Chapter 4

DISCUSSION

4.1 APPRAISAL OF DEMOGRAPHIC, SOCIO-ECONOMIC, AND LIFE STYLE RELATED PARAMETERS INFLUENCING NUTRITIONAL STATUS

The collection, analyses, interpretation and reporting about the nutritional scenario of a population and region is meant for appropriate response strategies and human welfare. Such studies help us to identify problem as well as policy and programme formulation. Anthropometric nutritional assessment warrants timely warning and intervention, which in turn helps in evaluating severity of malnutrition and success of interventions (WHO, 1995). The main concern of such studies would be identification and mitigation of malnutrition prevailing in the society. Many studies were conducted to identify the associated factors of malnutrition and its consequences (Deurenberg et al., 1991; Pryer, 1993; Shetty and James, 1994; Delpeuch et al., 1994; Ahmed et al., 1998; Nubé et al., 1998; Khongsdier, 2005; Shannon et al., 2008; Bisai et al., 2008; Sen et al., 2010a). Most of these factors were human misery pertaining to war, famine and social inequality which may have different manifestations in different context. The present cross-sectional study conducted among Limboo adults of Sikkim. It includes anthropometric and body composition measurements, and indicators of socio-economic condition to reflect on nutritional status and health. The study villages are Langang, Tikjek, Linghom, Darap, Singpheng, and Nambu of West Sikkim. The study consists of 992 (male: 496; female: 496) Limboo individuals of 18-64 years, selected through multistage sampling method. The present study has also recorded demographic, socio-economic, and life-style related data which will be discussed in the following paragraphs.

The population of Sikkim was composed of 7.18% of 0-14 years, 65.96% of 15-59 years and 6.87% of 60 + years individuals. Economically active population of the state i.e. individuals of 15-59 years of age is 65.96% which is higher than the national rate of 56.30 % as per the Census of India (2011). Still there is higher percentage of younger population of 0 -14 years (7.18%) than the elderly 60 + years (6.87%). Large numbers of people were in the productive phase of their life. The population sampled for the present study falls under this economically viable age group with average age of 34.73 (±12.47). Sikkim Human Development Report (2014) has recorded 50 % working population of which 60 % were males and 40 % were females. In the present study 71.8% individuals were manual labour with 46.5% males and 54.5% females. The manual labour category mostly comprised of agriculture labour and farmers in the present study. On the other hand non-manual or individuals with salaried jobs were 15.8% including males (66.2%) and females (33.8%). In the studied population, more individuals were engaged in land tilling and allied jobs. As per the Sikkim Human Development Report (2014), the people cultivating land have decreased from 1,01,202 to 82,707 during the year 2001 to 2011. However number of agricultural labourers during the same period has increased from 9,081 to 11,582. The decrease of land cultivators were 11% and increase in agriculture labourer were 53% during period of 2001-2011. Further, people engaging in work other than agriculture such as household industry and other works have increased to 22% and 44%, respectively (Sikkim Human Development Report, 2014).

Three different sectors of economy bear mention in the Sikkim Human Development Report (2014). These are Agriculture, Industry and Services of which major contribution was noted from Industry sector. Furthermore, higher numbers of individuals were reported as Self-Employed (731) individuals followed by Regular

Wage (222) individuals and Casual Labour (47) individuals per 1000 individuals. These figures are better and higher than states of Northeast India. In the present study participants mostly come from occupation demanding manual labour (71.8%) followed by non-manual (15.8%) and other (12.4%). As mentioned earlier, non-manual category of occupation includes the jobs with less physical endurance and mostly consists of salaried jobs. Students and unemployed individuals were categorised as "others". Many young participants in the present study even reported agriculture and farming as self-employed, which involves manual work. Such prevailing notions among the people of Sikkim may be responsible for the higher percentage of manual and self-employed individual in Sikkim Human Development Report (2014) and the present study. Other factor fuelling this attitude could be the recently popularised organic mission (farming) by the state government. Still important impetus is provided by education and literacy as well as quest for self sufficiency in the future.

At all India level, households with cultivation as the main source of income was 30.10% and manual casual labour was 51.18%. In the Northeastern region of the country, household depended on the cultivation and manual casual labour was 33.12% and 38.98%, respectively. In the state of Sikkim the figure was 45.43% and 19.78%, for cultivation and manual casual labour, respectively as the source of income (Socio Economic and Caste Census/SECC, 2011). Agricultural land in Sikkim was estimated to be around 79,000 hectares, i.e. 11.1 % of the total geographical area in the year 2010 (Gazetteer of Sikkim, 2013). The percentages of participants coming from landless families were 9.80% and individuals from households with land less than 0.99 acre were 23.10% in the present study. Together land less and people with land less than 0.99 acre constitute 32.86% and remaining 67.10% were from the households with land holding ≥ 1 acre. The numbers of male and female participants coming from families with less than 0.99 acre were 139 (42.6%) males and 187 (57.4%) females. The 357 (53.6%) male and 309 (46.4%) female individuals were from families with land 1 acre and above.

The reported total literacy rate in the state was 82 %, with 87 % and 76 % for male and female respectively. Percentage of literacy rate with residence is 80 % and 89 % for rural and urban respectively (Census of India, 2011; Sikkim Human Development Report, 2014). In the present study 75.3% and 24.7% individuals was literate and illiterate, respectively. Further, the present study sample was segregated as illiterate (24.7%), upto 8th grade (39.0%), 9-12th grade (3%), graduate (6.7%), post graduate (1.2%) and diploma/professional degree (1.2%). Earlier, people use to go outside Sikkim for higher education which was affordable for few people. Now Sikkim has built good infrastructure in the field of education. Literacy has brought profound impact on the standard of living of the people irrespective of rural and urban residence, which has obvious impact on health and nutrition.

In the present study 75.1% Limboo individuals were married and 24.9% were unmarried. The sex ratio (number of females per 1,000 males) of the state has improved from 875 in 2001 to 889 in 2011 census. Community specific sex ratio of Limboo of Sikkim is 938 is higher than the state average and closer to national sex ratio of 943. However, for the purpose of the present study proportion of male and female was kept equal. The mean age of marriage for girls in Sikkim in year 2007–08 was 21.5 years as against the all-India figure of 19.8 years. The percentage of girls marrying below 18 years still accounts for 16 % in the state as against the national average of 22%. In Sikkim, 12 per cent women in the age group of 15 –19 years begin childbearing, compared with 16 per cent at the national level. More rural teenagers are likely to become mother compared to urban counterpart in the state.

In the present study 11.5% of individuals were classified as having family monthly income below ₹ 4999/=. This indicates still a large number of people have difficulties in fulfilling their daily needs. In the state of Sikkim family monthly income of ₹ 5000/= - ₹ 9999/= can be considered as families able to afford daily needs of life. Last category of family monthly income of ₹ 10000/= and above can be regarded as fortunate families, which may include middle class and upper class. In the present study percentage of later two types of families was 38.0% and 50.5%, respectively. This reflects that the community is prospering as it reflects their purchasing power. Purchasing power has significant role in the market based economy. In contrast the total number of rural household reported from Sikkim was 88723, among which the percentage of households with less than ₹ 5000/= monthly earning was 72.99%, followed by 13.98% households with earning above ₹ 10000/= and then 12.89% households with the earning ranging ₹ 5000/= - ₹ 10000/= (SECC, 2011).

Further, the study population consists of a majority of households with more than five and above family members (66.43%), which is taken as the large family in the present study. The percentage of family with the family members less than 5 was 33.56%. The mean household size in India was 4.8, which is 4.6 for Sikkim. In India 50.54% household was with less than 4 members and 49.46% house hold was with 5 and more family members in their family. In Sikkim, 54.11% was reported as family with less than 4 members and 45.89% was reported as family with the family members of 5 and above. The plausible fact here is that small families in Sikkim are increasing and already crossed 50%, which is in contrast to present study population.

The census of India (2011) has identified house types based on the condition of the house such good house (53.2%), liveable house (41.5%) and dilapidated house (5.3%) in the country. The distribution of good, liveable, and dilapidated houses in urban areas was 46.0%, 47.5% and 6.5%, respectively. Similarly, distribution for rural areas was 68.5%, 28.6% and 2.9% respectively. SECC (2011) has indentified four types of house kacha house, pakka house, semi kacha house and semi pakka house in rural and urban India. The rural distribution of various house types was 30.26 %, 48.0%, 14.02% and 6.28%, respectively at national level. The rural areas of Northeast India reported kacha house, pakka house, semi kacha house and semi pakka house to be 29.05%, 20.53%, 47.55% and 1.30%, respectively. The distribution of house types in rural Sikkim was 8.83% kacha house, 30.76% pakka house, 58.14% semi kacha house and 0.40% semi pakka according to SECC (2011). In the present study house type category like semi pakka house was not considered because such houses with pakka wall & kacha roof were not observed in the study area as in SECC (2011). Almost every house was found with better roof such as tin sheet and concrete material. The participants of the present study were largely from pakka house (55.10%) followed by kacha house (26.40%) and semi packha house (18.4%).

The improved source of drinking water available to households in Sikkim in the year 2012 was 85.2 % in rural and 98.8 % in urban areas (Sikkim Human Development Report, 2014). In India, 43.5 % of households have tap water as the main source of drinking water, which is further divided into treated source and un-treated source (Census of India, 2011). The more urban households (62.00%) are benefitting from treated tap water than rural (17.90%). In contrary, more untreated tap water source was available to rural households (13.0%) compare to urban households (8.6%). Other sources of drinking water available in the country were well (11.0), hand pump (33.5%), tubewell/Borehole (8.5%), spring (0.5%), River/Canal (0.6%) lake/pond (0.8%) and other sources (1.5%). In the state of Sikkim tap water was a common source of drinking water, which accounts for 85.3% followed by well (0.6%), handpump/tubewell (0.1%) and other sources (14.1%). In the recent census the tape water is further divided into treated and untreated and this account for 29.2% and 56.1% in the state respectively (Census of India, 2011). In the present study sources of drinking water was categorised as government supply and piped from spring by the individuals themselves. Hence, the individual participants coming from households with government supply source of drinking water were 59.4% against the piped water source of 41.6% in the present study. According to census of India (2011) statistics, there was a positive change in the parameters identified for the sources of drinking water in the country. However, Sikkim needs to improve the water treatment compared to other Northeast states as there were 56.1% households availing untreated tap water for drinking which was also supported by the finding of the present study.

In India latrines with water closet facility was available to 36.4% households followed by 9.4% pit latrine, 1.1% other types of latrines and 53.1% no latrine. In the Sikkim, the condition observed to be improved two folds with 75.0% households have water closet latrine, followed by 12.0% pit latrine, 0.2% other latrines and 12.8% no latrine. On a recent survey by NSSO, Sikkim emerged on the top of all the Indian states with proper sanitary toilets and using them (NSSO, 2015). Earlier the NSSO (2012) had revealed that 99.1 % of rural households and 100 % of urban households had access to improved sanitation, which is also corroborated by *Swachhta* status report (2016). Sikkim is the first and only *Nirmal Rajya* (cleanest state) in the country to achieve 100 % sanitation in 2008 (Sikkim Human Development Report, 2014). In the present study data on sanitation like availability of toilet was enumerated which was 86.5% and 13.5% of households with commode toilets and pit toilets, respectively.

In Sikkim, the proportion of people below the poverty line (BPL) came down from 30.9% in 2004–05 to 8.19% in 2011–12, an average annual rate of decline of over 17%. The number of people living below poverty line in Sikkim has come down from 1.70 lakh in 2004–05 to 51,000 in 2011–12 and the proportion of the poor in the Himalayan state remains well below the national average (Sikkim Human Development Report, 2014). Now Sikkim stands only next to Goa, which is supported by the result published for the poverty gap ratio for Sikkim (urban 0.45 and rural 0.96). These values also stand on top of other states for urban and stand second to Goa for rural. In the present study socio-economic status of the population was assessed using Kuppuswamy scale, which is widely used by epidemiological and clinical studies reported from India. The socio-economic status identified in the present study was upper middle (UM), lower middle (LM) and upper lower (UL) with 17.2%, 30.4% and 52.3%, respectively. The observed contrast may be due to study location which was the villages of West Sikkim.

Positive trends in various parameters of the human condition is expected after the involvements of local, regional and global organization and governments with lessons from the past century were due to war and miseries human condition was worst which improved with the end of the war. Impact of industrialization was profound on the life of human living in different part of the world. Initially the industrialization demonstrated a positive impact on human health and now it is degrading. Furthermore, local and regional culture has equal influence on the health and nutrition of a population. Some of the features of population change like a large section of the population fall under the 15-59 years of age, sex ratio and increasing small family indicated the population of Sikkim in transition. Such demographic transition is not an isolated process it is usually accompanied by changed in the occurrence in types of diseases which in turn is associated with food habits and behaviours (Olshansky and Ault, 1986; Popkin et al., 2012; Baker and Friel, 2014). The state of Sikkim is prospering. However it has to deal with inherent challenges of NCDs which is so widespread (Kaveeshwar and Cornwall, 2014; Upreti et al., 2017). The NCDs like diabetes, CVD, cancer etc has been largely due to change in food habits and behaviours of the population which comes with modernity and mechanization. Anthropometric assessment is able to distinguish changes in the human body, which can potentially lead to such diseases. So, anthropometric assessment of nutritional status is critical for public health and welfare in Sikkim.

4.2 ANTHROPOMETRIC ASSESSMENT AND NUTRITIONAL STATUS AMONG THE LIMBOO INDIVIDUALS

4.2.1 EFFECT OF SEX ON ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES

The present study was conducted among the 992 adult male and female Limboo individuals of West Sikkim, India. The participants of the study were from rural areas. The descriptive characteristics (mean ± SD) of the various anthropometric measurements and derived indices of nutritional status and body composition are presented in Table 3.2 and 3.3. The anthropometric measurements recorded were height, weight, armspan, RAL, LAL, MUAC, NC, SH, WC, HC, TSF, BSF, SSF and SISF. It is clearly presented, the mean of the anthropometric variables such as height (159.43 cm ± 5.89 vs. 148.81 cm ± 5.11), weight (57.18 kg ± 8.86 vs. 51.46 kg ± 9.38), arm span (163.06 cm ± 6.53 vs. 150.86 cm ± 6.57), RAL (67.72 cm ± 3.00 vs.

63.04 cm ± 3.03), LAL (67.52 cm ± 2.99 vs. 62.79 cm ±3.01), MUAC (26.18 cm ± 2.46 vs. 24.70 cm ±2.77), NC (35.16 cm ± 2.34 vs. 31.53 cm ± 2.23), and SH (86.92 cm ± 3.10 vs. 80.67 cm ± 3.09) were significantly higher ($p<0.001$) among the male individuals compared to females in the present study. However, measures of adiposity such as WC (80.03 cm ± 7.44 vs. 83.22 cm ± 10.54), HC (87.95 cm ± 5.66 vs. 89.95 cm ± 8.04), TSF (6.81 mm ± 2.95 vs. 10.99 mm ± 4.07), BSF (3.97 mm ± 1.56 vs. 5.80 mm ± 2.65), SSF (10.57 mm ± 4.42 vs. 12.18 mm ± 4.49) and SISF (7.76 mm ± 3.63 vs. 10.53 mm ± 4.56) were significantly high among the female individuals compared to male individuals.

Further, the indices of adiposity like BMI (23.21 kg/m^2 ± 3.83 vs. 22.48 kg/m^2 ± 3.18), BAI (31.60% ± 4.47 vs. 25.75% ± 3.08), WHtR (0.56 ± 0.07 vs.0.50 ± 0.05),WHR (0.93±0.09 vs. 0.91± 0.06) and CI (1.30 ± 0.10 vs. 1.23± 0.06) and body composition parameters like UFA (4.32 cm^2 ± 1.94 vs. 2.86 cm^2 ± 1.43), AFI (8.57 ± 2.60 vs. 5.06 ± 1.88), PBF (24.20 % ± 4.80 vs. 12.76% ± 5.09), FM (12.77 kg ± 4.60 vs. 7.63 kg ± 4.04) and FMI (5.76 kg/m^2 ± 1.99 vs. 3.00 kg/m^2 ± 1.57) were observed to be high among Limboo females compared to males (Table 3.3). The remaining indices such as CRI (0.55 ± 0.01 vs. 0.54 ± 0.02), TUA (55.02 cm^2 ± 10.47 vs. 49.17 cm^2 ±11.15), UMA (52.16 cm^2 ± 9.54 vs. 44.85 cm^2 ± 9.77), BFMA (42.16 cm^2 ± 9.54 vs. 38.35 cm^2 ± 9.77), FFM (49.55 kg ± 5.73 vs. 38.68 kg ± 5.35) and FFMI (19.49 kg/m^2 ± 1.93 vs. 17.45 kg/m^2 ± 2.10) were observed to be high among Limboo males compared to females. The sexual dimorphism in various anthropometric and body composition variables is a well-established fact which has evolutionary and ecological significance in human and other animals alike (Wells, 2012).

Some populations of the neighbouring area such as Dhimal, Mech, and Rajbanshi were observed to exhibit significant sex differences in height and weight.

However, the differences were not significant in BMI across these ethnic groups (Datta Banik et al., 2009). The sexual dimorphism in human height and weight is a well-established phenomenon. Ample studies have shown higher height and weight among males (Bhadra et al., 2002; Das and Bose, 2006; Datta Banik et al., 2007; Mukhopadhya, 2009; Datta et al., 2015; Verma et al., 2016; Mondal et al., 2016, 2017). The sex difference in NC was also shown by studies conducted among Nigerians (Igiri et al., 2008) and Indonesian (Lindarto et al., 2016). Indian studies have shown significantly high NC among male individuals than females among tribals and non-tribals of India (Mondal et al., 2016, 2017). The NC is a relatively new measure of regional adiposity. The result of linear regression also substantiated the presence of sexual dimorphism in the anthropometric and body composition variables of the present study population. The strong association of sex of individual was observed on parameters like height, armspan, SH, PBF, and FFM with adjusted R^2 of above 0.45.

Some of the earlier studies showing sexual dimorphism on different anthropometric measures were of Johnston et al. (1982), Stini (1978), Bogin (1999). Until recently researcher were continuously able to show the sexual dimorphism in the various anthropometric variables (Deurenberg-Yap et al., 2000; Janssen et al., 2000; Ben-Noun and Laor, 2004; Yusof et al., 2007; Igiri et al. 2008; Flegal et al. 2009; Peltz et al., 2010). The most of the studies conducted among different Indian populations have shown such sexual dimorphism (Bhadra et al., 2002; Das and Bose, 2006; Datta Banik et al., 2007; Mukhopadhya, 2010; Datta et al., 2015; Verma et al., 2016; Mondal et al., 2017). In the present study male Limboo individuals were observed taller, heavier, and larger compared to their female counterparts. The study by Kirchengast (2010) has reviewed thoroughly the presence of such sexual difference in human life history from newborn via adolescents to old age, which was substantiated by finding of sexual dimorphism among adolescents of 6-18 years and among 19-92 years adults. The trends in body composition parameter shown by Kirchengast (2010) were observed similar to the present study mainly among adults (see Tables 3.4 & 3.5).

A study conducted among Chinese, Malay and Indian of Singapore observed significantly ($p<0.001$) high height, weight, BMI, WC, HC, WHR, and WHtR, among male individuals and only PBF and BAI among female individuals (Lam et al., 2013, 2015). Besides height and weight, all the adiposity measures and indices were high among female Limboo individuals in the present study. Another study on Mexican Americans by Peltz et al. (2010) has shown high height, weight, BMI, WC, WHR, FFM, among males and indices like FMI and PBF were high among females. Further, in contrast to the present study height, weight, BMI, WHR, and NC observed among the male individuals of Israeli urban district was high and the central obesity measures like WC and HC were high among female as in the Limboo individuals of the present study (Ben-Noun and Laor, 2004). A study among Sri Lankan adults observed significantly high WC and WHR among males and high BMI among females (Katulanada et al., 2011). Interesting adiposity indices including BMI, WC, WHR, and WHtR were high among females in the present study.

Some Indian studies observed high BMI among males (Bhadra et al., 2002; Basai et al., 2008; Mukhopadhyay, 2010). A study done on a population with high prevalence of undernutrition has shown high BMI among male individuals and high TSF, BSF, SSF, SISF, UMA, UFA, PBF, FM, and FMI among female individuals (Bisai et al., 2008). Further, a study by Bhadra et al. (2002) reported high WC among the young adult Bengalee males compared to females. A study by Rosell et al. (2005)

found a significant difference in height between male and female British individuals interestingly difference was non-significant in weight and BMI. Sex difference in BMI among Inuvialuit adults was reported non-significant (Hopping et al., 2010). There is no consistency in sexual dimorphism of mainly adiposity indices which may be due to escalating adiposity among populations. The influence of early life poor energy supply and diseases rate in a population may have implication in body composition dimorphism (Wells, 2012). The departure from the sexual dimorphism observed in the present study is worth consideration.

4.2.2 COMPARISON OF MEAN ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES OF LIMBOOS OF SIKKIM WITH AVAILABLE STUDIES

The mean height observed among the male and female Limboo individuals was 159.43 cm ± 5.89 and 148.81 cm ± 5.11 respectively in the present study. The most advanced countries such as Norway, Sweden, the Netherlands, the UK, Germany, the U.S. are considered as tallest nations of the world (Sunder, 2003; Fredriks et al., 2000; Komlos and Kriwy, 2002; Cavelaars et al., 2000; Schonbeck et al., 2013). Their height usually ranged from 166 cm – 170 cm among women and 180 cm – 184 cm among men (Bjelica et al., 2012). The mean height recorded for the Limboo population is clearly below this ranged and below the mean height of various populations of the world. The comparison of height of the different population of the world is presented in Table 4.1 for males and females. The height reported from the populations like Orang Asli, Abuja, Inuit, Hispanic, Maori, Maasai, Mexican American, as well as other American, Mediterranean, European, and Asian males were higher than that of the present study (see Table 4.1). The mean heights reported for male individuals of Native Hawaiian and Pacific Islander (NHPI), Bantu, and Baka Pygmy were lower than the mean height of male Limboo individuals. Similarly, the reported mean heights of female individuals of populations such as Abuja, Inuit, Hispanic, Maori, Maasai, Samoan, Mexican American, American, Mediterranean, European, and Asian were higher than the female Limboo individuals of the present study. Exceptions were the Orang Asli, Merida, Bangladeshi, Bantu, and Baka Pygmy females whose heights were lower compared to Limboo female.

Human height is subjected to nutritional status during childhood and adolescence. In this sense, human height may give us retrospection on the nutritional status of a population (Komlos and Baur, 2004; Hiermeyer, 2009). Cohort and birth cohort studies based on nationally representative data has suggested the positive influence of early life SES on height and BMI in India (Perkins et al., 2011; Som et al., 2014). The observed height of individuals from Chennai and New Delhi of India and Karachi of Pakistan were higher than the present study (Patel et al., 2017). Similarly, the reported mean height by NNMB for rural Indian adult males and females, and males of Mumbai were observed to be higher compared to Limboo individuals of the present study. The mean height of Limboo male individuals was higher than some tribes of Andaman, Odisha, West Bengal, Assam and Meghalaya such as Bhumij, Bathudi, Bhuiya, Jarawas, Khond, Miris, Munda, Kora Mudi, Santal, Rengma Naga, Pnar and War Khasi. Similarly, some female population were seen below the mean height of the Limboo female such as Savar, Mumbaian, Kora-Mudi, Santal, Oraon and Jarawas of Odisha, West Bengal, Maharashtra, and Andaman. The populations of Darjeeling like Dhimals and Rajbanshi were observed to be taller in terms of mean height compared to the present study. The comparison of mean height of the present study with Indian and Northeast Indian population was presented in Table 4.2 and 4.3, respectively.

Human height is partially genetic in nature which is largely influenced by individual diet and nutritional intake, work effort, as well as by external factors such as the disease environment (Kues, 2010). The adult height is perceived as a result of growth pattern and environmental factors (Boetsch et al., 2008). A large number of tribes and non-tribes of different zones of India were observed with higher mean height than the Limboo male and female of the present study which is evident from Table 4.2 and Table 4.3. The positions of Limboo mean height in the given comparative table is grim about their past life. This may be the reflection of harsh environment, poor growing up environment, diseases and nutrition prevailing there in the recent past (Wells, 2012). In this context, the Limboo population of Sikkim still bears environmental stress of past which has public health significance.

The BMI is based on body weight in that sense it will indicate the change in current nutritional status (Komlos, 1989; Komlos and Baur, 2004; Hiermeyer, 2009). The observed mean BMI among the Limboo male and female individuals was 22.48 $kg/m^2 \pm 3.17$ and 23.21 $kg/m^2 \pm 3.83$, respectively, as presented in Table 3.3. The overall mean BMI observed among the Limboo individuals irrespective of sex was 22.85 $kg/m^2 \pm 3.53$. The mean value observed for female Limboo individuals were significantly ($p<0.01$) high compared to male individuals. The mean BMI of the Limboo individuals of the present study is comparatively depicted with non-Indian populations in Table 4.4. The reported mean BMI of the different population of Africa such as male Maasai, Baka Pygmy and female Maasai, Bantu, Abuja were comparatively lower. Similar, lower mean value of BMI among Orang Asli, an indigenous population of Malaysia, was observed. Other Asian populations with relatively lower mean BMI were males of Thailand, Sri Lanka, and Bangladesh and females of Korea and Singapore. Interestingly mean BMI value of Asian females of

USA was lower in relation to other populations of USA. The females of Poland and West Europe were also observed with lower BMI compared to the females of the present study.

The adult males and females of Abuja, Inuit, Inuvialuit, Mexican American, Maori, Pacific, and NHPI were observed with high mean BMI compared to both Limboo males and females of the present study which is evident from Table 4.4. The female individuals of ethnic people like Bantu, Merida, and Samoa were also observed with high mean BMI compared to the present study. Other female populations associated with comparatively high mean BMI as shown in Table 4.4 are American, African American, Chinese American, Hispanic and Non-Hispanic people of USA. African American and Hispanic males were the other populations reported with high mean BMI compared to the present study. Interestingly English, Dutch and Portuguese along with Jordanian and Moroccan observed with high mean BMI compared to the present study. Similarly, Asian countries such as Philippines, Korea, Thailand, Mongolia, Indonesia and Sri Lanka were observed with high mean BMI compared to Limboo females of the present study. Furthermore, Asian of New Zealand, Asian of the USA, Chinese of the USA, including other males of Asian countries like Korea, Singapore, Mongolia, and Indonesia were reported with high mean BMI than males of present study.

Table 4.1: Comparative table showing mean height of Non-Indian populations with Limboo individuals

Population	Sample size	Country	Male	Female	Reference
American	268	USA	177.0 ± 7.0	163.0 ± 7.0	Janssen et al., 2000
Bangladesi women	2202/1999/1888	Bangladesh	NR	147.9 ± 5.2	Hosegood and campbell 2003
Caucasian	2982	Western Europe	175.7 ± 7.1	163.3 ± 6.8	Kyle et al., 2003
Filipino	1943	Philippines	NR	150.7 ± 4.92	Adair et al., 2004
Thi	98	Thiland	161.2 ± 5.6	151.7 ± 4.9	Pongchaiyakul et al., 2005
British (White and Non-white)	9963	UK	176.7 ± 6.5	163.7 ± 5.9	Rosell et al., 2005
Jordan	233	Jordan	NR	153.4 ± 4.0	Ahmad et al., 2006
Orang Asli	47	Malaysia	160.0 ± 5.40	148.00 ± 4.91	Yusof et al., 2007
Samoan	55	Ohu, Hawaii	NR	166.6 ± 6.6	Novotny et al., 2007
Asian Indian	117	New Zealand	169.6 ± 7·3	156·8 ± 5·8	Rush et al., 2009
Pacific	104	New Zealand	173·8 ± 6·9	160·9 ± 5·9	Rush et al., 2009
Maori	109	New Zealand	174·2 ± 7·2	161·5 ± 5·5	Rush et al., 2009
European	124	New Zealand	176·9 ± 6·3	164·2 ± 6·1	Rush et al., 2009
Maori	252	New Zealand	171 ± 9.0	16.0 ± 7.0	Taylor et al., 2010
Mexican American	165	Texas	172.9 ± 0.08	160 ± 0.09	Peltez et al., 2010
European	200	New Zealand	176 ± 8.0	164.0 ± 6.0	Taylor et al., 2010
NHPI	44	Pacific Island	110.4 ± 19.1	97.2 ± 31.0	Moy et al., 2010
Baka Pygmy	33	West Cameroon	155.00	146.00	Travaglino et al., 2011
Bantu	31	West Cameroon	172.00	160.00	Travaglino et al., 2011
Korean (40-59 yrs)	771	Korea	169.0 ± 6.0	153.0 ± 5.0	Kim et al., 2011
Korean (18-39 yrs)	771	Korea	174.0 ± 6.0	155.0 ± 5.0	Kim et al., 2011
Hispanic	147	USA	170.0 ± 7.7	155.5 ± 6.5	Hull et al., 2011

Continuation of Table 4.1

Population	Sample size	Country	Male	Female	References
Asian	58	USA	170.2 ± 6.9	156.8 ± 7.1	Hull et al., 2011
Moroccan	192	Netherland	174.0 ± 0.8	157.8 ± 0.4	Ujcic-Voortman et al., 2011
Dutch	214	Netherland	179.6 ± 0.5	160.8 ± 0.5	Ujcic-Voortman et al., 2011
Korean (> 60 yrs)	711	Korea	167.0 ± 5.0	161 ± 6.0	Kim et al., 2011
African Amreican	73	USA	174.5 ± 7.6	162.2 ± 7.5	Hull et al., 2011
Caucasian	202	USA	177.3 ± 7.4	162.7 ± 6.8	Hull et al., 2011
Turkish	196	Netherland	171.3 ± 0.5	167.0 ± 0.5	Ujcic-Voortman et al., 2011
Inuit	70	Greenland	166 (160 -170)	155 (152-159)	Andersen et al., 2013
Abuja	163	Nigeria Urban	161.0 ± 7.0	157 ± 8.0	Adediran et al., 2013
Abuja	173	Nigeria Rural	162.0 ± 7.0	158 ± 8.0	Adediran et al., 2013
Chinese Ancestry	53	Singapore	170 ± 1.0	160 ± 1.0	Lam et al., 2013
Polish	90	Poland	182.4 ± 6.7	170.3 ± 1.2	Lutoslawska et al., 2014
Marida	138	Mexico	NR	147.96 ± 4.51	Datta Banik and Dickinson., 2015
Bengladeshi	260	Bengladesh	160.6 ± 6.2	148.8 ± 5.8	Sultana et al. 2015
Chinese, Malay,Indian	415	Singapore	170.0 ± 0.07	158 ± 6.0	Lam et al., 2015
Maasai	96	Kenya	172.55 ± 5.97	160.26 ± 5.54	Galvin et al., 2015
Polish	674	Poland	176.22 ± 7.15	162.17 ± 6.60	Agniszka and Jerry, 2015
Indonesian	554	Indonesia	167.6 ± 6.85	155.5 ± 6.65	Lindarto et al., 2016
South Aisan	3772	India and Pakistan	166.0 ± 7.0	152 ± 6.0	Patel et al., 2017
Limboo	496	Sikkim India	159.43 ± 5.89	148.81 ± 5.11	Present Study

Table 4.2: Comparative table showing mean height of Indian populations with Limboo individuals

Population	Sample size	State of India	Male	Female	Reference
Mumbai	40071	Maharastra	161 ± 6.1	148.0 ± 6.2	Shukla et al., 2002
Jarawas	13	Andaman	152.27 ± 3.74	142.65 ± 3.29	Sahani, 2004
Bathudi	183	Odisha	159.4 ± 6.4	NR	Bose and Chakrabarty,2005
Oraon	200	West Bengal	158 ± 6.9	144.0 ± 6.1	Mittal and Srivastava. 2006
Kora-Mudi	250	West Bengal	158.9 ± 6.2	147.7 ± 5.6	Bose et al., 2006d
Santal	213	West Bengal	160.5 ± 6.4	149.8 ± 5.9	Bose et al., 2006a
Santal	168	West Bengal	160.9 ± 6.6	150.5 ± 6.0	Mukhopadhyay, 2006
Bhil	401	Madhyapradesh	161.4 ± 5.5	NR	Adak et al., 2006
Gond	9.4	Madhyapradesh	162.3 ± 5.6	NR	Adak et al., 2006
Bengalee	171	West Bengal	NR	152.8 ± 5.1	Ghosh and Bandyopadhyay., 2006
Dalit women	220	Andhra Pradesh	NR	150.0 ± 5.0	Schmid et al.,2006
Dhanka	360	Rajasthan	168.5 ± 6.7	154.4 ± 6.2	Bhardwaj and Kapoor, 2007
Paraja	50	Odisha	160.1 ± 5.8	NR	Chakrabarty et al.,2008
Dhimal	159	West Bengal	163.34 ± 0.49	152.42 ± 0.54	Banik et al.,2009
Mech	141	West Bengal	164.93 ± 0.51	152.74 ± 0.48	Banik at al.,2009
Brahmin	60	Uttrakhand	NR	152.9 ± 5.6	Gautam and Thakur, 2009
Rajput	150	Uttrakhand	NR	154 ± 5.3	Gautam and Thakur, 2009
Arya	52	Uttrakhand	NR	152.4 ± 4.9	Gautam and Thakur, 2009

Continuation of Table 4.2

Population	Sample size	State of India	Male	Female	Reference
Thakur	100	Madhya Pradesh	NR	154.8 ± 5.2	Gautam and Thakur, 2009
Nicobarese	259	Nicobar Islands	161.2 ± 6.1	150.2 ± 5.8	Sahani et al., 2010
South Indian	436	South India	167.7	153.7	Rao et al., 2012
Rajbanshi	620	West Bengal	162.1 ± 5.7	150 ± 5.4	Mondal, 2012 (thesis)
NNMB	21918	10 State	163.7 ± 6.65	151.0 ± 6.07	NNMB III Repeat Rural Servey, 2012
Rural	2616	India	NR	150.8 ± 0.12	Mohan et al., 2016
Urban poor	2008	India	NR	151.5 ± 013	Mohan et al., 2016
Urban middle class	2229	India	NR	153.8 ± 0.18	Mohan et al., 2016
Sabar	111	West Bengal	159.9 ± 5.9	149.0 ± 5.0	Ghosh et al. 2018
Limboo	496	Sikkim	159.43 ± 5.89	148.81 ± 5.11	Present Study

Table 4.3: Comparative table showing mean height of Northeast Indian populations with Limboo individuals

Population	Sample size	States of India	Male	Female	Reference
Pnars	50	Meghalaya	157.60 ± 5.69	NR	Khongsdier, 2001
Miris	50	Assam	159.3 ± 5.8	NR	Khongsdier, 2001
Kaibarta	100	Assam	160.0 ± 6.5	NR	Khongsdier, 2001
Lalung	49	Assam	160.1 ± 6.4	NR	Khongsdier, 2001
Mech	50	Assam	160.34 ± 4.43	NR	Khongsdier, 2001
Rajbanshi	50	Assam	161.39 ± 5.93	NR	Khongsdier, 2001
Ahom	100	Assam	162 ± 5.6	NR	Khongsdier, 2001
Kochs	100	Assam	162.6 ± 6.2	NR	Khongsdier, 2001
Kalitas	100	Assam	163.1 ± 5.7	NR	Khongsdier, 2001
Brahmin	100	Assam	163.41± 6.00	NR	Khongsdier, 2001
War Khasi	438	Meghalaya	157.64 ± 4.71	NR	Khongsdier, 2002
DibongiyaDeori	98	Assam	164.2 ± 6.4	NR	Gogoi and Sengupta, 2002
Tangkhul Naga	257	Manipur	162.0 ± 5.94	151.3 ± 5.50	Mungreipy et al. 2011
Hmars	389	Mizoram	159.92 ± 5.46	150.31 ± 5.42	Robert Varte et al., 2014
Hmars	48	Meghalaya	164.41 ± 4.9	153.08 ± 5.65	Robert Varte et al., 2014
Rengma-Naga	422	Assam	152.15 ± 8.21	156.08 ± 8.30	Rengma et al., 2015
Karbi (19-29 yrs)	300	Assam	NR	152.52	Gosswami & Bhattacharya, 2015
Karbi (32-39 yrs)	300	Assam	NR	152.58	Gosswami & Bhattacharya, 2015
Karbi (40-49 yrs)	300	Assam	NR	152.52	Gosswami & Bhattacharya, 2015
Karbi	625	Assam	160.75 ± 6.68	150.15 ± 5.12	Mondal et al., 2016
Nyishi	543	Arunachal Pradesh	NR	154.73 ± 5.91	Bharali et al., 2017
Limboo	496	Sikkim	159.43 ± 5.89	148.81 ± 5.11	Present Study

In India, the National Nutrition Monitoring Bureau (NNMB, 2012) conducted the study among the rural populations of 10 states of India and the given mean BMI for India was lower compared to the values of the present study (NNMB, 2012). As depicted in Table 4.5, the mean BMI reported for the different Indian tribes like Bhil, Gond, Khond, Bhuiya, Munda, Bathudi, Savar, Paraja, and Ho from Indian states of Madhya Pradesh, Odisha, and Bihar were comparatively lower than observed value of males and females of the present study. The relatively lower mean BMI was reported among Santal, Kora, Oraon of West Bengal, Santal, Bhumij, Bathudi, Dhodia, Kukna, Chaudhari of Odisha which ranged from 17.6 $kg/m^2 \pm 2.9$ to 20.9 $kg/m^2 \pm 3.1$ (Kshatriya and Acharya, 2016a). Recently reported mean BMI of the inhabitants of Andaman and Nicobar Islands including native people were lower compared to the present study. Similarly, earlier reported mean values of BMI of male and female Jarawas of Andaman were comparatively lower (Sahani, 2004; Sahani et al., 2018). Other male population observed with comparatively lower mean BMI were Santals, Lodha, Dhimals, Mech, Kora-Mudi, Oraon, and Savar of West Bengal (see Table 4.5). Among them, Dhimals, Mech, and Oroan population are situated in Darjeeling and Jalpaiguri districts of West Bengal. The mean BMI of male populations of northeast India such as Rajbanshi, Ahom, Tangkhul Naga, Koch, Kalita, Brahmins, Dibongiya Deori, Hmar, Lalung, Kaibarta, Mech, War Khasi and Pnars were lower than the present study. Similar, low mean values were reported for females of Tankkhul Naga, Karbi, Hmar, Nyishi and Rengma-Naga recently.

The comparatively higher mean BMI than the male Limboo individuals of the present study were observed among Hmar of Shillong, Rengma-Naga of Assam, and Nicobarese of Nicobar Islands. The mean BMI of Nicobarese, urban poor and urban middle-class females (Mohan et al., 2016) were observed high compared to the present study. The locations of the study by Mohan et al. (2016) were Jaipur, Kolkata, Kochi, Pondicherry, Jammu, Chandigarh, Bikaner, Ahmadabad, Nagpur, Belgaum, Madurai, Dibrugarh and Lucknow. High mean BMI was also reported among south Indian female (Rao et al., 2012). The mean BMI value reported for most of the populations of Northeast, India was below the mean BMI observed for Limboo adults of the present study (see Table 4.6). Exception were the people dwelling in Indian cities.

Comparisons of Non-Indian mean BMI in the present study was similar to BMI trend given by NCD-RisC (2016). The regions like South Asia, East and South East Asia, and sub-Sahara Africa were spotted with relatively lower BMI according to NCDRisC. On the other side, region observed with high mean BMI was Micronesia and Polynesia for both men and women, and for women of the Middle East, and the Caribbean who were observed with world highest mean BMI ranging above 30 kg/m^2 (NCD-RisC, 2016). The observed mean BMI of the present study was quite near to the mean value observed for Nepal and higher than that of Bangladesh and Afghanistan. However, other countries of South Asia such as Bhutan and Pakistan were observed with high mean BMI compared to the present study (NCD-RisC, 2016). The Indian state of Sikkim where the present study was conducted is near to Bangladesh and surrounded by above mention countries like Nepal and Bhutan. The rural and tribal population of India was observed with lower mean BMI. The high mean BMI was mostly observed among urban dwellers in India. In India generally observed high mean BMI among tribes of Northeast India and low mean BMI among the tribes of central India could be due to their adaptation to the environment. However, the possible influence of socio-economic factors and the living condition cannot be rule out.

Table 4.4: Comparative table showing mean BMI of Non-Indian population with Limboo individuals

Population	Sample size	Country	Male	Female	Reference
American	268	USA	27.7 ± 4.7	26.6 ± 6.2	Janssen et al., 2000
Caucasian	2982	Western Europe	24.0 ± 2.6	22.5 ± 3.3	Kyle et al., 2003
Thi	98	Thiland	22.3 ± 2.7	23.8 ± 4.0	Pongchaiyakul et al., 2005
British (White and Non-white)	9963	UK	24.8 ± 3.3	24.0 ± 3.9	Rosell et al., 2005
Orang Asli	47	Malaysia	20.5 ± 2.90	21.0 ± 4.77	Yusof et al., 2007
Mongolian	200	Mongolia	24.4 ± 0.4	24.9 ± 4.4	Dugee et al., 2009
European	124	New Zealand	25.8 ± 3.4	24·8 ± 4·5	Rush et al., 2009
Asian Indian	117	New Zealand	26.1 ± 4.1	26·3 ± 4·6	Rush et al., 2009
Maori	109	New Zealand	30.4 ± 5.3	30·0 ± 5·9	Rush et al., 2009
Pacific	104	New Zealand	31.3 ± 4.4	33·1 ± 6·3	Rush et al., 2009
Inuvialuit	48	Canada	28.6 ± 7.7	30.5 ± 8.8	Hopping et al., 2010
NHPI	44	Pacific Island	34.0 ± 6.4	33.7 ± 8.8	Moy et al., 2010
Mexican American	165	Texas	27.3 ± 7.2	25.4 ± 8.2	Peltez et al., 2010
European	200	New Zealand	28.8 ± 4.9	31.9 ± 6.4	Taylor et al., 2010
Maori	252	New Zealand	32.7 ± 6.2	33.3 ± 7.4	Taylor et al., 2010
Asian	58	USA	23.2 ± 2.6	21.7 ± 2.5	Hull et al., 2011
Caucasian	202	USA	25.6 ± 3.9	24.6 ± 5.7	Hull et al., 2011
African Amreican	73	USA	26.7 ± 5.1	28.5 ± 5.7	Hull et al., 2011
Hispanic	147	USA	27.5 ± 4.6	28.8 ± 5.7	Hull et al., 2011
Colombo	1767	Sri Lanka	21.1 ± 3.7	22.8 ± 4.5	Katulanda et al., 2011
Korean (> 60 yrs)	711	Korea	23.7 ± 3.0	21.4 ± 3.3	Kim et al., 2011
Korean (18-39 yrs)	771	Korea	24.1 ± 3.5	23.8 ± 2.9	Kim et al., 2011

Continuation of Table 4.4

Population	Sample size	Country	Male	Female	Reference
Moroccan	192	Netherland	25.60 ± 0.4	28.9 ± 0.3	Ujcic-Voortman et al., 2011
Turkish	196	Netherland	26.20 ± 0.3	25.2 ± 0.3	Ujcic-Voortman et al., 2011
Dutch	214	Netherland	25.0 ± 0.3	28.1 ± 0.6	Ujcic-Voortman et al., 2011
Abuja	173	Nigeria Rural	23.17 ± 2.93	23.02 ± 3.17	Adediran et al., 2013
Abuja	163	Nigeria Urban	27.70 ± 3.19	27.83 ± 5.92	Adediran et al., 2013
Inuit	70	Greenland	25.5 (23.5 - 29.1)	23.9 (22.0 - 30.0)	Andersen et al., 2013
Chinese Ancestry	53	Singapore	30.1 ± 6.2	26.0 ± 6.0	Lam et al., 2013
Polish	90	Poland	23.6 ± 2.4	21.1 ± 1.6	Lutoslawska et al., 2014
Polish	674	Poland	27.60 ± 4.39	26.63 ± 5.05	Agniszka and Jerry, 2015
Maasai	96	Kenya	19.02 ± 3.06	18.58 ± 2.83	Galvin et al., 2015
Chinese, Malay,Indian	415	Singapore	24.1 ± 4.1	22.9 ± 4.2	Lam et al., 2015
Bengladeshi	260	Bengladesh	20.49 ± 3.29	21.27 ± 3.89	Sultana et al. 2015
Indonesian	554	Indonesia	27.7 ± 3.52	28.1 ± 3.63	Lindarto et al., 2016
African Amreican	86	USA	29.21 ± 6.96	31.11 ± 6.57	Wright et al., 2016
South Aisan	3772	India and Pakistan	24.29 ± 4.96	26.49 ± 5.80	Patel et al.,2017
Limboo	496	Sikkim, India	22.48 ± 3.17	23.21 ± 3.83	Present Study

Table 4.5: Comparative table showing mean BMI of Indian populations with Limboo individuals

Population	Sample size	State of India	Male	Female	Reference
Mumbai	40071	Maharastra	21.8 ± 3.8	22.7 ± 4.7	Shukla et al., 2002
Jarawas	13	Andaman	19.24 ± 1.74	20.54 ± 1.93	Sahani, 2004
Bathudi	183	Odisha	18.4 ± 1.9	17.9 ± 2.5	Bose and Chakrabarty,2005
Bhil	401	Madhyapradesh	18.3 ± 1.9	NR	Adak et al., 2006
Gond	9.4	Madhyapradesh	18.6 ± 1.7	NR	Adak et al., 2006
Kora-mudi	250	West Bengal	18.7 ± 1.8	18.3 ± 2.1	Bose et al., 2006d
Oraon	200	West Bengal	18.8 ± 2	18.7 ± 2.4	Mittal and Srivastava 2006
Santal	168	West Bengal	20.5 ± 2.6	19.5 ± 2.5	Mukhopadhyay, 2006
Bengalee	171	West Bengal	NR	20.9 ± 4.2	Ghosh and Bandyopadhyay., 2006
Dalit Women	220	Andhra Pradesh	NR	18.2 ± 2.2	Schmid et al.,2006
Paraja	50	Odisha	17.3 ± 1.8	NR	Chakrabarty et al.,2008
Dhimal	159	West Bengal	19.54 ± 0.16	19.13 ± 0.21	Banik et al.,2009
Mech	141	West Bengal	21.82 ± 0.21	21.93 ± 0.30	Banik at al.,2009
Brahmin	60	Uttrakhand	NR	18.6 ± 2.5	Gautam and Thakur, 2009
Rajput	150	Uttrakhand	NR	19.4 ± 3.2	Gautam and Thakur, 2009
Arya	52	Uttrakhand	NR	19.8 ± 3.8	Gautam and Thakur, 2009
Thakur	100	Madhya Pradesh	NR	19.9 ± 5.3	Gautam and Thakur, 2009
Nicobarese adults	259	Nicobar Islands	23.3 ± 2.9	23.5 ± 4.1	Sahani et al., 2010
South Indian	436	South India	24.8	25.4	Rao et al., 2012
Rajbanshi	620	West Bengal	20.3 ± 2.3	20.5 ± 3.1	Mondal 2012 (thesis)
NNMB	21918	10 State	20.3 ± 3.47	20.7 ± 4.09	NNMB 2012
Rural	2616	India	NR	22.2 ± 0.1	Mohan et al., 2016
Urban poor	2008	India	NR	24.6 ± 0.1	Mohan et al., 2016
Urban Middle Class	2229	India	NR	26.6 ± 0.1	Mohan et al., 2016
Sabar	111	West Bengal	19.4 ± 2.6	18.1 ± 2.3	Ghosh et al. 2018
Limboo	496	Sikkim, India	22.48 ± 3.17	23.21 ± 3.83	Present Study

Table 4.6: Comparative table showing mean BMI of Northeast Indian populations with Limboo individuals

Population	Sample size	States of India	Male	Female	Reference
Kaibarta	100	Assam	18.3 ± 2.0	NR	Khongsdier, 2001
Ahom	100	Assam	18.7 ± 1.5	NR	Khongsdier, 2001
Brahmins	100	Assam	18.86 ± 2.07	NR	Khongsdier, 2001
Brahmins	100	Assam	18.86 ± 2.07	NR	Khongsdier, 2001
Kalitas	100	Assam	18.9 ± 2.2	NR	Khongsdier, 2001
Lalungs	49	Assam	19.2 ± 1.4	NR	Khongsdier, 2001
Kochs	100	Assam	19.2 ± 2.5	NR	Khongsdier,2001
Miris	50	Assam	19.6 ± 5.1	NR	Khongsdier,2001
Rajbanshi	50	Assam	19.62 ± 2.63	NR	Khongsdier, 2001
Pnars	50	Meghalaya	19.85 ± 1.46	NR	Khongsdier, 2001
Mechs	50	Assam	20.49 ± 1.13	NR	Khongsdier, 2001
Dibongiya Deori	98	Assam	20 ± 2.1	NR	Gogoi and Sengupta,2002
War Khasi	438	Meghalaya	20.06 ± 2.65	NR	Khongsdier, 2002
Bathudi	226	Odisha	NR	17.9 ± 2.5	Bose and chakraborty, 2005
Tangkhul Naga	257	Manipur	20.9 ± 2.39	21.23 ± 2.78	Mungreipy et al. 2011
Hmars	389	Mizoram	20.97 ± 2.26	20.66 ± 2.56	Robert Varte et al., 2014
Hmars	48	Meghalaya	24.04 ± 2.99	23.18 ± 3.22	Robert Varte et al., 2014
Rengma-Naga	422	Assam	22.66 ± 2.07	22.30 ± 2.43	Rengma et al., 2015
Karbi (19-29 yrs)	300	Assam	NR	21.53	Gosswami & Bhattacharya, 2015
Karbi (32-39 yrs)	300	Assam	NR	22.18	Gosswami & Bhattacharya, 2015
Karbi (40-49 yrs)	300	Assam	NR	23.39	Gosswami & Bhattacharya, 2015
Karbi	625	Assam	22.33 ± 3.37	22.03 ± 3.31	Mondal et al.,2016
Nyishi	543	Arunachal Pradesh	NR	21.30 ± 2.44	Bharali et al.,2017
Limboo	496	Sikkim	22.48 ± 3.17	23.21 ± 3.83	Present Study

The mean MUAC values obtained for male and female Limboo individuals of the present study was 26.18 cm ± 2.46 and 24.70 cm ± 2.77, respectively. The overall mean MUAC for individuals of the present study was 25.44 cm ± 2.71. The mean value observed among males of the present study was higher compared to the females. Further, the values are above the cut-offs for undernutrition. Influence of mother's low MUAC was shown on low birth weight babies and early infancy (Assefa et al., 2012; Wilkinson et al., 2015). Today MUAC is frequently used among patients in hospitals (e.g., Roy et al., 2013; Benítez Brito et al., 2016) such as a study from Spain observed mean MUAC among hospitalised men (27.47 cm ± 4.24) and women (26.26 cm ± 4.72) were higher compared to the present study. Another study from Bangladesh reported higher mean MUAC (25.9 cm ± 2.9) among males and lower (25.3 ± 3.3) among females compared to the present study (Sultana et al., 2015). The mean MUAC obtained in a comparative study conducted among non-pregnant women of the rural areas of four third world countries such as Democratic Republic of Congo (25.7 cm ± 2.3), India (24.0 cm ± 3.1), and Pakistan (23.2 cm ± 2.7) were observed lower except for Guatemala (27.2 cm ± 3.2) then that of the present study (Hambidge et al., 2018). The observed mean values of BMI and MUAC for Limboo individuals of both sex was above the cut-off points of undernutrition, which suggest the present population is fairly above the risk of underweight and related diseases and infections (Khongsdier, 2002, 2005).

Some early studies have attributed the ethnic difference observed in BMI to CRI (Sitting height to Stature ratio) as among Australian aborigines (Norgan, 1994a, 1995). This effect has been later elucidated among the Inuit and the Maltese women (Charbonneau-Roberts et al., 2005; Galloway et al., 2011; Abou-Hussein et al., 2011; Andersen et al., 2004). A similar comparative study was able to show significantly larger WC and WHR among Australian aborigines compared to European. In contrast, BMI and HC were significantly lower among the Australian Aborigines (Piers et al., 2003). Other factors contributing to the difference in the indicators of adiposity may be the different life style and socio-economic status. This was attributed to short leg length or high sitting-height-to-stature ratio i.e. CRI. Further, short leg length or high CRI among adults can be considered indices of adverse environmental conditions in early life (Velásquez-Meléndez et al. 2005). In the present study CRI (0.55 ± 0.01 vs. 0.54 ± 0.02) was significantly high among the male Limboo individuals. The values obtained in the present study were higher than that reported among Australian Aborigines (0.48) and closer to the representative values of 0.54 given for Western Pacific regions (WHO, 1995). The typical ratio of European and Indo-Mediterranean descent was 0.52 – 0.53 and African population have lower values from 0.51 – 0.52 (WHO, 1995). Since the observed value of 0.54 ± 0.02 was closer to the range given for European and Indo-Mediterranean descent which suggest no need for BMI correction using CRI in the population of the present study (Abou-Hussein et al., 2011).

Obesity among the Limboo population of the present study was also studied by central obesity indices. The overall mean values of WC, HC, WHtR, WHR, and CI observed for the Limboo individuals of the present study was 81.62 cm ± 9.25, 88.95 cm ± 7.02, 0.53 ± 0.07, 0.92 ± 0.07, 1.27 ± 0.09, respectively. Similarly, observed mean values of WC (80.03 cm ± 7.44 vs. 83.22 cm ± 10.54), HC (87.95 cm ± 5.66 vs. 89.95 cm ± 8.04), WHtR (0.50 ± 0.05 vs. 0.56 ± 0.07), WHR (0.91 ± 0.06 vs. 0.93 ± 0.09), and CI (1.23 ± 0.06 vs. 1.30 ± 0.10) were higher among female compared to male Limboo individuals. Therefore, female Limboo individuals than male individuals were at risk of diseases related to high adiposity. The values were above the given cut-off points in case of WHR and WHtR for both sexes. The mean value of WC was observed below the cut-off points among males and above the cut-off points among females. The observed mean CI was more than the recommended cut-off points among females only. This could be a sign of increasing metabolic syndrome (MetS) among the present population (Ghosh et al., 2004).

Due to ethnic difference in body size, the meaningful comparison of mean values of central obesity among the populations of different regions of the world was not feasible. The comparison of the mean value of central adiposity within a region would be relatively justifiable. As a result, the comparison here is confined to Asian and Indian populations. The observed mean WC (72.5 cm ± 8.26 and 70.2 cm ± 6.86) and HC (88.3 cm ± 5.83 and 88.4 cm ± 6.81) among Orang Asli men and women of Malaysia were lower compared to the present study (Yusof et al., 2007). Further, reported mean WC of obese Filipino adults was higher compared to the present study, however, lower among normal weight Filipino. The reported WHR mean values were lower compared to present study among obese and normal weight individuals (Tanchoco et al., 2003). Furthermore, reported mean WC was higher among Indonesian male (95.9 cm ± 9.77) and female (90.1 cm ± 9.42) individuals compared to the present study (Lindarto et al., 2016).

The observed mean BMI, WC, WHR and WHtR was 22.76 kg/m^2 ± 2.51, 81.00 cm ± 4.61, 0.79 ± 0.06, and 0.53 ± 0.03, respectively among the women of Tripura which were found associated with cardiometabolic risks (Sen et al., 2017). The population of the present study may be at risk, as the observed mean values of Limboo women were higher than women of Tripura (Bajaj et al., 2014; Pinter et al., 2017). Among the observed mean WC of rural (74.5 cm ± 0.23), urban (83.4 cm ± 0.26), and urban middle class (86.1 cm ± 0.23) and HC of rural (90.4 cm ± 0.21), urban (94.5 cm ± 0.23), and urban middle class (94.4 cm ± 0.3), only rural area values were observed lower compared to the Limboo adults of the present study (Mohan et al., 2016). The mean WC observed among the Bengalee rural adult (male: 81.27 cm ± 8.52; female: 81.80 cm ± 11.05) and Marwari adult (male: 87.1 cm ± 12.5; female: 82.1 cm ± 10.8) males of West Bengal was higher compared to the males of the present study. The observed mean WC among females of these populations of West Bengal was lower compared to their male counterparts and the females of the present study. The mean HC values of Marwari (male: 97.9 cm ± 8.7; female: 103.4 cm ± 11.3) and rural Bengalee (male: 88.30 cm ± 6.52; female: 90.27 cm ± 9.86) populations were higher compared to the Limboo male and female of the present study (Das and Bose, 2006; Chanak and Bose, 2018). The mean WHR was high among the male (0.92 ± 0.06) and lower among female (0.91 ± 0.06) individuals of rural West Bengal compared to present study. The observed mean WHtR (male: 0.49 ± 0.05; female: 0.54 ± 0.07) was lower and CI (male: 1.28 ± 0.09; female: 1.31 ± 0.10) was higher among the rural Bengalee than the Limboo male and female of the present study (Chanak and Bose, 2018). In contrast, the WHR (male: 0.89 ± 0.08; female: 0.79 ± 0.06) and CI (male: 1.23 ± 0.11; female 1.17 ± 0.08) of Marwari of Kolkata were lower in comparison with the Limboo of the present study (Das and Bose, 2006).

Similarly, lower mean were reported by Mukhopadhyay (2010), NNMB (2012), Mungreiphy et al. (2012), Varte et al. (2014), Mondal et al. (2016) and Ghosh et al. (2018) from rural, urban, tribal and northeast Indian populations. Among rural Indian men, the mean WC and HC was 77.4 cm ± 10.76 and 85.1 cm ± 7.76, and among women, WC and HC was 72.00 cm ± 11.20 and 86.00 cm ± 8.87, respectively as reported by NNMB (2012). The observed mean values of WC (73.35 cm ± 8.13

and 70.62 cm ± 8.75) and HC (82.13 cm ± 6.51 and 81.49 cm ± 6.03) of Santal (Mukhopadhyay, 2010) and the mean of WC (75.2 cm ± 6.2 and 68.9 cm ± 9.3) and HC (84.6 cm ± 9.1 and 83.1 cm ± 9.2) of Sabars (Ghosh et al., 2018) male and females were observed lower than the present study. The mean values of WC (78.5 cm ± 9.29 vs. 69.92 cm ± 7.28), HC (90.71 cm ± 5.45 vs. 89.66 cm ± 7.21), WHR (0.86 ± 0.06 vs. 0.78 ± 0.04), and WHtR (0.48 ± 0.06 vs. 0.47 ± 0.04) were found lower among female Hmar individuals than their male counterparts oppose to the present study. The observed mean values among Hmars were lower than the corresponding values observed among the Limboos of the present study (Varte et al., 2014). A comparative study has observed low WC, HC, WHtR, and CI among males and females of Delhi, Manipur, and Kerala compared to the corresponding values of the present study. In the same study, WHR were observed high compared to the present study with exception of Kerala (Mungreiphy et al., 2012). The mean value of WC, HC, WHR, and WHtR observed among the male and female Karbi individuals were lower than the present study (Mondal et al., 2016). The mean value of WC was lower among male and female of rural Chandigarh, Jharkhand, Maharashtra, and Tamil Nadu (Pradeepa et al., 2015). So in India, more affluent people are at risk of central adiposity related risks compared to their tribal and rural counterpart. However, the population of the present study is from the rural area of Sikkim and the observed mean values are well above the cut-off points in indices like WHR, WHtR, WC (females), and CI (females).

Skinfolds were popularly used to assess fat patterns and fat distribution in population studies. The sex specific mean values of TSF (6.81 mm ± 2.95 vs. 10.99 mm ± 4.07), BSF (3.97 mm ± 1.56 vs. 5.80 mm ± 2.65), SSF (10.57 mm ± 4.42 vs. 12.18 mm ± 4.49) and SISF (7.76 mm ± 3.63 vs. 10.53 mm ± 4.56) were significantly

($p<0.05$) higher among females in the present study. The figures suggest increased truncal subcutaneous adiposity than peripheral adiposity which was observed high among female Limboo individuals. The studies on subcutaneous adiposity and subcutaneous body fat distribution among European White adult and Asian adult have shown the ethnic difference in susceptibility to diabetes and body fat distribution (Bose and Mascie-Taylor, 1995, 2001). The observed overall mean of TSF, BSF, SSF and SISF were 8.90 mm ± 4.12, 4.89 mm ± 2.36, 11.38 mm ± 4.53, and 9.14 mm ± 4.35 respectively.

The Orang Asli population of Malaysia were observed with higher mean BSF (male: 8.27 mm ± 5.04; female: 13.1 mm ± 7.14), TSF (male: 8.31 mm ± 3.89; female: 13.5 mm ± 5.19), SSF (male: 11.2 mm ± 4.19; female: 14.5 mm ± 6.47), and SISF (male: 8.63 mm ± 3.13; female: 11.4 mm ± 5.42) compared to the present study (Yusof et al. 2007). However, excluding BSF, the difference was not big. The observed mean TSF (male: 13.85 mm ± 6.90; female: 21.41 mm ± 7.41) and SSF (male: 20.66 mm ± 9.01; female: 23.60 mm ± 7.92) measured among residents of South Asian cities such as Chennai, Delhi, and Karachi were higher than the present study (Patel et al. 2017). Similarly, the reported mean BSF (4.48 mm ± 2.42), TSF (7.23 mm ± 3.60), SSF (13.83 mm ± 7.67), SISF (13.29 mm ± 8.86) of male slum dwellers (Chakraborty et al. 2009c), TSF (male: 14.0 mm ± 5.8; female: 22.3 mm ± 5.9), BSF (male: 9.2 mm ± 4.0; female: 14.2 mm ± 3.7), and SSF (male: 20.7 mm ± 9.2; female 36.2 mm ± 11.0) of young adult Bengalee population (Bhadra et a. 2002), and TSF (male:20.4 mm ± 6.7; female: 25.7 mm ± 6.3) and BSF (male: 16.7 mm ± 6.2; female: 18.8 mm ± 5.6) of the Marwaris of Kolkata, West Bengal India (Das and Bose 2006) were high compared to the present study. The study among Sabar and Santal of West Bengal observe lower mean value of skinfold viz. TSF, BSF, SSF, and

SISF than the Limboos of the present study (Mukhopadhyay, 2010; Ghosh et al. 2018). An earlier study among Bethudi men of West Bengal observed lower skinfolds values than the present study (Bose et al. 2006a). Comparatively fewer studies have reported lower mean values of skinfolds among Indian populations. The truncal skinfolds values were higher than the peripheral skinfolds values in the studies cited above which indicates the increased fat deposition in visceral area.

The skinfolds were utilised to calculate PBF, the mean value of which was 12.76% ± 5.09 for male and 24.20% ± 4.80 for female Limboo individuals of the present study. PBF rather than BMI is thought to responsible for predisposing individuals to total and cardiovascular mortality. The study by Hull et al. (2011) reported high mean values of PBF among Caucasian (male: 19.2% ± 8.9; female: 30.0% ± 10.8), African American (male: 19.5% ± 9.3; female: 37.1% ± 8.8), Hispanic (male: 23.9% ± 8.6; female: 39.1% ± 7.3) and Asian (male: 18.4% ± 6.4; female: 29.3% ± 7.1) compared to Limboo individuals of the present study (Hull et al., 2011). The mean PBF value of Caucasian (male: 19.8% ± 5.4; females: 28.7% ± 6.4) and Mexican American (male: 27.1% ± 9.2; female: 35.6% ± 11.5) were also higher than the present study (Kyle et al., 2003; Peltz et al., 2010). Similarly, a study conducted among the European, Moari, Pacific, and Asian Indian were observed with many folds high mean value of PBF compared to the corresponding values in the present study (Rush et al., 2009). These populations may be more vulnerable to CVDs. A study among Koreans (male: 21.6% ± 5.7; female: 34.2% ± 5.6) and Buryat of China (male: 19.95% ± 7.31; female: 33.12% ± 5.85) observed high mean PBF compared to the Limboos of the present study (Kim et al., 2011; Zhao et al., 2013). However, mean PBF (male: 15.9% ± 5.78; female: 19.8% ± 5.7) of Orang Asli were observed lower compared to the present study (Yusof et al., 2007).

The mean PBF (BIA) observed was high among the individual of Chennai, Delhi, and Karachi (Patel et al., 2017). The reported mean PBF of the male slum dwellers (Chakraborty et al., 2009c), and PBF of the Marwaris of Kolkata (Das and Bose, 2006) were high compared to the present study. Further, the high mean of PBF was observed among the urban adults of Hyderabad, India (Rao et al., 2012). Another recent study conducted among the different tribes of West Bengal and Odisha reported higher mean PBF than that of the present study such as Kora, Oraon, Bhumij, Bathudi, Dhodia, Kukna, and Chaudhari (Kshatriya and Acharya, 2016). However, same populations were observed with lower BMI than the present study. These tribes of West Bengal and Odisha may be more at risk of adiposity related diseases compared to the present study. The reported mean PBF was high among male and was lower among females individuals of Delhi and Manipur compared to the Limboos of the present study (Mungreiphy et al., 2012). Recently a study among the adult Sabars of West Bengal reported lower PBF compared to the present study, however, the difference was not as wide as in the case of non-Indian studies (Ghosh et al., 2018). A study by Bose et al. (2006a) among Bathudi men also observed lower PBF than the present study.

The body composition indices such as FMI and FFMI are considered as the better indicator of adiposity and undernutrition respectively (Peltz et al., 2010; Hull et al., 2011). These indices are considered as better than BMI and PBF. However, few studies have utilised these indices to assess nutritional status of population and individuals. The derived FM (12.77 kg ± 4.60 vs.7.63 kg ± 4.04), and FMI (5.76 kg/m^2 ± 1.99 vs.3.00 kg/m^2 ± 1.57) were observed high among female Limboo individuals compared to male individuals. In contrast, FFM (9.55 kg ± 6.55 vs. 4.32

kg ± 1.00) and FFMI (3.78 kg/m^2 ± 2.66 vs. 1.96 kg/m^2 ± 0.48) were observed high among the male Limboo individuals (Table 3.3).

The observed mean values of FM, FFM, FMI, and FFMI of Caucasian males and females were higher than the present study (Kyle et al., 2003). Mexican American was also reported with high mean FM, FFM, and FMI compared to the present study (Peltz et al., 2010). The study by Hull et al. (2011) reported mean values of FM, FFM, FMI, and FFMI of Caucasian, African American, Hispanic and Asian male and female adults. A study conducted among European, Maori, Pacific, and Asian Indian were observed with many folds high mean value of FM, and FFM compared to the corresponding values in the present study (Rush et al., 2009).

A study among Koreans observed high mean values of FM (male: 15.5 kg ± 5.6; female: 19.9 kg ± 5.3), FFM (male: 54.7 kg ± 6.0; female: 37.5 kg ± 3.6), FMI (male: 5.4 kg/m^2 ± 1.9; female: 8.2 kg/m^2 ± 2.1) and FFMI (male: 19.1 kg/m^2 ± 1.7; female: 15.5 kg/m^2 ± 1.2) compared to Limboo males and females of present study (Kim et al., 2011). Similarly, the Orang Asli population of Malaysia were observed with higher mean FFM (male: 4.37 kg ± 5.61; female: 36.7 kg ± 7.45) compared to the present study (Yusof et al., 2007). However, mean FM (male: 8.64 kg ± 4.60; female: 9.29 kg ± 3.78) of Orang Asli were observed lower compared to the present study (Yusof et al., 2007).

The observed mean values of the FM, FFM, FMI and FFMI were also high among the Marwaris compared to the present study (Das and Bose, 2006). High mean FMI and FFMI were observed among the urban adults of Hyderabad, India (Rao et al., 2012). Among tribal and non-tribal adults of Manipur, the observed value of FFM and FFMI were higher than the corresponding values in the present study. However, FMI observed among tribal and non-tribal population were lower compared to the present study (Datta et al., 2013). Bathudi men of West Bengal were also reported with lower FM, FFM, FMI and FFMI than the present study (Bose et al., 2006a). The above cited populations of America, Europe, Asia and India seem better than the Limboo individuals of the present study in two compartments of body composition.

Individuals not classified as overweight by BMI, with lower lean mass or FFM are just as unhealthy as those who are considered obese. Studies have shown rising adiposity among the Indian tribes which comes with cardiovascular diseases and other risks, at the time undernutrition is still prevalent (Das and Bose, 2015; Kshatriya and Acharya, 2016). In this regard, the FFM and FFMI could be very useful along with upper arm composition. However, few studies from India have undertaken such assessment among adult Indian tribes (Jaswant and Nitish, 2014).

The mean TUA (55.02 cm^2 ± 10.47 vs. 49.17 cm^2 ± 11.15), UMA (52.16 cm^2 ± 9.54 vs. 44.85 cm^2 ± 9.77), was high among male Limboo individuals (Table 3.3). On the other hand indices and components like UFA (4.32 cm^2 ± 1.94 vs. 2.86 cm^2 ± 1.43), AFI (8.57 ± 2.60 vs. 5.06 ± 1.88) was high among female Limboo individuals compared to male individuals. Similarly high TUA, UMA and low UFA, AFI were observed among the Rajbanshi adults of North Bengal (Mondal, 2012). However, mean values of TUA and UMA were high among Limboo adults of the present study and UFA and AFI were lower compared to Rajbanshi of North Bengal (Mondal, 2012). This also suggests the less fat among hill dwellers than the foothill and flatland dwellers. The paucity of literature relating to upper arm composition among Indian and Non-Indian adults limits further discussion.

4.2.3 EFFECT OF AGE ON ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES

The studies from both India and aboard have shown the influence of age on anthropometric and body composition variables (Bose et al., 2006a; Hull et al., 2011; Rao et al., 2012). Some of the studies were conducted among elderly (de Mutsert et al., 2014; Peter et al., 2014; Ablove et al., 2015; López-Ortega and Arroyo, 2016). These changes indicate the underlying changes in body size and composition among the studied population with advancing age. Studies from India have reported such age specific variation on anthropometric variables of tribal (Bose et al., 2006a,b) and non-tribal (Singal and Sidhu, 1983; Kaur and Talwar, 2011) populations. The studies reported were from Punjab and Odisha of India. Until recently no such work has been conducted among the populations of Northeast India (Mondal et al., 2016). The present study is the first to highlight such age related changes in body size and composition using anthropometry among Limboos of Sikkim. Such age associated variation in body size and composition can have implication in the propensity to various NCDs.

The sex specific variation in different anthropometric and body composition variables with age was evident in the study population (Table 3.4 and Table 3.5). Anthropometric variables like height, SH and TSF among male Limboo individuals and height, SH, TSF, BSF and SISF among female Limboo individuals were found declined in later age in the present study. The measurements like NC, WC, and HC were observed increased in 30-49 years age group from 18-29 years and change was not significant in 50-64 years age group. The measurements such as MUAC, BSF, SSF, and SISF among males and weight, MUAC, and SSF among females were observed changing across the age groups with peak in the middle age group. No significant change were observed in arm span, RAL, and LAL among the Limboo individuals of both sexes in the present study. Most of the variables were observed declining during later age in the present study.

Age specific variation on derived anthropometric and body composition indices was evident from Table 3.5. The BMI was significantly ($p<0.001$) high during 30-49 years age group among both male and female Limboo individuals and declined significantly ($p<0.001$) during 50-64 year age was only evident among female individuals. Among the individuals of both sexes indices like BAI, WHtR, WHR, CI, FFM and FFMI showed significant ($p<0.001$) increase during middle age and changes in the later age were non-significant ($p>0.001$). The indices like TUA, UMA, BFMA, FM, and FMI was observed significantly different across age groups of both male and female Limboo individuals. These indices rises until the middle age and then decline among the both sexes. The declined in PBF and UFA was observed during 50-64 years of age. As in the present study increase anthropometric and body composition variables during middle age were shown among individuals of Hyderabad, Santals of West Bengal, and Karbis of Assam (Mukhopadhyay et al., 2010; Rao et al., 2012; Mondal et al., 2016). The morbid individuals of four ethnic groups such as Asians, blacks, Puerto Ricans, and whites supported the hypothesis that body fat is lower in the elderly than in middle-aged persons (Mott et al., 1999).

The linear measurements like height and SH were negatively associated with age as observed by different studies (Bose et al. 2006a; Bisai et al. 2008). The decline in height with age was supported by studies (Kyle et al. 2003; Mukhopadhyay et al. 2010; Kim et al. 2011; Rao et al. 2012). The SH was observed negatively associated with age among Kora-Mudi (Bose et al., 2006d). The decline in height and SH in the present study is also vindicated by linear regression on both sexes. The MUAC was not associated with age in some studies (Bose et al., 2006a). However, observed association was mild positive with age for MUAC, NC, WC, HC, SSF, BMI, BAI, WHtR, WHR, CI, TUA, UMA, BFMA, FM and FMI among the male Limboo individuals of the present study. Similarly, MUAC, NC, WC, HC, TSF, SISF, BMI, BAI, WHtR, WHR, CI, TUA, UMA, BFMA, FFM and FFMI among female Limboo individuals were observed with mild positive association with age in the present study. The indices such as CRI, AFI, and PBF among the female Limboos were negatively correlated with age. Linear regression corroborated these findings. The variation explained by age of these anthropometric and body composition variables were negligible in females. The highest variation explained by age among males was of central adiposity measures like WC (10.5%), WHtR (13.5%), WHR (10.0%), and CI (11.3%).

Unlike, a study on Kora-Mudi, the present study observed a negative association of few adiposity measures with age among women such as TSF, SISF, PBF, and AFI (Bose et al., 2006a). The trend observed among Caucasian, African American, Hispanic and Asian individuals declined in FFMI after certain age among both males and females (Hull et al., 2011). Instead, body composition components like FFM and FFMI was observed positively associated with age among both male and female Limboo individuals of the present study. On the other hand, FM was observed not associated with age among both sexes. Age was positively associated with FMI among males and not associated with females in the present study. In contrast, to present study, among the Bishnupriya Manipuris of Cachar district, Assam the PBF and FM were observed increasing with age, on the other hand the FFM was found decreasing irrespective of sex (Das and Roy, 2010).

The influence of age on the anthropometric, the skinfolds, and the body composition parameters was shown by studies conducted among the tribal men and women of Keonjhar, Odisha, India (Bose et al., 2006a, 2007). Other similar results were reported among the Indian population such as among Kora-Mudis of West Bengal, (Bisai et al., 2008) and adults of Hyderabad (Rao et al., 2012). Studies conducted among elderly observed declining trend in anthropometric, skinfolds and body composition variables and rising undernutrition with age among various populations (Peter et al., 2014; López-Ortega and Arroyo, 2016). However, there are clear exceptions in the present study such as mild correlation of variables with age, few adiposity indices among male and female were negatively associated with age such as height, SH, UFA, and AFI in both sexes. The SSF among males and TSF and SISF skinfolds among females were negatively associated with age in the present study. The reason for different result obtained in the present study than the study conducted among tribes of Odisha and West Bengal may be due to lower prevalence of undernutrition among the present population and increasing adiposity. The second reason could be due to their inhabitation in the different geographical location (Bose et al., 2006a; Bisai et al., 2008).

4.2.4 REGRESSION OF BMI AND HEIGHT ON OTHER ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES

The anthropometric and body composition variables such as height, arm span, RAL, and LAL were not associated with BMI among both sexes. The remaining variables were observed to be associated with BMI. This means the change in any of the variables such as weight, MUAC, NC, HC, SH, TSF, BSF, SSF, SISF, BAI, WHtR, WHR, CI, CRI, TUA, UMA, UFA, AFI, PBF, FM, FFM, FMI, and FFMI will bring change in BMI or vice versa. The observed association is supported by correlation and regression analyses of the present study.

Regression analyses were also conducted to seek the relation between height and other anthropometric and body composition variables. However, height showed non-significant association with skinfolds excluding SISF among female Limboo individuals. In comparison, the linear measurement like armspan, RAL, LAL and SH were best predictors of height among the Limboo individuals. When step-wise multiple regressions were conducted to estimate height from anthropometric measurements the model containing RAL, SH, armspan, WC, weight, and LAL was observed as a best-fit model among the male Limboo individuals of the present study. Similarly, the model containing armspan, SH, LAL, Weight, MUAC, and WC was found as a best-fit model for female Limboo individuals.

Definitely, human height is an important part of nutritional assessment along with its application in prediction and standardisation of physiological parameters such as lung volumes, muscle strength, glomerular filtration, basal metabolic rate and for adjustment of drug dosage in patients (WHO, 1995; Mohanty, 2001; Chhabra, 2008) and identification of decomposed or mutilated body (Singh, 2012). Usually, nutritional assessment of population based on field survey do not include a physically challenged individual who cannot stand erect due to reason like pain, weakness, compression, fractures of vertebrae or paralysis (Yousafzai et al., 2003). However, the inclusion of such subjects for the study or designing special study for such group of population is equally important. The proper nutrition enhances the survival of disabled individuals and their quality of life. Ageing could also lead to height lost among the elderly population which may hinder the accurate measurement of their height (Fatmah, 2009; 2010). Hence, a reliable proxy of height can fill this gap.

4.2.5 PREVALENCE OF UNDERWEIGHT USING BMI AMONG LIMBOO INDIVIDUALS OF THE PRESENT STUDY

According to NCD-RisC (2016) estimation, a significant concentration of underweight was shown in large countries of sub-Saharan Africa and Asia. Estimation was made for the year 1975 and 2014. During 2014 underweight was highest in India followed by China, Indonesia, Bangladesh, Pakistan, Vietnam, Nigeria, Ethiopia, Philippines, Democratic Republic of Congo, and Thailand among men. Similarly, among women, India stands on top followed by China, Bangladesh, Indonesia, Pakistan, Vietnam, and Japan. The prevalence of overall underweight was 7.5% among the individuals of the present study irrespective of sex. The prevalence observed in the present study was about 6 times lower than the underweight estimated for Indian males (46.2%) and females (41.6%) by NCD-RisC (2016). The prevalence reported for various Asian and South Asian countries were high as attested by the reported mean values.

The prevalence of underweight reported among Maasai of Nilotic region of Africa was 51.0 % and 59.0%, respectively for males and females (Galvin et al., 2015). The overall underweight irrespective of sex reported among the Orang Asli of Malaysia was 26.7%. The underweight reported among these ethnic populations were higher compared to the present study. According to Bangladesh Demographic and Health Survey (2011, 2014), the percentage prevalence of underweight (<18.5 kg/m^2) was 18.6% and 26.7% among men and women of Bangladesh, respectively. The reported prevalence of Bangladesh is 3-4 times higher than that of the present study, as the prevalence of combined CED was 6.8% and 8.3 % among Limboo men and women, respectively. However, estimated prevalence is 5.2% and 5.4% for male and female individuals of Bangladesh, much lesser than that of the present study and estimates for India (NCD-RisC, 2016).

In India prevalence of underweight (BMI < 18.5 kg/m^2) given by NNMB was 35% each among adult men and women of rural India (NNMB, 2012). Recently NFHS-4 (2015-2016) reported 20.2% and 22.9% underweight among Indian men and women respectively. However, estimated underweight (men: 46.2%; women: 41.6%) prevalence by NCD-RisC, (2016) is higher than that reported by NNMB (2012) and NFHS-4 (2015-2016). This indicates a high prevalence of underweight among Indian population which is a serious situation according to WHO guidelines. The highest prevalence of underweight men in India was reported from Tripura (39.8%), followed by Rajasthan (39.3%), Chhattisgarh (37.2%) and Gujarat (35.7%) based on NFHS-3 data (Patil and Shinde, 2014). Similarly, prevalence of underweight among women was high in Gujarat (41.8%), followed by Orissa (41.5%), Uttar Pradesh (38.3%) and West Bengal (37.0%) based on NNMB data of 2011-12 (Meshram et al., 2016a). Among young adult female Bengalees of Kolkata, the prevalence of underweight was 30.3% (Ghosh et al., 2009). A cross-sectional study reported higher underweight female (31.7%) compared to male (23.6%) among Bengalee individuals (Bose et al., 2009). The reported underweights among different Indian populations are still many folds higher compared to the present study. According to NFHS-4, which is a latest nationwide survey concluded recently observed the lower prevalence of undernutrition (male: 2.4%; female: 6.4%) in the state of Sikkim among other states and the union territory of India.

The high prevalence of underweight among the marginalised (tribal) population of the country was revealed by various other studies. Such as reported underweight among male and female Sabar was 46.8% and 56.5%, respectively

(Ghosh et al., 2018). Other such population with high prevalence of underweight were Mahali (men: 42.2%; women: 63.6%), Bhumij (men: 52.3%), Birhor (men: 19.4%; women: 33.3%) and Santal (men: 55.0%; women: 52.5%) of West Bengal (Das and Bose, 2010; Das et al., 2013; Ghosh and Bose, 2015; Ghosh and Bose, 2017). In each of the above cited studies, high prevalence of underweight was observed among women than men as in the present study. A review on the nutritional status of tribal populations of India reported the highest prevalence of CED to be in West Bengal (64.2%) and lowest in Sikkim (4.8%) (Bisai and Bose, 2008). East zone of the country including West Bengal, Odisha and Jharkhand, was at the bottom with high degree of undernutrition ever since earlier (Bharati, 2007). A significant review of the prevalence of underweight among tribes of India observed above 60% - 94% prevalence among Kathodi, Damor, Sahariya, Garasia, Bhil, and Mina of Rajasthan. On the contrary, highest prevalence in the state of West Bengal, was 60.9% among Hill Kheria (Das and Bose, 2015).

Compared to the present study, prevalence of underweight reported among other populations of northeast India mainly of Assam such as Brahmins (43%), Kalitas (55%), Jogis (50%), Kaibaratas (61%), Ahom (52%), Kochs (50%), Rajbanshi (42%), Boro-Kacharis (11.22%), Lalungs (34.69%), Mech (6%), Miris (34%), Pnars (14.28%) were high (Khongsdier, 2001). The same author had reported War Khasi with the prevalence of CED I (23.83%) and CED II (11.30%) (Khongsdier, 2002). Other studies observed higher underweight among tribal (20.45%) and non-tribal (7.43%) of Manipur compared to the Limboo individuals of the present study (Datta et al., 2015). A recent study among the Nyishi women of Arunachal Pradesh also reported the higher prevalence of underweight (10.50%) compared to the present study (Bharali et al., 2017). Observed underweight prevalence among Tangkhul Naga male (14.4%) and female (16.2%) were comparatively high (Mungriephy et al., 2011; Mungriephy and Kapoor, 2010). Only prevalence reported for Hmars of Shillong (5.08%) were found closer to the present study excluding Hmars of Mizoram (26.80%). On the closer look the prevalence of CED I, CED II, and CED III were 5.8%, 0.6%, and 0.4%, respectively among Limboo male individuals. Similarly, the prevalence was 6.5%, 1.6%, and 0.2%, respectively among female Limboo individuals. This prevalence of different grades of CED between males and females of the present study was non-significant ($p>0.05$).

Prevailing high underweight prevalence in India can be view in terms of Chronic Energy Deficiency (CED) which affects day to day productivity of an individual. This also predisposed individuals to morbidity and mortality. Apparent high prevalence of CED among the different Indian population implies low productivity, which may hamper productivity more among women. Further, several Indian studies have reported the difference in the prevalence of undernutrition between males and females (Kshatriya and Acharya, 2016b; Das and Bose, 2015). These studies have suggested such difference arises in the nutritional status of Indian adults because of the cultural preference for the male in the Indian society. In this sense females get deprived in every sphere of life including assess to nutrition and health which begin very early in life (Pande et al., 2003; Pandey et al., 2002; Barker et al., 2006). This phenomenon is at least not supported by BMI based CED prevalence in the present study.

4.2.6 PREVALENCE OF UNDERNUTRITION USING MUAC AMONG LIMBOO INDIVIDUALS OF PRESENT STUDY

The prevalence of undernutrition identified by MUAC among Limboo male and female individuals of the present study was 6.45% and 13.91%, respectively. The female Limboo individuals were significantly more undernourished than male Limboo individuals based on MUAC. This is in contrast, to sex specific underweight prevalence reported among Limboo male and female individuals using BMI. The evolving explanation for the difference in the nutritional status between sexes could be the perception of the thin and beautiful body among females in the backdrop of raising adiposity. However, the possibility of other condition cannot be ruled out.

The reported prevalence of undernutrition was 8.7%, 5.5%, 40.6%, and 48.9%, respectively from rural areas of Democratic Republic of Congo, Guatemala, India, and Pakistan (Hambidge et al., 2018). The overall prevalence of undernutrition based on MUAC was 10.18% among the Limboo individuals of the present study irrespective of sex. Compared to the prevalence reported by Hambidge et al. (2018) for non-pregnant rural women of India and Pakistan the prevalence observed in the present study was low. However, the prevalence observed for female Limboo individuals was high compared to the prevalence observed for Democratic Republic of Congo and Guatemala (Hambidge et al., 2018). The higher prevalence of undernutrition (34.8%) was reported compared to present study among male individuals of Bangladesh in a cohort study design to assess the protective effects of MUAC against all cause of mortality (Chen et al., 2014). The MUAC cut-off utilised by above cited studies for both sexes was < 23 cm (Hambidge et al., 2018 and Chen et al., 2014).

Studies from West Bengal, India reported higher prevalence of undernutrition among male slum dweller of Kolkata (84.2%), Bhumij (48.2%), Kora-Mudi women (51.2%), Santal (male: 54.4%; female: 64.7%) and Rajbanshi (40.64%) compared to the present study (Basai and Bose, 2009; Chakraborty et al., 2009b; Das and Bose, 2012; Ghosh and Bose, 2015). Other studies have provided strong evidence of association of MUAC with mortality among elderly population (e.g., Wijnhoven et al., 2010; Selvaraj et al., 2017). In the present study age, wise prevalence of undernutrition based on MUAC was observed higher among females across age group viz. 18-29 years (22.03%), 30-49 years (6.22%), and 50-64 years (31.58%) compared to the males. Among males, comparatively high prevalence of undernutrition based on MUAC was found among 50-64 years adults (10.98%).

4.2.7 UNDERNUTRITION ASSESSED BY THE COMBINATION OF BMI AND MUAC

Further, the combined use of BMI with MUAC can provide a better assessment of CED (Ferro-Luzzi et al., 1992; James et al., 1994; Ferro-Luzzi and James, 1996; Ahmed et al., 1998; Bisai and Bose, 2009). The rate of CED simultaneously identified by MUAC and BMI was 3.4% among male and 7.0% among female Limboo individuals of the present study. On the other hand, individuals identified as normal by BMI and undernourished by MUAC was 15 (3.02%) and 34 (6.85%), males and females, respectively. The prevalence of undernutrition given by the combination of MUAC with BMI was low which is still a warning sign and required monitoring according to WHO guidelines. A recent study among male Bhumijs of West Bengal observed 79.8% undernutrition simultaneously using MUAC and BMI (Ghosh and Bose, 2015).

It is clear from the above discussion that the reported prevalence of underweight by different studies ranges from high prevalence (20% - 39%) to very high prevalence (above 40%) in India (NNMB, 2012; NFHS-4, 2015-2016; NCD-RisC, 2016). This situation according to WHO (1995) classification of CED prevalence is serious to critical in the country. Similarly, the rate of prevalence of underweight observed among the individuals of the present study can be considered as a warning sign and required monitoring as per WHO guidelines (5-9%). This prevalence rate was lower compared to the prevalence reported for India as a whole and the state wise as well. This implies that Sikkim as a state and India as a whole is not free from risks associated with undernutrition.

The factors responsible for CED given by various studies were low SES, education, age and sex (Khongsdier, 2002; Bharati et al., 2007), poor sanitation and infectious diseases (Sahn and Younger, 2009; Chantler et al., 2016 and Janmohamed et al., 2016) and inadequate dietary intake (Ramachandran, 2007; Antony and Laxmaiah, 2008; Mahal and Karan, 2008). Influences of caste and tribal status on the nutritional status were studied among some population of central and south India (Adak et al., 2006; Little et al., 2016). Such a low prevalence of undernutrition in Sikkim can be attributed to the development taking place in the state. The various indicators of human development also show positive trend along with decreasing undernutrition among the people of Sikkim. Sikkim was among the top five Indian states in the Human Development Index (HDI), which went up from 0.582 in 1996 to 0.665 in 2006 (Sikkim Human Development Report, 2014). Other indicators like literacy, women participation in work and sanitation are already mentiond. The BMI is also known as an indicator of the socio-economic development of a society or community which can be regarded true in case of Limboo individuals of Sikkim.

Egalitarian nature of society may be contributing to overall development in Sikkim (Ackerson et al., 2008).

4.2.8 PREVALENCE OF OVERWEIGHT AND OBESITY AMONG THE LIMBOO INDIVIDUALS OF THE PRESENT STUDY

The prevalence of overweight and obesity in the present study was assessed using BMI. The trend of BMI among different population of the world depicts the rising prevalence of overweight/obesity. The existence of dual burden of malnutrition is another concern as depicted by countries such as Bangladesh, Korea, Singapore, Mongolia, and Indonesia, Sub-Sahara Africa. In the last 39 years or nearly four decades, USA and Russia were replaced by China as the highly obese country of the world. Similarly, India replaced France and Ukraine at 5th and 3rd position in the world obesity prevalence chart. This dynamic in human history is worth concern and has significant bearing in development of any country. This could be the result of the ongoing nutrition transition in those countries including India (Popkin et al. 2012; Khan and Talukder, 2013).

According to study by NCD-RisC, (2016) the highest prevalence of obesity (BMI > 30 kg/m^2) was observed among men of China (16.3%), followed by USA (15.7%), Brazil (4.5%), Russia (4.0%), and India (3.7%). Again Chinese (12.4%) women were on top followed by women of USA (12.3%) and India (5.3%). Countries observed with lower prevalence of obesity in relation to India among men was Mexico (3.3%), Germany (3.1%), UK (2.6%), Italy (2.2%), France (2.1%), Argentina (1.4%), Poland (1.4%), and Ukraine (1.1%). Women of countries like Russia (5.0%), Brazil (4.8%), Mexico (3.7%), Egypt (2.7%), Turkey (2.6%), Germany (2.3%), Iran (2.1%), UK (2.1%), Italy (1.8%), France (1.7%), Ukraine (1.3%), and Poland (1.1%)

were observed with lower prevalence of obesity (BMI > 30 kg/m^2) compared to India. In the estimates of obesity prevalence, Asian countries such as China and India has attained and surpassed USA, Brazil, and Russia from 1975 to 2014 (NCD-RisC, 2016).

The observed prevalence of overweight among Mexican American (men: 35.0%; women: 27.1%), NHPI (men: 25%; women 36%) were high compared to the present study (Peltz et al., 2010; Moy et al., 2010). In contrast, the observed overweight among men (22.9%) and women (19.9%) Inuvialuit of Canada was lower compared to that of Mexican American and NHPI (Hopping et al., 2010). Such comparatively high overweight was observed among Australian aboriginal (male: 49.4%; female: 50.6%) and Inuit (male: 34.0%; female: 15.9%), with the only exception being Inuit overweight females (Andersen et al., 2004; Avery et al., 2015). The reported overweight among women of Samoan (22%) and Inuvialuit (19.9%) was lower than that of the Limboo women of the present study (Novotny et al. 2007; Hopping et al., 2010). Further, the observed prevalence of obesity (BMI > 30 kg/m^2) was higher among indigenous population such as Mexican American (male: 35.0%; female: 26.3%), NHPI (male: 73.0%; female: 55.0%), Inuvialuit (male: 39.6%; female: 45.9%), Samoan women (female: 58%), and Inuit (male: 13.5%; female: 23.3%) compared to the Limboo population of the present study (Andersen et al., 2004).

The prevalence of overweight reported among Dutch (male: 33.4%; female: 28.1%), Moroccan (male: 37.2%; female: 24.7%), and Turkish (male: 44.6%; female: 32.3%) of Netherland were comparatively high (Ujcic-Voortman et al., 2011). The observed obesity of Dutch (male: 11.0%; female: 16.5%), Moroccan (male: 13.2%; female: 39.1%), and Turkish (male: 16.3%; female: 39.6%) was higher compared to the present study (Ujcic-Voortman et al., 2011). The reported obesity among the Maori and European males (66.7% and 32.5%) and females (63.3% and 59.7%) of New Zealand were higher compared to the present study (Taylor et al., 2010). Another study on Turkish adult males and females observed high overweight (male: 41.5%; female: 30.6%) and obesity (male: 20.6%; female: 39.9%) compared to the Limboo adults of the present study (Oguz et al., 2008). Studies from Sub-Sahara African countries have also reported the higher prevalence of overweight and obesity (Adediran et al., 2013; Obirikorang et al., 2015). However, the lower prevalence of overweight reported among Maasai was 4.1% for males and 4.6% for females compared to the present study (Galvin et al., 2015).

The prevalence of overweight (male: 35.7%; female: 36.9%) and obesity (male: 17.5%; female: 26.4%) reported from Mongolia were higher compared to the present study (Chimeddamba et al., 2016). Another study of Mongolia reporting the similar higher prevalence of overweight and obesity compared to the present study (Dugee et al., 2009). Still, other Asian countries reporting higher prevalence were Indonesia (overweight: 79.9%) and Pakistan (obesity: 4.84%) (Lindarto et al., 2010; Khan et al., 2017). However, overweight observed among the Filipino men (17.0%) and women (23.3%) and the observed overweight/obesity (10.10%) among Orang Asli adults of Malaysia were lower compared to the present study (Yusof et al., 2007).

Overall prevalence of overweight and obesity among the Limboo individuals of the present study was 21.37% and 4.03%, respectively. The sex specific prevalence of overweight (BMI > 25 kg/m^2) was high among female (24.40%) compared to male (18.35%) Limboo individuals of the present study. The prevalence of obesity was 5.85% among female and 2.23% among male Limboo individuals of the present study. The prevalence of overweight and obesity, both was significantly high among female Limboo individuals. The studies cited above from countries of America, Africa, Europe and Asia observed a higher prevalence of overweight and obesity in their studies compared to present study with some exceptions. Interestingly the prevalence of overweight among Limboo females was higher than their Inuit, Samoan, and Inuvialuit counterparts in some of the studies cited above. These populations come from the high obesity prevalence zone of the world (NCD-RisC, 2016). However, the prevalence of obesity in the present study was far lower comparatively.

Utilizing Asia-Pacific BMI classification (WHO, 2000), the prevalence of overweight among Limboo individuals of the present study was 17.14% for both male and female individuals. The prevalence of Obesity I was 18.75% for male and 24.40% for female Limboo individuals of the present study. Similarly, the prevalence of Obesity II was 2.02% and 5.85% among male and female Limboo individuals, respectively. Compared to the prevalence assessed using WHO (1995) classification, the prevalence given by using Asia-Pacific classification was higher in the present study. The sex combined prevalence of BMI >25 kg/m^2 was 25.20% and BMI > 23 kg/m^2 was 42.64%. A study from Balochistan, Pakistan observed 21.73% prevalence of obesity utilizing the Asia Pacific cut-offs (WHO, 2000) which was higher than the prevalence percentage given by using WHO (1995) classification in the same study (Khan et al., 2017). Such differences in the prevalence rate on the use of two different criteria were also seen in other studies (Mungriephy and Kapoor, 2010). High prevalence of overweight and obesity noticed using Asia-Pacific criteria was due to shift in the cut-off points. The Asia-Pacific classification is the recommended classification of BMI for Asians (WHO, 2000).

According to NNMB (2012) the prevalence of overweight/obesity was high among south Indian states of India like Kerala, Tamil Nadu, Karnataka and Andhra Pradesh followed by the states of Maharastra, Gujarat, Madhya Pradesh, and lowest among the people of Odisha, West Bengal, and Uttar Pradesh among both men and women. A significant study by Meshram et al. (2016b) reported prevalence of overweight/obesity (BMI $\geq$ 23 kg/m^2) to be about 28.9% among adults (male 28.2%; female 29.5%), and ranged from a low (21%) in the East to a high (40%) in the Southern region. This study supported the trend observed by NNMB (2012) cited above. The study area includes the rural areas of Kerala, Tamil Nadu, Karnataka and Andhra Pradesh, Maharastra, Gujarat, Madhya Pradesh, Odisha, West Bengal, and Uttar Pradesh, Punjab, Meghalaya and Arunachal Pradesh (NNMB, 2012; Meshram et al., 2016a,b). On a closer look, the reported overweight/obesity (male 19.9%; female 23.2%) using BMI $\geq$ 23 kg/m^2 as criteria by NNMB was lower than the study by Meshram et al. (2016b). The finding of the present study was higher compared to NNMB (2012) and lower compared to Meshram et al. (2016b). Using same criteria among the rural south Indian population of Tamil Nadu, the prevalence of overall (sex combined) overweight (14.9%), Obesity I (16.1%) and Obesity II (3.3%) were observed higher than the present study (Little et al., 2016).

A study conducted among the different populations of Tamil Nadu, Maharashtra, Jharkhand, and Chandigarh observed 24.6%, 16.6%, 11.8% and 31.3% prevalence of overweight ($>$23 kg/m^2), respectively. The rates given for Maharashtra and Chandigarh were higher than the present study. The prevalence of obesity (BMI $>$ 25 kg/m^2) reported by the same study was high for Chandigarh (15.9%) and Tamil Nadu (15.2%) in contrast to Jharkhand (7.8%) and Maharashtra (11.3%) which was again lower compared to present study. This study further observed the high prevalence of overweight/obesity among urban inhabitant (Pradeepa et al., 2015).

Two significant studies from West Bengal have reported the prevalence of overweight/obesity among Marwaris of Kolkata and BHCP population of Jalpaiguri, West Bengal, India (Das and Bose, 2006; Sen et al., 2013). The prevalence of overweight observed among Marwaris (male 44.5%; female: 71.8%) and BHCP of Jalpaiguri (male: 9.67%: female 29.3%) was high compared to the present study except for BHCP males. It also holds for the prevalence (male: 23.67%: female: 20.33%) given using Asia Pacific cut-offs especially among BHCP (Sen et al., 2013). There are few studies which have reported higher overweight among the tribal population like Nicobarese and Jarawas of India (Sahani, 2004; Sahani et al., 2010). Among male Nicobarese, the reported increase in the prevalence of overweight was 5.42% to 22.01% during the 1960s to 1999 and among females the increase was 4% to 21.78%. While obesity observed among the population during 1999 was 2.70% in men and 8.89% among women which was absent during the 1960s (Sahani et al., 2010). As assessed during 2001 as a part of the longitudinal study, the prevalence of overweight was 16.66% among Jarawas (Sahani, 2004). These suggest the penetration of overweight/obesity in every stratum of Indian society urban to traditional. However, recent observation of overweight and obesity were relatively lower among Car Nicobarese, Great Andamanese, Jarawas and Onge (Sahani et al., 2018).

A significant study among Indian tribes has observed the prevalence of overweight and obesity (Kshatriya and Acharya, 2016). The studied male and female Indian tribes were observed with the lower prevalence of overweight/obesity (BMI > 23 kg/m^2) compared to the present study. The tribes studied were Santal, Kora, Oraon of West Bengal and Santal, Bhumij, Bathudi, Dhodia, Kukna, and Chaudhari of

Odisha (Kshatriya and Acharya, 2016). Among them, the highest prevalence was observed among the Bhumij (25.0%), Dhodia (24.2%) Chaudhari (16.1%) and Kukna (16.7%) male individuals. Similarly, among females, the highest prevalence was observed with Dhodia (23.3%) followed by Santal of Odisha (15.1%), Kukna (15.0%), Santal of West Bengal (12.3%), Bhumij and Chaudhari (10.7%). Recently a study has observed 4.5% overweight among male Sabars of West Bengal (Ghosh et al., 2018). It is clear here that males are more at risk of raising overweight/obesity than females. Among the Bhotia of Uttaranchal, the prevalence of overweight/obesity ranged from 1.1% - 24.8% along different altitude. The prevalence of undernutrition was lower among the males compared to females in the studies assessing underweight among tribes of mainland India, consequently, the rising prevalence of overweight and obesity were high among males compared to females among these tribes of India.

The observed prevalence of overweight among Karbi women (4%-18%), Rengma Naga (male: 9.95%; female: 11.63%) and overweight/obese (BMI >23kg/m^2) among Tankul Naga (male: 17.6%; female: 27.1%) and Niyshi women (19.52%) were lower compared to Limboos of Sikkim (Mungreiphy and Kapoor, 2010; Mungreiphy et al., 2011; Bharali, 2017). Among the college students of Manipur, observed prevalence of overweight among Tribal (male: 2.90; female; 12.70%) and among Non-Tribal (male: 6.59%; female: 7.92%) was lower compared to present study using BMI criteria of WHO (1995). Similarly, prevalence of obesity was observed low among tribal (male: 0.0%; female: 1.59%) and non-tribal (male: 0.0% female: 2.92%) (Datta et al., 2015). A recent study has given lower obesity prevalence (male:15.52; female: 15.26) among Karbi individuals compared to the present study (Mondal et al., 2016). The only study among Hmar of Manipur observed higher overweight (24.4% for rural and 40.0% urban) than the present study (Lalnuneng and Khongsdier, 2017).

The overweight/obesity prevalence was observed high among tribal males than females of West Bengal and Odisha (Kshatriya and Acharya, 2016), however, some tribal females of Northeast India were observed with high prevalence of overweight/obesity than their male counterparts (Mungreiphy and Kapoor, 2010; Mungreiphy et al., 2011; Datta et al., 2015; Rengma et al., 2015). The non-tribal females population of West Bengal like Marwaris and BHCP were also observed with high overweight/obesity than their male counterparts. This disparity in the prevalence of overweight/obesity between male and female of different regional and ethnic groups in India may be worth concern. According to published studies, the obesity epidemic was prevalent among urban, rural, and traditional societies of India which is clear from above paragraphs. The degree of prevalence may vary in these segments of societies. The obesity was observed high among south Indian states, in rural and urban areas. However, in general, obesity was highly prevalent among urban people than their rural counterparts. The observed overweight/obesity among Limboos of the present study was lower than the regional prevalence given for south India. The population of Bengal like BHCP and Marwari of Jalpaiguri and Kolkata respectively were reported with lower overweight/obesity than the present study. Further, the Chandigarh city was observed with higher overweight and obesity than the present study. However, the central Indian tribes were observed with the lower prevalence of overweight and obesity compared to the present study. Furthermore, tribes of northeast of India were observed with the lower prevalence of overweight and obesity compared to the present study, with some exception.

According to NFHS-4 (2015-2016) report, the prevalence of overweight/obesity was 34.8% and 26.7%, respectively among men and women of Sikkim, which was 11.9% and 15.4%, respectively during NFHS-3 (2005-2006)

Survey. The noted increased was nearly more than twice for men and little less than twice for women. Overweight/obesity among urban men and women of Sikkim reported by NFHS-4 (2015-2016) was 41.5% and 34.1%, respectively higher than the present study. Among rural men and women, overweight/obesity was 29.7% and 23.1%, respectively which was higher compared to Limboo males and lower compared to Limboo females. As the present study was conducted among the Limboo adults of West District of Sikkim and the prevalence given for the district by NFHS-4 (2015-2016) was 22.8% for females lower than the present study and 30.6% for males higher than the present study. Further, among the eight Northeast Indian states, Sikkim stands on top followed by Mizoram (21.0%) and Arunachal Pradesh (20.6%) for men and Manipur (26.0%) and Mizoram (21.1%) for women. If one compares Darjeeling and Jalpaiguri districts of West Bengal with the Northeast Indian states owing to its continuity with Northeast and especially with Sikkim, the Darjeeling districts stand on 4th and 3rd position with its overweight prevalence among men and women respectively. On the other hand, Jalpaiguri stands on 8th and 7th position for men and women respectively. Unlike that of NFHS-4 (2015-2016), the present study was conducted on a relatively homogeneous population of Sikkim, which is first of its kind in the state of Sikkim. Such a study sample provides control over some factors influencing human health and nutrition which could be community specific behaviours such as food habits, beliefs and daily life style as well as heredity. The prevalence rates observed in the present study were lower than the NFHS-4 (2015-2016) at the state level and at district level prevalence was lower for females only. The prevalence given by NFHS-4 (2015-2016) was higher among males of Sikkim. However, the prevalence was higher among females in the present study.

Age specific prevalence of overweight and obesity were found higher among middle age 30-49 years male and female Limboo individuals. The Limboo females were suffering from high overweight and obesity than males across age groups (see Table 3.19). However, using Asia-Pacific classification more men were overweight than the female in the age group 30-49 years (21.30% vs. 17.56%) and 50-64 years (20.88% vs. 14.67%). Middle age group of 30-49 years (21.30% vs. 17.56%) had the high prevalence of overweight irrespective of sex. The prevalence of obese I and obese II was observed high among the females of each age groups of the present study. The females were more at risk of being obese than males. Again obesity I was observed high among 30-49 years age group and obese II among the age group 50-64 years. Using both traditional and Asia-Pacific BMI criteria, higher overweight and obesity was observed among the Limboo individuals of middle age (30-49 years) and above. The age was reported as the main predictor of obesity in India (Midha et al. 2011). Decreasing trend in obesity during later age was observed among Indian elderly (Ghosh et al. 2001; Bose and Chaudhuri 2003; Ghosh 2004). The decrease in various adiposity measures was shown among individuals of 60 years and above by the studies cited in contrast to present study.

4.2.9 PREVALENCE OF CENTRAL OBESITY AMONG LIMBOO INDIVIDUALS OF THE PRESENT STUDY

There is no doubt estimation of abdominal fat depot using anthropometry is a cheap and reliable method to evaluate the risk of cardiometabolic diseases (Pinter et al. 2017). The comparison of anthropometric variables of general and regional adiposity like BMI, WC, HC, and WHR between American populations and urban and rural population of Chennai, India supported the hypothesis that Southeast Asian Indians are particularly predisposed towards central adiposity (Bajaj et al., 2014). The neo-natal anthropometry has also revealed high visceral area and low lean mass among European newborn compared to high sub-scapular skinfold among Indian newborns (Yajnik et al., 2003). The body frame dimensions were considered responsible in ethnic difference in obesity and fatness (Henneberg and Ulijaszek, 2010).

In the present study, prevalence of central obesity was higher compared to the overweight/obesity observed by the BMI. The overall prevalence of overweight or central adiposity related risk increase along with each index such as WC (34.98%), WHtR (65.52%), WHR (97.18%), and CI (67.74%) in the present study. The sex specific prevalence of risk by WC (male: 10.89%; female: 59.07%), WHtR (male: 48.79%; female: 82.26%), WHR (male: 98.99%; female: 95.36%), and CI (male: 43.55%; female: 91.94%) also increases with each index used in the present population. The females were more at risk of central obesity related diseases with respect to measures of central obesity like WC, WHtR, and CI with exception of WHR. Based on WHR males were more prone to central obesity related diseases than females. However, the difference was narrow and non-significant. In every age group of the present study, more women were centrally obese than men. The females of middle age group 30-49 years were more centrally obese and more males of 50-64 years were centrally obese as identified by WC, WHtR, and CI than their counterparts. In the present study prevalence of central obesity ranged from 10.89% to 98.99%, which is alarming.

Studies have reported high adiposity among Asian and Indian compared to European (Gallagher et al., 1996; Deurenberg-Yap et al., 2000; Rush et al., 2004; Bajaj et al., 2014). However, some studies have observed high central adiposity prevalence such as among Maori, European, and Turkish than the present study (Oguz et al., 2008; Taylor et al., 2010). Among Maori males and females, the central obesity based on WC was 70.2% and 89.4%, respectively and among European males and females, 66.5% and 89.3%, respectively. The observed WHtR defined central obesity prevalence was higher among European (male: 79.2%; female: 84.9%) compared to Maori (male: 90.1%; female 89.8%) (Taylor et al., 2010). Similarly, among Turkish adults, 58.7% were observed with high obesity based on WC, of which men were 43.2% and women were 73.8% (Oguz et al., 2008). The corresponding prevalence of central obesity based on WC among the Limboo individuals were lower and prevalence based on WHR and WHtR were higher compared to the individuals of Ghana (Obirikorang et al., 2015). In the studies cited here, females were more at risk of central adiposity than males, which was also true for present study with some exceptions.

A study reported from Mongolia has shown the prevalence of high WC compared to the present study which was 46.5% and 65.1% among men and women, respectively (Dugee et al., 2009). The prevalence of central obesity observed among individuals of Pakistan based on WC and WHR were 10.9% and 44.4%, respectively (Khan et al., 2017). The reported central obesity based on WHR among the Filipino individuals was 7.9% and 39.5%, respectively among males and females. In the same population, central obesity based on WC was 2.7% and 10.7% respectively among male and female individuals (Tanchoco et al., 2003). Central adiposity observed among Pakistani and Filipino individuals were lower compared to Limboo adults of Sikkim.

In India, overall prevalence of central obesity among rural residents was 21% which was significantly higher among women (27 %) compared to men (14 %). The prevalence was 39% in the Southern region, followed by the Northern (19.4%), Western and Eastern regions (18.8% each), and lowest in the Northeastern (12.2%) region (Meshram et al., 2016b). Similar prevalence of abdominal obesity related risk was observed in south Indian states compared to other states using WC. Baring Maharashtra and Gujarat states like Kerala, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Odisha, West Bengal, and Uttar Pradesh were observed with high WHtR ranging from 50% - 80% (NNMB, 2012). The prevalence of high WHR among the males of Delhi, Manipur and Kerala was 12%, 42%, 12%, respectively, however, among females of Delhi, the prevalence was 04%, and altogether absent among females of Manipur and Kerala. The prevalence of elevated WHtR among males and females of Delhi was 16% and 20% and among males and females of Manipur was 22% and 16%, respectively, which was meagre in case of male (0%) and female (02%) of Kerala (Mungriephy et al., 2012). This observed prevalence rates among different Indian populations were lower compared to the observations of the present study.

Such a high prevalence of central adiposity was reported to link with cardiovascular mortality and other NCDs (Feldstein et al., 2005; Prospective Studies Collaboration, 2009; Cerhan et al., 2014; Kaplan et al., 2014; Sahakyan et al., 2015; Qi et al., 2015). So, Limboo individuals of the present study were at high risk of mortality related to central adiposity. Assessment of regional fat distribution by central adiposity indices is a reasonable way of gauging adiposity related problem in clinical and population studies. Since body fat distribution (WC) is well considered as a MetS along with high triglycerides, low cholesterol, high glucose levels and high blood pressure (Vakil et al., 2012; Takata and Fujimoto, 2013; Adedoyin et al., 2013; Despres, 2014) it was observed to be associated with increased risk of hypertension and diabetes (Warren et al., 2012). This is equally true in case of other central adiposity indices (WHO, 2008; Feldstein et al., 2005; Kaplan et al., 2014; Qi et al., 2015). Owing to observed high central adiposity prevalence, the present population seems to be under risk of MetS, morbidity and cardiovascular mortality.

The indices of central adiposity are best for complementing BMI to identify individuals at increased risk for various obesity related morbidity due to the accumulation of abdominal fat (WHO, 2000a, 2008; Nam et al., 2012). The BMI is also known as a measure of general adiposity and cannot discriminate body fat distributions which have implications in related morbidity and mortality (Reis et al., 2009; Oliveros et al., 2014; Sahakyan et al., 2015). The combined use of central adiposity indices with BMI can overcome this limitation of BMI (Coutinho et al., 2013; Oliveros et al., 2014; Sahakyan et al., 2015). In the present study, the Limboo male individuals simultaneously identified at the risk of obesity related morbidity and mortality by the combination of BMI with WC, WHtR, WHR, and CI each were 42.94%, 34.88%, 37.90%, and 21.17%, respectively. Similarly, among Limboo females such simultaneously identified risky adiposity using BMI with WC, WHtR, WHR, and CI each were 10.89%, 46.77%, 46.77%, and 45.16%, respectively. The number obtained is alarming and needs effective management.

The studies have formulated the concept of normal weight obesity which is either combination of normal weight BMI with central obesity or elevated PBF (Coutinho et al., 2013; Oliveros et al., 2014; Sahakyan et al., 2015). Such normal weight central obesity was associated strongly with MetS among Chinese adults (Fu et al., 2014). In the process of combined assessment of adiposity using central adiposity indices such as WC, WHtR, WHR, and CI with BMI the present study obtained normal weight central obesity among Limboo individuals of the present study. The prevalence of normal weight central obesity was 16.13% using WC and

BMI, 13.91% using WHtR and BMI, 61.09% using WHR and BMI, and 22.38% using CI and BMI among male Limboo individuals. The corresponding combinations of normal weight central obesity observed among female Limboo individuals were 0%, 35.48%, 48.59%, and 46.77%. Among the male and female Limboo individuals the highest prevalence of normal weight central obesity was given by WHR with BMI. Studies have found the normal weight central obesity associated with higher mortality than obesity defined by BMI (Sahakyan et al., 2015). The mortality includes total mortality (death due to any cause) and caused specific mortality like cardiovascular mortality among US populations (Sahakyan et al., 2015). In such a background, one can imagine the escalated risk among the individuals who were identified as obese by both indices simultaneously in the present study.

4.2.10 FAT AND FITNESS AMONG THE LIMBOO INDIVIDUALS OF THE PRESENT STUDY

A study among individuals of Ashanti region, Ghana observed elevated PBF of 99.6% (Obirikorang et al., 2015). The observed prevalence of elevated PBF among Mexican American males and females was 64.2% and 53.5%, respectively (Peltz et al., 2010). The Korean population was observed with the relatively low prevalence of elevated PBF which was 30% in men and 42.4% in women (Kim et al., 2011). The studies cited have observed higher PBF compared to the present study (Peltz et al., 2010; Kim et al., 2011; Obirikorang et al., 2015). However, among Orang Asli of Malaysia, the prevalence of elevated PBF was 0.80% lower than the present study.

The overall prevalence of elevated PBF among Indian tribes (21.7%) reported were higher compared to the present study (Kshatriya and Acharya, 2016). Such high prevalence of elevated PBF among tribal populations of mainland compared to the

Limboos of Sikkim, an Eastern Himalayan tribe may have geographical significance. It is paradoxical that Indian tribes mostly associated (Das and Bose, 2015) with undernutrition were observed with high PBF compared to the present study. Studies have observed elevated PBF among male slum dweller (75.68%) of Kolkata, Marwari (male: 90.9%; female: 97.3%) of Kolkata and Asian Indian (male: 30%; female: 33%) populations (Dudeja et al. 2001; Das and Bose 2006; Chakraborty et al., 2009c).

The over fat or obese individuals identified using Niemen (1995) and Muth (2009) criteria were 1.61% and 3.02%, respectively in the present study. The sex specific cut-off of male (>25%) and female (>32%) may be responsible for the high prevalence of over fat individuals identified by Muth (2009) cut-offs compared to general cut-off (>33%) of Niemen (1995). Individuals at risk of elevated PBF were 6.35%, irrespective of sex as identified using cut-offs of 25% for men and 30% for women. Similarly, sex specific prevalence of over fat was absent among male and 3.23% among female in the present study. Using Muth (2009) criteria, the obese males were 1.21% and obese females were 4.84%. Further, individuals identified at risk of elevated PBF using cut-offs of 25% for men and 30% for women, was 1.21% and 11.49%, males and females, respectively. However, elevated PBF identified in the present study using different criteria were still lower compared to the studies from Ashanti region, Ghana (Obirikorang et al., 2015), Mexican American (Peltz et al., 2010) and Indian tribes (Kshatriya and Acharya, 2016). As a result, a significantly large proportion of present population seems fit compared to Indian and Non-Indian population discussed above. The reason could be the Himalayan habitat of the present study population which influence nutrition, health and level of physical activity.

Some studies suggest the trunk fat as a better predictor of MetS than BMI and PBF (Fu et al., 2014). Other still suggests normal weight obesity defined as normal

BMI and elevated PBF as a better risk predictor than using any one in isolation (Coutinho et al., 2013; Oliveros et al., 2014; Sahakyan et al., 2015). In the present study, overweight, obese I, and obese II female Limboo individuals identified with elevated PBF was 3 (0.60%), 29 (5.85%) and 24 (4.84%), respectively. The number of male Limboo individuals identified as overweight with elevated PBF was absent, and 3 (0.60%) males each of obese I and obese II with elevated PBF was observed. There was only 1 (0.20%) female identified as normal weight obese in the present study. Still, the present population seems relatively fit than the other Indian population.

The high adiposity and low lean mass were found associated with arterial stiffening in Asian Indians with type II diabetes mellitus in North India, with significant sex differences (Anoop et al., 2015). The sex difference in PBF was also apparent in the above cited studies among Indian population (Dudeja et al., 2001; Das and Bose, 2006; Chakraborty et al., 2009c). The condition of low lean mass and high adiposity predisposed individuals to sarcopenia. The Asian Indians have higher body fat composition and lesser muscle mass (sarcopenia) than the White or African counterparts (Joshi, 2012). Prevalence of presarcopenia was higher among Asian Indian subjects with type II diabetes compared with age- and sex-matched participants without diabetes (Anbalagan et al., 2013). The prevalence range of PBF based on different proposed classification in the present study was 1%-6.35%. The risk was high among females (range 0% - 11.49%) compared to males (range 0%-1.21%) in the present study. In contrast present population seems at lower risk of sarcopenia owing observed PBF among them. A study observed high proportion of fat among newborn of India compared to UK (Yajnik et al., 2003). The Chinese and Malays had less body fat but still more than that observed in Caucasians (Deurenberg-

Yap et al., 2000; Nube, 2009). Low adiposity among people with typical East Asian features compared to Indian could be extended to people of northeast India who are typically East Asian (mongoloid features) in appearance. The possibility is there of high PBF among people of mainland India compared to northeast India.

4.2.11 COMPONENTS OF BODY COMPOSITION AMONG LIMBOO INDIVIDUALS OF THE PRESENT STUDY

The importance of muscle mass and fat mass with regard to diseases outcome and newly recognised fact of normal-weight obesity (Batsis et al., 2013; De Lorenzo et al., 2016) makes body composition component analyses important. Such metabolically obese but normal-weight (normal-weight obesity) patients may be at a much higher risk for cardiometabolic dysregulation, endothelial dysfunction, insulin resistance and cardiovascular complications. Individuals of normal weight BMI with regard to high fat mass and low lean mass are equally unhealthy as obese individuals defined by BMI. This condition as discussed was related with the high incidence of diabetes in India. Such condition among elderly has implication on CVDs and functional impairment (Broadwin et al., 2009; Batsis et al., 2013; De Lorenzo et al., 2016). In this regard, the FM and FFM could be very useful and this is equally true with upper arm composition. This leads to the distinction of two components of BMI or body weight, which were further corrected by height to evaluate morbidity and mortality (Van Itallie et al., 1990; Zhu et al., 2003). As a result, the FMI and FFMI enable comparison of FM and FFM across ethnic groups and populations (Peltz et al., 2011; Hull et al., 2012). Studies have observed increased FMI and decreased FFMI with age which has implication in sarcopenia and functional impairment in elderly (Broadwin et al., 2009; Hull et al., 2012). However, the present study did not observe such trend and cannot infer sarcopenia and functional impairment among Limboo individuals due to the given age range. The body component analyses have clear implications on adult health and nutritional status (Elia and Ward, 1990).

The present study population had elevated FMI of 7.96% irrespective of sex, which was higher compared to all other prevalence given by different classification systems such as 25% and 30%, Niemen (1995), and Muth (2009). Further, the sex specific prevalence of high FMI (2.02% for male and 13.91% for female) of Limboo individuals of the present study was high compared to the prevalence of PBF given by different proposed classifications. This suggests the 7.96% population of the present study may be at risk of certain adiposity related disorder (Liu et al., 2013). The studies from India and aboard have shown the association of morbidity with the high FMI and the low FFMI (Kyle, 2003; Khongsdier, 2005, Peltz et al., 2011; Rao et al., 2012; Hull et al., 2012). The study by Liu et al. (2013) has given cut-offs of FMI for male (7.00) and female (7.90) adults which were observed closed to the cut-offs given by Indian studies and the reference taken was MetS. Utilizing MetS as a reference, the FMI was suggest as a better marker of risky fat accumulation than PBF and BMI, which was independently and positively associated with the presence of MetS (Liu et al. 2013). The normal individuals according to FFMI cut-off by Khongsdier (2005) was almost absent in the present study which is also a concern.

4.3 ASSOCIATION OF SOCIO-ECONOMIC, DEMOGRAPHIC, AND LIFE STYLE VARIABLES WITH NUTRITIONAL STATUS

The access to good quality of life which ensures the health, optimum diet and hygienic living are main determinants of desired nutritional health and fitness. Such accessibility is facilitated by a number of socio-economic factors like age, sex, education, residence, income, etc. The BMI is also viewed as an indicator of living standard in developing countries (Nube et al., 1998). The BMI was directly related to socio-economic status among women in India and elsewhere (Subramanian and Smith, 2006). Recently, Indian states with high prevalence of overweight and obesity have shown rich and poor, and urban and rural people affected by overweight and obesity. In relatively underweight states the overweight and obesity were mostly found among urban and rich people (Sengupta et al., 2015). The inverse association of obesity with SES as in western countries is likely to appear in India (Stunkard, 1996; Ball and Crawford, 2005).

In India, the prevalence of undernutrition based on BMI has been reported to be associated with age, sex, land own, education, residence, family size, social status, occupation and income (Khongsdier, 2002, 2005; Arlappa et al., 2005, 2009; Bose et al., 2006a; Barker et al., 2006; Bose et al., 2007, 2009; Chakraborty et al., 2009a; Das and Bose, 2010; Das et al., 2013; Patil and Shinde, 2014; Subasinghe et al., 2014; Sengupta et al., 2015). Studies done to assess undernutrition have pointed out additional factors such as number of siblings, residence, clean water supply, hygienic sanitary facility, birth intervals and mother’s age at childbirth influencing nutritional status (Vella et al., 1992; Sommerfelt and Stewart, 1994; Frongillo et al., 1997; Zere and McIntyre, 2003; Hien and Kam, 2008; Mondal and Sen, 2012).

Further, studies have found associations of farming, low income, household food distribution with CED (Gittelsohn et al., 1991; Barker et al., 2006). In the present study rate of prevalence of underweight (CED 7.56%) was lower than the prevalence observed elsewhere in India. Among the different variables, middle age group (30 – 49 years) individuals were significantly less likely to get underweight (OR 0.48; 95% CI 0.27 – 0.85). Other variables such as sex, marital status, education, occupation,family monthly income, SES, family size, land holding, house type, drinking water, hygienic toilet were not found associated with underweight in the present study. The observed rate of underweight in the present study was relatively small which could be the reason for no association. The factors influencing underweight, not included or missed in the present study could be another reason.

The prevalence of obesity among Indian adults have been reported to influenced by age, sex, income, education, residence, social status and rural-urban migration (Prasad et al., 2013; Varadharajan et al., 2013; Som et al., 2014; Pengpid and Peltzer, 2014; Gouda and Prusty, 2014; Pradeepa et al., 2015; Rai 2015; Little et al. 2016). Influence of caste on the prevalence of overweight and obesity were studied among some populations of south India (Arlappa et al., 2009; Little et al., 2016). Some studies are also published on the association of food habits with obesity (Gupta et al., 2010; Singh and Kirchengast, 2011; Satija et al., 2013; Prasad et al., 2013, Agrawal et al., 2014).

The efforts have been made to assess the association of high BMI with given socio-economic, demographic, and life style variables of Limboo individual of the present study using χ^2 test. The association was assessed between high BMI at cut-offs of 25 kg/m^2 and 23 kg/m^2. The commonly associated socio-economic, demographic, and life style variables were age, marital status, occupation, SES assessed using χ^2 test. The variables like family monthly income, house type, family type and drinking water facilities were observed partially influencing the high BMI using above mention criteria. Similarly, the association was further assessed using logistic regression. In the present study factor highly influencing overweight was non-manual occupation (OR 11.12; 95% CI 4.82 – 25.67), followed by the manual occupation (OR 4.64; 95% CI 2.11 – 10.19). The middle age group (OR 3.01; 95% CI 2.09 – 4.33) was an equally important factor followed by marital status (OR 3.27;

95% CI 2.07 – 5.17) and SES (OR 2.92; 95% CI 1.94 – 4.38) among the Limboo individuals of the present study for influencing overweight. The prevalence of overweight was 1.57 (95% CI 1.15 – 2.14) times high among female than male individuals. Lastly, high family monthly income was 1.77 (95% CI 1.05 – 2.97) times likely to predisposed individual to overweight than lower income groups.

The strongest factor associated with obesity was non-manual occupation (OR 14.76; 95% CI 1.87 – 116.70), followed by age group 30 – 49 years (OR 3.94; 95% CI 1.66 – 9.33), 50 – 64 years (OR 3.89; 95% CI 1.44 – 10.46), UM SES (OR 3.38; 95% CI 1.53 – 7.47) and female individual (OR 3.11; 95% CI 1.53 – 6.33). The high odd ratios suggest non-manual occupation predisposed individual to obesity more than manual occupation and unemployed individuals/students in the present study. The most consistent factors influencing the prevalence of overweight and obesity among the Limboos of the present study were sex, age, occupation and SES.

A study on Rengma Naga of Assam reported the association of the part time occupation with overweight (Rengma et al., 2015). Among the villagers of Maharashtra, non-farming male and female were shown with high BMI compared to farming counterparts (Barker et al., 2006). The occupations like unskilled manual, skilled manual, agriculture, and agriculture labour were observed least likely to predisposed individuals to overweight/obesity (Griffiths and Bently, 2005). The study by Millett et al. (2013) has shown walking, cycling and boarding the public transport for going to work place less likely to cause overweight/obesity and related morbidities in India. In the present study non-manual occupation excludes all the jobs involving physical labour which could be the reason behind obtained high odds.

The high SES in India is known to influence the prevalence of overweight and obesity (Subramanian and Smith, 2006; Subramanyam and Subramanian, 2011). The fact is corroborated by the findings of the present study. Similar, observations were made by other Indian studies which suggest the Limboo individuals of Sikkim were also under similar influence (Griffiths and Bently, 2005; Das and Bose, 2006; Gupta et al., 2012; Pradeepa et al., 2015). In the present study, high level of SES was observed with the high risk of being overweight as in the NHFS-2 sample (Griffiths and Bently, 2005). Further, high SES was shown as a predictor of overweight and obesity in nationally representative data of NFHS (1992-1993, 1998-1999 and 2005-2006) (Wang et al., 2009). The various components of SES like the non-poor, high income and high level of education were significantly associated with overweight and obesity among the urban women of India (Gouda and Prusty, 2014). In the present study, only income above ₹10000/= was found associated with overweight which was not associated with obesity. Other studies reporting the association of high family monthly income and level of education with overweight and obesity were Sen et al. (2013) and Rengma et al. (2015). However, educational attainment in the present study was not a significant factor for overweight and obesity.

The middle age (30-49 years) individual was observed with high overweight like in case of Rengma Naga and ever married Indian women (Rengma et al., 2015; Sengupta et al., 2014; Meshram et al., 2016a). Among the Rengma Naga, women aged 30 + years were more prone to overweight and obesity. Women of Karnataka above 30 years were observed with increased odds of overweight/obesity (Griffiths and Bently, 2005). Other Indian studies have reported the similar trend (Midha et al., 2011; Pradeepa et al., 2015). The similar observation was made on the Malaysian population (Rampal et al., 2007).

As already discussed the sexual dimorphism was observed in different anthropometric and body composition variables taken in the present study. This was also exhibited by the prevalence of the overweight and obesity. These observations were further attested by high odds of being overweight and obese. Similar, findings were reported among Rengma Naga of Assam and Bengalee Hindu Caste Population of West Bengal (Sen et al., 2013; Rengma et al., 2015). Studies have observed high odds for married individuals for being overweight and obesity in India (Sen et al., 2013; Gouda and Prusty, 2014). The present study also found unmarried Limboo individuals with high odds of being overweight and obese. The overweight and obesity were less likely to be associated with individuals dwelling Kacha house and drinking the piped source of water in the present study, as the corresponding odd ratios were significantly below 1.

The indices of central obesity taken in the present study were WC, WHtR and WHR. The high adiposity identified by WC was found associated with age, marital status, occupation, SES, among both male and female Limboo individuals, however, the house types were only found associated with male Limboo individuals. The socio-economic, demographic and life style variables associated with high adiposity given by WHtR among males were age, marital status, occupation, SES, house type and toilets facility and only age among females. Similarly, age marital status, occupation among male and absent of such association among female Limboo individuals with high WHR was observed in the present study. The above-mentioned associations were obtained using χ^2 test.

The association was further assessed using logistic regression and the results were not different than these obtained using χ^2 test. The chances of being at risk of high WC was observed significant for female compared to male, married compared to unmarried individuals, middle age and elderly adults compared to young adults, non-manual and manual occupation compared to unemployed individuals, lastly individuals of high SES. Among the female Limboo individuals, middle age, married, and high SES were observed with highly significant ($p<0.001$) odds. Education and Kacha house were least likely to cause high WC. Interesting the WHtR was observed associated with all the variables associated with high WC. The association was highly significant ($p<0.001$). Additionally, Pakka house was found significantly ($p<0.05$) associated with high WHtR. Further, high WHR was least likely among females and individuals educated upto 8th grade to cause high WHR. Rest of the variables were not found associated with high WHR. Hence, the factors such as sex, age, marital status, occupation, high SES were significant predictors of high regional or central adiposity in the present study.

The chances of being at risk of high WC and WHR were more for female than male individuals (Pradeepa et al., 2015; Meshram et al., 2016b). The regional adiposity assessed by WC and WHR among the population different states of India were found associated with middle age group (40 – 59 years), old age group (>60 years), less educated people, housewife, and service/business holder (Meshram et al., 2016b). Age and high SES was observed with significant odd ratios for being at risk of high WC among the population of Tamil Nadu, Chandigarh, and Maharashtra (Pradeepa et al., 2015). Similar, results were obtained for being overweight/obese defined by WC and BMI among the population of Tamil Nadu, Chandigarh, and Maharashtra using χ^2 test (Pradeepa et al., 2015). The responsible factors for central obesity were closer to the findings of the studies cited above.

4.4 COMPARISON AND CUT-OFFS ESTIMATION OF NEW INDICES OF ADIPOSITY

4.4.1 COMPARISON OF AVAILABLE INDICES OF ADIPOSITY

In a study conducted among Norwegian adults, BMI was the best indicator of skinfolds derived PBF than WC based on ROC-AUC analysis (Kjaer et al., 2015). Studies have found PBF as the better predictor of cardiovascular risk factors compared to BMI (Segal et al., 1987; Oreopoulos et al., 2010; Zeng et al., 2012). The BMI was shown as the better predictor of PBF (skinfolds derived) compared to BAI among Buryat adult men and women (Zhao et al., 2013). The bio-impedance derived PBF among Bangladeshi women explained 45% of BMI (Shaikh et al., 2016). The BMI was found as the better index compared to BAI in predicting bio-impedance derived PBF among Korean women and DEXA derived PBF among Chinese adults (Sung et al., 2014; Lam et al., 2013). Another study among Asians also suggested similar conclusion utilizing MetS as a reference (Lam et al., 2015). Still, other studies have considered BAI as a less reliable measure of adiposity compared to BMI, WC, and HC (Snijder et al., 2012; Freedman et al., 2012; Kuhn, 2014).

In the present study, BMI (AUC 0.95), WC (AUC 0.94) and WHtR (AUC 0.94) were better predictors of excess adiposity than NC (AUC 0.93), BAI (AUC 0.90) WHR (AUC 0.86) and CI (AUC 0.80) among male Limboo individuals. Similarly, among the female Limboo individuals BMI (AUC 0.94), WC (AUC 0.92) and WHtR (AUC 0.90) were better predictors of excess adiposity compared to NC (AUC 0.87), BAI (AUC 0.87) WHR (AUC 0.73) and CI (AUC 0.71). These values were observed using skinfolds derived PBF as a reference. Again using BMI (>23 kg/m^2) as reference WHtR (AUC 0.93) and WC (AUC 0.92) were better predictors of high adiposity followed by BAI (AUC 0.89), NC (AUC 0.87), WHR (AUC 0.76), and CI (AUC 0.63) among male Limboo individuals. Likewise, among female WHtR (AUC 0.91), BAI (AUC 0.91) WC (AUC 0.90) were better index followed by NC (AUC 0.88), WHR (AUC 0.70) and CI (AUC 0.65).

According to AUC analysis WHtR (AUC 0.95) and WC (AUC 0.92) were observed as better predictors of excess adiposity followed by BAI (AUC 0.87), WHR (AUC 0.84), NC (AUC 0.81), and CI (AUC 0.68) among male Limboo individuals using BMI 30 kg/m^2 as reference. Among females, it was BAI (AUC 0.98), WHtR (AUC 0.97), WC (AUC 0.96), followed by NC (AUC 0.93), WHR (AUC 0.79) and CI (AUC 0.77). This comparison was based on BMI (>30 kg/m^2). The study by Marques-Vidal et al. (2012) has shown stronger association of BMI and WC with cardio-vascular risk factors and cytokine than that of BAI. The study was conducted using CoLaus study of a large sample from Switzerland. Similarly, a study based on 1140 female sample drawn from the SUNSET study which consisted of three ethnic groups of Netherlands concluded BMI, WHR and WHtR as a better predictor of cardiovascular risk factors (Snijder et al., 2012). A study among Xavante Indians clearly showed that BAI is not a better predictor of adiposity than WC in men or BMI and WC in women (Kuhn, 2014). Another important study in this regard concluded that BAI indicated only total adiposity not risk factors (e.g., Hung et al., 2012; de Lima et al., 2012). Studies suggest further investigations in this respect (Hung et al., 2012; Marques-Vidal et al., 2012; Snijder et al., 2012; Gupta and Kapoor, 2014). Therefore finding of the present study also suggests BAI cannot take the place of BMI and other regional adiposity indices like WC and WHtR.

The implication of regional adiposity is now well known fact. NC can be considered as a measure of upper body adiposity which is relatively easy to assess.

Studies have reported a significant and strong association of NC with the conventional measures of abdominal adiposity like WC, WHR, WHtR and BMI (Hingorjo et al., 2012; Ozkaya and Tunckale, 2016; Joshipura et al., 2016; Assyov et al., 2017). MetS was found to be associated with NC (Joshipura et al., 2016; Yan et al., 2014; Assyov et al., 2017; Pereira et al., 2014; Liang et al., 2015). Studies have investigated the cardiovascular risk, diabetes and other mortality risk based on NC (Medeiros et al., 2011; Liu et al., 2015; Dai et al., 2016; Yoon et al., 2016; Cho et al., 2015). However, both NC and BAI were no better than the indices like BMI, WC, WHtR, and WHR as observed among the Limboo individuals of the present study.

4.4.2 SUITABLE CUT-OFFS FOR BAI AND NC

A number of studies have successfully utilised the ROC-AUC analysis for deciding population specific cut-offs as in the present study (Yang et al., 2010; Hingorjo et al., 2012; Lindarto et al., 2016; Mondal et al., 2017). Here the comparison of cut-off observed in the present study with other such available cut-offs was done. In the present study cut-offs of BAI was 27.38 % (sensitivity of 91% and specificity of 71%) and 35.35 % (sensitivity of 68% and specificity of 90%) for male and female, respectively in the present study using PBF as reference (25% for male and 30% for female). The BAI > 25.68 % (sensitivity 89%; specificity 77%) and > 30.90 % (sensitivity 90%; specificity 75%) were identified as the suitable cut-offs using BMI > 23 kgm2 as reference. When BMI > 30 kg/m^2 was used as reference, the cut-offs for BAI were 30.93% and 35.90%, respectively for male and female Limboo individuals. At the level of BMI 30 kg/m^2, the sensitivity and specificity was 80% and 96% for male and 97% and 90% among female, respectively. This suggests that BAI may overestimate the adiposity compared to the available indices like PBF and BMI. The similar finding was put forth by Zwierzchowska et al. (2013). The study by Gupta and

Kapoor (2013) concluded that BAI can be used as an additional marker of adiposity as observed sensitivity and specificity of BAI was closer to BMI.

Further, the cut-offs based on PBF (25% for male and 30% for female) for NC was 36.95 cm and 36.65 cm for male and female Limboo individuals, respectively. The sensitivity and specificity using PBF, were 99% and 77% among males and 68% and 90% among females. The cut-offs of NC estimated based on BMI (> 23 kgm2) were 35.55 cm for male and 31.70 cm for female Limboo individuals. The corresponding sensitivity and specificity was 85% and 85% among males and among females, it was 75% and 85%. Similarly, BMI > 30 kg/m^2 as reference the cut-offs found were 38.25 cm and 33.15 cm for NC among male and female Limboo individuals. The sensitivity and specificity were 80% and 92% among males and 90% and 83% among females.

The decided NC > 37 cm for men and >34 cm for women were the best cut-offs for determining the subjects with BMI > 25.0 kg/m^2. Likewise, NC > 39.5 cm for men and > 36.5 cm for women were the best cut-offs for determining the subjects with BMI > 30 kg/m^2 (Ben-Noun et al., 2001). A cut-off of 39 cm and 35 cm for NC among men and women, respectively was suitable for assessing MetS and Obstructive Sleep Apnea Syndrome (Onat et al., 2009). The study conducted by Ben-Noun et al. (2001) and Onat et al. (2009) were among adults of Israel and Turkey. Another study from Beijing China, observed the NC of > 38 cm for men and > 35 cm for women as the best cut-off point for determining overweight subjects. The same study gives NC of > 39 cm for men and > 35 cm for women as the best cut-off point to determine subjects with MetS (Yang et al. 2010). Close to the present study at the BMI of 23.00 kg/m^2 and 25.00 kg/m^2, males had NC of 35.70 cm and 37.50 cm, while cut-offs for females was 32.2cm and 33.5cm, respectively. The study recommended NC of >35.5

cm in men and >32 cm in women as the cut-off points for overweight/obesity among adults of Karachi, Pakistan (Hingorjo et al., 2012).

Some Indian studies have made an effort to established suitable cut-offs for NC (Kumar et al. 2012; Aswathappa et al. 2013; Mondal et al. 2017). These studies were conducted among the adult population of Wardha Maharashtra, Kolar Karnataka, and Karbi Anglong Assam. NC of > 36 in diabetics and > 37 in non-diabetics was put forth as the best cut-offs to identify subjects with central obesity (Aswathappa et al. 2013). Using reference of BMI 25 kg/m^2 corresponding NC was 38 and 34.7 among men and women of Wardha, Maharashtra (Kumar et al., 2012). At the BMI 23.00 kg/m^2 the NC cut-offs given for males and females were 35.5 and 30.4, respectively among the adults of Karbi Anglong, Assam. Similarly, at BMI >30.00 kg/m^2 the given cut-offs were 38.0 and 33.0 for male and female adults of Karbi Anglong, Assam (Mondal et al., 2017). Cut-off levels reported by Hingorjo et al. (2012) and Mondal et al. (2017) among the adults of Karachi Pakistan and Assam India were closer to the cut-off levels identified in the present study especially at the level of BMI 23 kg/m^2 and 30 kg/m^2. The test characterstics like sensitivity and specificity in the present study were not excellent as in the Israeli study of Ben-Noun (2001), yet better than that of Karbi population (Mondal et al., 2017).