	0.000	0.025	94.610	0.000	0.096
Abdominal SFT(mm)	10.817	0.001	0.012	12.580	0.000	0.028	71.611	0.000	0.075
Calf SFT(mm)	78.612	0.000	0.081	5.774	0.003	0.013	62.855	0.000	0.066
Biacromial Dia(cm)	866.487	0.000	0.494	14.646	0.000	0.032	20.863	0.000	0.023
BiiliacDia(cm)	7.004	0.008	0.008	41.996	0.000	0.086	61.541	0.000	0.065
Wrist Dia(cm)	646.778	0.000	0.421	3.866	0.021	0.009	11.504	0.001	0.013
Elbow Dia(cm).	573.663	0.000	0.392	20.221	0.000	0.044	1.194	0.275	0.001
Knee Dia(cm)	31.282	0.000	0.034	74.120	0.000	0.143	12.307	0.000	0.014
Ankle Dia(cm)	638.240	0.000	0.418	3.886	0.021	0.009	10.396	0.001	0.012
Waist Cir(cm)	34.698	0.000	0.038	38.339	0.000	0.079	9.220	0.002	0.010
Hip Cir(cm)	38.871	0.000	0.042	48.064	0.000	0.098	42.499	0.000	0.046
Upperarm Cir(cm).	41.851	0.000	0.045	37.676	0.000	0.078	4.596	0.032	0.005
Forearm Cir(cm)	322.024	0.000	0.266	23.242	0.000	0.050	7.195	0.007	0.008
Chest Cir(cm).	11.051	0.001	0.012	29.375	0.000	0.062	21.009	0.000	0.023
Abdominal Cir(cm).	25.585	0.000	0.028	29.752	0.000	0.063	13.374	0.000	0.015
Calf Cir(cm).	0.012	0.913	0.000	52.045	0.000	0.105	31.431	0.000	0.034
BMI(Kg/m2)	14.293	0.000	0.016	53.881	0.000	0.108	57.265	0.000	0.061
WHR	262.025	0.000	0.228	1.695	0.184	0.004	8.924	0.003	0.010
Height Index	8.005	0.005	0.009	18.845	0.000	0.041	10.174	0.001	0.011
TSF3	31.714	0.000	0.034	13.242	0.000	0.029	81.678	0.000	0.084

Variable	*Gender*			*Ethnicity*			*Residence*		
	F value	*P Value*	*Partial Eta²*	*F value*	*P Value*	*Partial Eta²*	*F value*	*P Value*	*Partial Eta²*
TSF6	82.012	0.000	0.085	12.736	0.000	0.028	100.850	0.000	0.102
TE Ratio	129.580	0.000	0.127	4.828	0.008	0.011	1.399	0.237	0.002
RFPI	25.311	0.000	0.028	0.064	0.938	0.000	23.419	0.000	0.026
AMC	332.045	0.000	0.272	39.125	0.000	0.081	21.443	0.000	0.024
AMA	256.250	0.000	0.224	10.039	0.000	0.022	115.041	0.000	0.115
H W Ratio	27.946	0.000	0.031	55.082	0.000	0.110	48.103	0.000	0.051
Ponderal Index	150.301	0.000	0.145	57.948	0.000	0.115	53.870	0.000	0.057
Body Density	107.345	0.000	0.108	14.618	0.000	0.032	87.709	0.000	0.090
%B F	108.103	0.000	0.109	14.551	0.000	0.032	89.029	0.000	0.091
FFW	425.280	0.000	0.324	59.134	0.000	0.118	13.718	0.000	0.015
Bone Mineral content	963.303	0.000	0.520	25.573	0.000	0.054	0.555	0.456	0.001
TBW	382.186	0.000	0.301	59.305	0.000	0.118	15.065	0.000	0.017
Body Fat	0.081	0.776	0.000	29.987	0.000	0.063	79.677	0.000	0.082

Table 4: Interactions of gender, ethnicity and residence on anthropometric variables and indices

Interacting variables	*F value*	*P Value*	*Partial Eta²*
Height			
Gender*residence	4.049	0.018	0.009
Sitting height			
Residence*ethnicity	7.391	0.001	0.016
Weight			
Gender*residence*ethnicity	4.499	0.011	0.010
Biceps			
Residence*ethnicity	6.775	0.001	0.015
Gender*ethnicity	6.122	0.002	0.014
Triceps skinfold			
Gender*ethnicity	11.215	0.000	0.025
Residence*ethnicity	11.123	0.000	0.024
Gender*residence*ethnicity	3.564	0.029	0.008
Subscapular skin fold			
Gender*ethnicity	3.063	0.047	0.007
Residence*ethnicity	2.445	0.087	0.005
Gender*residence*ethnicity	6.990	0.001	0.015
Suprailiac skin fold			
Residence*ethnicity	3.913	0.020	0.009
Gender*residence*ethnicity	14.133	0.000	0.031
Abdominal skin fold			
Residence*ethnicity	3.093	0.046	0.007
Gender*residence*ethnicity	16.796	0.000	0.036
Calf skinfold			
Gender*residence	14.726	0.000	0.016
Gender*ethnicity	7.303	0.001	0.016
Residence*ethnicity	10.458	0.000	0.023
Biacromial diameter			
Gender*residence	23.283	0.000	0.026
Gender*residence*ethnicity	6.766	0.001	0.015
Biilliac diameter			
Gender*ethnicity	5.575	0.004	0.012
Ethnicity*residence	7.165	0.001	0.016
Elbow diameter			
Gender*ethnicity	3.735	0.024	0.008
Gender*residence	25.789	0.000	0.028
Ethnicity*residence	12.059	0.000	0.026

Interacting variables	*F value*	*P Value*	*Partial Eta²*
Knee diameter			
Gender*ethnicity	4.433	0.012	0.010
Gender*ethnicity*residence	3.317	0.037	0.007
Ankle diameter			
Gender*ethnicity	7.514	0.001	0.017
Ethnicity*residence	6.048	0.002	0.013
Gender*ethnicity*residence	7.550	0.001	0.017
Hip circumference			
Gender*ethnicity*residence	3.951	0.020	0.009
Upper arm circumference			
Gender*ethnicity	11.463	0.000	0.025
Gender*residence	4.226	0.040	0.005
Ethnicity*residence	3.144	0.044	0.007
Forearm circumference			
Gender*ethnicity	4.808	0.008	0.011
Ethnicity*residence	10.120	0.000	0.022
Chest circumference			
Ethnicity*residence	3.200	0.041	0.007
Calf circumference			
Gender*ethnicity	3.641	0.027	0.008
Gender*ethnicity*residence	17.253	0.000	0.037
Body Mass Index			
Gender*ethnicity*residence	5.721	0.003	0.013
Height index			
Gender*ethnicity	7.041	0.001	0.016
Gender*residence	22.890	0.000	0.025
Ethnicity*residence	6.078	0.002	0.014
Sum of three trunk skinfolds			
Ethnicity*residence	3.463	0.032	0.008
Gender*ethnicity*residence	13.665	0.000	0.030
sum of the six skinfolds			
Gender*ethnicity	3.569	0.029	0.008
Ethnicity*residence	6.203	0.002	0.014
Gender*ethnicity*residence	7.882	0.000	0.017
The trunk extremity ratio			
Gender*ethnicity	16.809	0.000	0.036
Ethnicity*residence	4.637	0.010	0.010
Gender*ethnicity*residence	26.921	0.000	0.057
Relative Fat Pattern Index			

Interacting variables	*F value*	*P Value*	*Partial Eta²*
Gender*ethnicity	5.941	0.003	0.013
Gender*residence	5.135	0.024	0.006
Gender*ethnicity*residence	7.218	0.001	0.016
Arm Muscle Circumference			
Gender*ethnicity	3.257	0.039	0.007
Gender*residence	3.201	0.041	0.007
Arm Muscle Area			
Gender*ethnicity	9.356	0.000	0.021
Gender*residence	17.461	0.000	0.019
Ethnicity*residence	10.011	0.000	0.022
Gender*ethnicity*residence	5.714	0.003	0.013
Height to weight Ratio			
Gender*ethnicity*residence	5.168	0.006	0.012
Ponderal index			
Gender*ethnicity*residence	5.827	0.003	0.013
Body density			
Gender*ethnicity	5.196	0.006	0.012
Gender*residence	5.198	0.023	0.006
Ethnicity*residence	8.333	0.000	0.018
Gender*ethnicity*residence	10.278	0.000	0.023
Percent of Body Fat			
Gender*ethnicity	5.121	0.006	0.011
Gender*residence	4.621	0.032	0.005
Ethnicity*residence	8.224	0.000	0.018
Gender*ethnicity*residence	10.205	0.000	0.022
Bone mineral content			
Gender*ethnicity*residence	4.243	0.015	0.009
Body fat			
Ethnicity*residence	3.209	0.001	0.017
Gender*ethnicity*residence	7.490	0.001	0.017

rural men(Roy *et al.*2015). In the present study also, higher BMI was observed in urban when compared to the rural men as observed earlier (Venkatramana and Reddy, 2002). Other studies carried on both sexes in urban and rural participants among endogamous populations showed higher BMI (Reddy,1998; Reddy *et al.*2019), weight, hip and waist circumferences and skinfold thickness (Maken and Varte, 2016; Reddy *et al.*2019) as observed in the present study. Height was significantly lower in urban than rural participants in one study (Reddy *et al.*2019) but opposite observation was made in another study (Maken and Varte, 2016).

Urban-rural differences in anthropometric variables may be due to the differences in life styles such as nutritional imbalance, socio-economic status and physical activity (Rao *et al.*2018; Abediran *et al.* 2013).

Ethnicity: Significant mean differences in BMI, RFPI, height, weight, waist, hip and upper arm circumference, WHR (Kamram *et al.* 2020; Karmegam *et al.* 2011; Reddy, 1998), were observed in earlier studies. In the present study also significant mean differences between most of the anthropometric variables in both genders of endogamous populations were observed. The ethnic variations in anthropometric variables may be due to differences in socio-economic and nutritional status, physical activity (Banik *et al.* 2009). To the best of our knowledge, we are the first to bring information on ethnic variation on some uninvestigated anthropometric variables like diameters of biacromial, biilliac, knee, ankle, elbow and wrist, AMC, AMA, body density, % body fat, BMC, FFW, TBW and BF among endogamous populations.

Significance of Effect of Gender, Residence and Ethnicity on Anthropometric Parameters

Till now gender, residence and ethnicity differences in anthropometric variables were reported using student independent 't' and one way analysis of variance. In this study to know the effect of gender, residence and ethnicity we have used two way multivariate analysis of variance (MANOVA) which not only report significant difference of variation in anthropometric variables among endogamous populations but also inform the percent of variation contributed by gender, residence and ethnicity in anthropometric variables through partial Eta^2 values. Eta^2 values report percent of variation contributed by the confounding variables such as gender, residence and ethnicity into the dependent variable(anthropometric) through which we know how gender, residence and ethnicity impact the dependent variable (anthropometric variable).

Earlier studies (Reddy, 1998) used multiple regression analysis to study the effect of gender. In this study we are first time using two way MANOVA due to the inclusion of 38 anthropometric variables and indies, which may have resulted into time consuming and also due to the limitations of using other tool for large number of variables.

While attempting to find predictors of disease or clinical outcomes in studies in which anthropometric parameters are included, the role of gender, residence and ethnicity are suspected as confounding variables. Till now the role of these variables on only few anthropometric variables or indices, are known. Ever increasing studies

are bringing the information on the role of new anthropometric variables in various disease conditions. To know the effect of gender, ethnicity and residence on the new emerging anthropometric variables in relation to the disease conditions, researchers have to perform further analysis. If the information on the effect of gender, residence and ethnicity on anthropometric variables or indices if known on most of these variables it will be handy information to the researchers and can be used to control their effects. In this direction, the present investigation attempts to provide the information on the effect of gender, ethnicity and residence on 38 anthropometric variables/ indices.

Gender was shown to influence anthropometric variables and indices to the extent of 1.2%-65.9, residence and ethnicity to the tune of 1%-11.5% and 1.8%-14.3% respectively suggesting that gender has a larger effect when compared to residence and ethnicity on anthropometric variables/indices. Researchers have to take gender in account for controlling its effect while attempting to find predictors of various clinical conditions. To know whether the gender, ethnicity and residence act alone or in combination influences the anthropometric variables/ indices, we performed two MANOVA and the results are presented in Table 4. In this table, we have given only the variable in which interactants interacted significantly. A total of 38 anthropometric variables/ indices on which either two or three of the gender or ethnicity or residence variables, were found to be interacting significantly. These observations suggest that either alone or in combination these variables are interacting and influencing the anthropometric variables/ indices. Interaction of variables such as gender, ethnicity and residence has been shown to contribute 0.9% to 5.7% variation in anthropometric variables/ indices.

Limitations

In this we have not studied the association of anthropometric variables in relation to disease which could have brought into the light the role of the variables in clinical conditions. In future studies we will attempt to investigate the role of anthropometric variables in disease conditions which may be helpful in identifying the high risk group of participants for particular disease.

Conclusion

The results of the study suggested no ethnic group specific gender and urban-rural differences. In most of the studied anthropometric variables and indices, significant differences were observed between ethnic groups. The present study brings important

information on the effect of gender, ethnicity and residence on 38 anthropometric variables/ indices which may be useful while finding the predictors of clinical conditions in which anthropometric variables and indices are included as independent variables.

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