A STUDY ON NUTRITIONAL STATUS USING ANTHROPOMETRY AMONG THE LIMBOO POPULATION OF SIKKIM

A thesis submitted to the University of North Bengal for the award of Doctor of Philosophy (science) in Anthropology

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Dedicated to the Limboo people for their good health.

DECLARATION

The thesis titled "*A Study on Nutritional Status using Anthropometry among the Limboo population of Sikkim*" is the result of genuine research carried out by me under the supervision of Prof. Jaydip Sen, Department of Anthropology, University North Bengal, Darjeeling. I further declare no part or full of the thesis has been submitted for any other degree, diploma, associated ship, and fellowship.

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CERTIFICATE

This is to certify that the Ph.D. thesis titled "*A Study on Nutritional Status using Anthropometry among the Limboo population of Sikkim*", submitted to the University of North Bengal, for the fulfilment of the requirements for the degree of Doctor of Philosophy in Anthropology (Science), University of North Bengal, embodies the result of bona fide research carried out by Shri Binu Dorjee under my guidance. No part or full of the thesis has been submitted for any other degree, diploma, associated ship, and fellowship.

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ABSTRACT

Nutritional status can assess optimum level of nutrition available to the community, which has prognostic value for related morbidity and mortality prevailing in the community. Nutritional status is helpful in promoting good health. Increasing overweight and obesity among the populations of developed and developing countries are known to cause diseases like hypertension, diabetes, cardiovascular diseases and certain types of cancer. The situation becomes worst in developing countries like India due to the persisting problem of undernutrition. Such simultaneous existence of undernutrition and overnutrition is a challenge to the policy maker and researchers. Obesity has even penetrated the traditional societies of India. This is intergenerational in nature which starts before conception and pickup during infancy and continues for generations. The alternation between underweight and obesity in a life cycle will soon become common in developing countries due to the exposure to an obesogenic environment and persisting undernutrition. In this background, understanding the prevalence of undernutrition, overweight, and obesity and its determinants is important and provides a stepping stone for further investigation and intervention. The present study is probably the first of its kind conducted among any homogenous population of Sikkim and will provide the basic data on the nutritional status and associated factors.

The objectives of the present study are as follows:

- To assess nutritional status and body fat distribution using anthropometric measurements and derived indices using internationally accepted cut-off points.

- To document associations of different socio-economic variables with nutritional status and body fat distribution.
- To assess age and sex related changes in nutritional status and body fat distribution.
- To compare findings of the present study with other available international and national data.

The present cross-sectional study was conducted among 992 adult Limboo individuals (males: 496; females: 496) aged between 18-64 years of age. The study location was villages of West Sikkim namely, Langang, Tikjek, Linghom, Darap, Singpheng, and Nambu. The individuals were selected using a multistage sampling method. Through this process, 15 villages were listed and then it was reduced to 6 villages depending on distances from the main urban centre of Gyalshing. The villages were selected based on the predominance of Limboo individuals. The data was collected during the period from January 2014 to April 2016 from above-mentioned 6 villages.

The demographic, socio-economic, and lifestyle variables such as sex, age, marital status, education, occupation, monthly income, SES, family size, land holding, house type, drinking water and toilets facility were collected to assess their influences on the nutritional status and the diseases outcomes. Anthropometric measurements such as height, weight, arm span, arm length and mid-upper arm circumference (MUAC), waist circumference (WC), hip circumference (HC), neck circumference (NC) and the skinfolds (BSF, TSF, SSF and SISF) were recorded following standard procedures (Weiner and Lourie, 1981; WHO, 2008; Ben-Noun et al. 2001). Various indices of nutritional status and body composition were derived from the anthropometric measurements were utilised to assess nutritional status exclusively and in combinations. The statistical analyses such as mean ± SD, ANOVA, χ^2, correlation, regression, logistic regression, ROC-AUC were conducted using SPSS 20.

The observed anthropometric measurements such as height, weight, arm span, RAL, LAL, MUAC, NC, SH were significantly high among the male Limboo individuals and adiposity measures like WC, HC, TSF, BSF, SSF, and SISF were high among female Limboo individuals. Similarly, anthropometric indices like CRI, TUA, UMA, BFMA, FFM, and FFMI were observed high among male Limboo individuals and indices of body adiposity such as BMI, BAI, WHtR, WHR, CI, UFA, AFI, PBF, FM, and FMI were observed significantly high among female Limboo individuals. Age related changes were observed in the anthropometric measurements of the male and female Limboo individuals excluding arm span and arm length. Similarly, influence of age was observed in all the anthropometric indices in the present study excluding on CRI among males.

The overall prevalence of undernutrition was 7.56% and 10.18% among Limboo individuals assessed using BMI and MUAC, respectively. The sex specific undernutrition based on BMI among males and females was 6.85% and 8.27%, respectively. The prevalence according to MUAC was 6.45% and 13.91%, respectively among males and females. The sex specific prevalence of overweight using traditional BMI classification was 18.35% and 24.4% for males and females, respectively. Similarly, obesity observed was 2.23% and 5.85% among male and female individuals, respectively. The sex difference in the prevalence of overweight and obesity was significant ($p < 0.05\%$). Using Asia-Pacific classifications, the observed overweight was equal among (17.14%) both sexes, and obese I (24.40%

vs.18.75%) and obese II (5.85% vs. 2.02%) were significantly ($p<0.05$) high among female than male individuals.

The prevalence of central obesity given 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%) were higher than the prevalence given by traditional BMI classification and Asia-Pacific classification. The male Limboo individuals were significantly at high risk by WHR and female Limboo individuals were significantly at high risk by WC, WHtR, and CI. The prevalence of obesity related risk simultaneously identified by BMI and one of the central obesity indices such as WC (male: 42.94%; female 10.89%), WHtR(male: 34.88%; female 46.77%), WHR (male: 37.90%; female: 46.77%), and CI (male: 21.17%; female: 45.16%) is worth concern for health policy and planning. Prevalence of normal weight central obesity by different combination like WC and BMI (male: 16.13%; female: 0%), WHtR and BMI (male: 13.91%; female: 35.48%), WHR and BMI (male: 61.09%; female: 48.59%), and CI and BMI (male: 22.38%; female: 46.77%) was alarming given its association with CVDs.

However, the prevalence of elevated adiposity assessed using PBF and FMI ranged from 1% to 7.96%, which is less than the prevalence given by various BMI and central adiposity indices. In spite of relatively low adiposity given by PBF and FMI, the absence of normal individuals based on FFMI with a large number of Individuals falling under the low FFMI category can cause sarcopenia, thereby leading to NCDs.

Undernutrition assessed by BMI was less likely to associate with any of the factors taken in the study. The overweight and obesity based on BMI were observed to be influenced by factors like sex, occupation, age, marital status, family monthly income, and SES. The central obesity assessed by WC and WHtR was associated with sex, age, marital status, occupation, family monthly income.

The present study population is at risk of adiposity related mortality and morbidity. The prevalence of adiposity was higher in the Limboo individuals of the present study compared to the rural and tribal populations of India.

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Chapter 1

INTRODUCTION

1.1 OVERVIEW

Nutrition is not just confined to biochemical or physiological processes involved in the intake and utilization of food substances by living organisms, including ingestion, digestion, absorption and metabolism of food, as it is usually defined (Norgan, 2002). Nutrition may be interpreted in a broader sense and be affected by a variety of psychological, sociological and economic function (Williams, 1999). This reflects the involvements of psychology, anthropology, sociology and economy in nutrition, diet and food policy planning. The definitions are not comprehensive if they are not willing to incorporate social welfare aspects of nutrition research which is firmly established. It is rightly pointed out nutrition science will be effective to address the relevant challenges and opportunities of the twenty-first century only as an integrated biological, social and environmental science.

Such an integrated approach is the mainstay of epidemiology, public health and biological anthropology when dealing with nutrition. In the broader sense science of nutrition is driving towards two major directions. First is more reductionist in its approach as it moves from biochemistry, physiology to gene and genomics. The other one is more toward the social and economic aspects of nutrition. This aspect of nutrition science is described more vividly by Kazarinoff and Habicht (1991) where on one side of spectrum lies molecular genetics, molecular biology, biochemistry, physiological chemistry, cell biology, analytical chemistry via psychology, physiology, pathology, immunology, clinical sciences reaches to epidemiology, sociology, anthropology, economics, policy sciences, demography and education on the other end of the spectrum. Hence, nutrition science is much wider in its research span as new technology and new societal change created new possibilities and demands (Pelletier et al., 2013). If one holds on the view that nutritional science is an integration of biological, social and environmental science than it will be easier to apply the findings of nutrition science to humanity and to deal with rising challenges.

The view of anthropology on nutrition is more comparative and evolutionary. Biological anthropologists are interested in the nutrition of contemporary populations, historic and pre-historic populations, and the *hominins* of evolutionary past (Dufour and Piperata, 2018). So, the three thematic areas of the biological anthropologist are

i) diet in the evolution of genus *Homo*,

ii) diet and nutrition in the transition from hunting and gathering to agriculture, and

iii) diet and nutrition in the current era of globalization.

The present study falls under the third thematic area of biological anthropology. The emergence of more or less discrete sub-discipline of nutritional anthropology dated back to 1970s when several review were published with more emphasis on social-cultural anthropology (Strickland and Tuffrey, 1997). Nutritional anthropology has been defined as 'the study of the interrelationship between diet and culture and their mutual influence upon one another' (Freedman, 1976). In this sense, nutritional anthropology revolves around the theories of socio-cultural anthropology to solve various problems of humanity related to diet and health. Subsequent efforts have been made to give it a more interdisciplinary approach with inputs from biological anthropology, public health and epidemiology (Haas & Pelletier, 1989, Unger et al., 2006). Indeed, a large depository of work generated using anthropometry to document nutritional character of the population around the world can be considered as a part of nutritional anthropology (Dorjee and Sen, 2016). The incorporation of nutritional anthropometry is well justified in the light of five direct methods put forth by D.B. Jelliffe in the year 1966 for the assessment of nutritional status. These are anthropometric measurement, biochemical assessment, clinical examination, dietary survey and vital statistics (Jelliffe, 1966).

Anthropometry remains unique to biological anthropology and has been continuously used to assess nutritional status of populations around the world. Nutritional status is the extent to which nutrients are available to meet metabolic needs, which is usually measured based on the various indices available. Nutritional status further infers that availability of various nutrients to individual and population, which has prognostic value for the related morbidity and mortality. Nutritional status is now recognized to be a prime indicator of the overall health of a population or an individual. The ultimate objective of nutritional assessment studies is related to the overall improvement of the quality of human health (Beghin et al., 1988).

Among five methods given by Jelliffe (1966) anthropometry is the mainstay of the present study. Since anthropometry is the technique employed in the present study a brief account of its development and facets are discussed.

1.1.1 ANTHROPOMETRY

Anthropometry is the science of human body measurements. The actual origin of anthropometry lies in arts not in science or medicine, artists working on to produce life like images were confronted with the right proportions and accuracies for which they devices scales and instruments. The artists involved in the pursuit of right proportions were influenced by the Pythagorean philosophy where man was made on the image of God and God was considered most immanent in number, proportion and harmony. So the artists were in rigorous search of that simple, linear and harmonic number of proportion. In this regard Vitruvius rule of human proportion can be considered as the first known contribution followed by Leon Battista Alberti (1404-1472) who is credited as the first person to devise an instrument to measure people. Another important contributor in this line of progress was a German physician, Johann Sigismund Elsholtz (1623-1688) who coined the term "Anthropometry" and also constructed the first anthropometric rod. Introduction of the meter in 1795 was another landmark development in this regard before which there was lots of variation in the scales used. This was a major difficulty faced by those involved in the pursuits of proportion and harmony (Tanner, 1981). During the 1740s the study of growth of the fetus and the young child were seriously pursue by Buffon. Probably he was the first to measure the human fetus, yet, procedures for taking measurements are unknown. Buffon influenced his friend, Montbeillard, to undertake the first growth study from birth to maturity.

The first longitudinal growth study from birth to maturity conducted by Montbeillard was on his son from 1759-1777, which is available on record. Minimum information on how measurements were recorded can be inferred from his publication (Tanner, 1981). Another intentional study conducted in this regard was records of boys' height of a famous institute, The Carlschule, which can be found in the Stuttgart City Archives. This is the second source of longitudinal growth studies (Tanner, 1981). Another study discussed by Tanner (1981) in this regard is a set of boys' data on height of the Marine Society of the United Kingdom. This is how search of harmony and proportions paved the way for the development of anthropometry during seventeen century and shaped the understanding of human growth.

It was Villerme who first conducted the anthropometric measurement with the purpose of human welfare. This Frenchman is considered as the chief founder of public health and public concern in France. As a surgical assistant in the Napoleonic wars, he became aware of misery of war and famine and postwar effects on manual laborers and prisoners. In 1829 Villerme published his classical analysis of the effect of poverty on the height of French recruits. Immediately after this, Quetelet conducted a first cross-sectional population survey of children, which actually comprises of two surveys first of height only and second of height and weight. This trend and tradition was continued later through the measurements in schools and infant welfare clinics and the London County Council Surveys of 1905 to 1965, to the modern British growth standards and the National Surveys of Health and Growth of 1970s. This activity is term as auxological epidemiology, the use of growth data to search out, and later to define, sub-optimal conditions of health (Tanner, 1981). Flourishing practice of human body measurement progressing through proportion and beauty to understanding growth and finally to human welfare is still a most widely use technique in the field of growth study and nutritional anthropometry.

Selection of conscripts and slaves is another area of the practice of anthropometry. This was mainly driven by then prevailing idea of human resource. In the nineteenth century, anthropometry was used in the creation and validation of racial typologies. This idea was challenged and overturned in the second half of the twentieth century with empirical testing of evolutionary and ecological mechanisms for human biological variation. Important insights were from Boas (1912) in his understanding of plastic opposed to typological of human morphology (Tanner, 1981; Ulijaszek and Komlos, 2010). After the recognization of human physical plasticity by Boaz (1912), it was used in the Human Adaptability section of the International

Biological Programme (HAIBP) studies as an explanatory framework for human adaptation. In fact, HAIBP studies strengthened anthropometric practice and standardized various parameters, which is still used in the field of nutritional anthropometry as a standard protocol (Ulijaszek and Komlos, 2010). Pioneering anthropometric approachs to body composition was made by the Czeck anthropologist Jindrich Matiegka and details were published in the American Journal of Physical Anthropology in the year 1921 (Brozek, 1961; Brozek and Prokopec, 2001).

The present study deals with nutrition anthropometry. Anthropometry is the single most universally applicable, inexpensive and non-invasive method available to assess the size, proportions, and composition of the human body (Sen et al., 2011; Sen and Mondal, 2012). Growth in children and body dimensions at all ages reflect the overall health and welfare of individuals and populations (Radhakrishna, 2012). Anthropometry is also utilized to predict performance, health and survival (WHO, 1995; Ahmad et al., 2006; Singh and Mehta, 2009). Recent research and understanding have demonstrated the relevance of anthropometry throughout life, not only for individual assessments but also for reflecting the health status and socio-economic circumstances of population groups (Gorstein and Akre, 1988; Steckel, 1995; WHO, 1995; Komlos and Snowdon, 2005).

Anthropometric measurements have advantage over other methods like clinical signs of malnutrition, biochemical indicators, and physical activity as indicators of nutritional status. Among these, anthropometric measurements should be preferred since body measurements are highly sensitive to even minor levels of malnutrition whereas biochemical and clinical indicators are useful only when the level of malnutrition is extreme (de Onis, 2000; Radhakrishna, 2012). Recent research has expanded the applications of anthropometry to include predicting who will benefit from interventions, indentifying social and economic inequity and evaluating responses to interventions (WHO, 1995; Bogin and Keep, 1999; Komlos and Baur, 2004).

Understanding nutritional status of vulnerable section of population like children, women and elderly are important (Gorstein and Akre, 1988; Sen et al., 2010a; Sen et al., 2011; Sen and Mondal, 2012; Sen and Mondal, 2013). However, idea about the health and nutritional status of adult men and women are also equally important as they form the backbone of the society. The demands of physical activity and productivity at work and role of breadwinner in the family is significant for economic growth of any country (Strickland and Tuffrey, 1997). Healthy children are better able to learn, and healthy adults are better able to contribute socially and economically (WHO, 2013). Nutritional status assessed using anthropometric characteristics of adults may serve as early guide to households and communities at nutritional risk.

1.2 LITERATURE REVIEW

The present study is solely concerned with anthropometric characteristics which signify the nutritional situation of the population under study. It further seeks to understand the associations of various socio-economic, demographic and life-style related factors on the anthropometric characteristics under study.

The major portion of literature search relevant to the field of the study has been conducted using “PubMed”. It is a free online database with over 27 million citations for biomedical literature from MEDLINE including life science journals, and online books relating to the fields of biomedicine and health, covering portions of the life sciences, behavioral sciences, chemical sciences, and bioengineering. This web base resource is developed and maintained by the National Center for Biotechnology Information (NCBI), at the U.S. National Library of Medicine (NLM), located at the National Institutes of Health (NIH) (https://www.ncbi.nlm.nih.gov/pubmed). Google and Google Scholar were also utilized to some extent. Literatures were also obtained through personal communication with some authors.

1.2.1 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG CHILDREN

Nutrition forms the foundation for normal human health and development. The process of malnutrition often starts in utero, and the first 1000 days of a child's life between a women's pregnancy and child's 2nd birthday are considered important for the normal growth and cognitive development. Girls and women remain vulnerable throughout the life cycle. Undernutrition like stunting and underweight among female children if continued through adult life also increases the chances of her children being born malnourished (Gillespie and Flores, 2000; Collins et al., 2003; Mason et al., 2014). Studies have reported the incidence of low birth weight (weight < 2500 kg at birth) among economically deprived section of societies (Collins et al., 2003, 2015; Sen et al., 2010b; Verropoulou and Basten, 2014; Esimai and Ojofeitimi, 2014; Gong et al., 2015). The prevalence of low birth weight is high in Asia than anywhere else and programs for its elimination should focus on intra-uterine growth retardation, prenatal care and maternal nutrition (Muthayya et al., 2009; Mason et al., 2014). Hence the studies of Tofail et al. (2012), Chiang Mai Low Birth Weight Study Group (2012), Wang et al. (2014), Shakya et al. (2015), Chang et al. (2014) are mentionable. Studies have also suggested the impact of low birth weight on adolescent and adult anthropometry (Harada et al., 2012, 2013). Breastfeeding and weaning practices during infancy are also important correlates of malnutrition among under 5-year old children with significance bearing on adult life. Any deviation during this period is irreversible (Zhou et al., 2012; Engebretsen et al., 2014; Roba et al., 2016).

Approximately 200 million children are unable to attain their full development potential because of stunting and micronutrient deficiencies (WHO, 2013; Christian et al., 2016). Malnourished children suffer from longer and more severe illnesses (Black et al., 1984; Sepulveda et al., 1988) and have a higher risk of mortality and morbidity (Schroeder and Brown, 1994) as compared to well nourished ones. The developmental delays like cognitive and motor development were found to be associated with preterm and low birth weight babies (Dewey et al., 1999,2011; de Kieviet et al., 2009; Oliveira et al., 2011;). Stunting and wasting were also reported to cause such developmental delays (Crookston et al., 2011a,b; Sudfeld, 2015a, 2015b; Christian et al., 2016).

The commonly used anthropometric measurements among children and adolescents are stunting (low height-for-age), underweight (low weight-for- age) and wasting (low weight-for-height) which were considered to be associated with specific biological process of growth failure (WHO, 1995, 2007; Rogol and Hayden, 2014). Studies have reported prevalence of stunting, wasting and underweight from many developing countries of the world (Casale et al., 2014; Darteh et al., 2014; Gaurav et al., 2014; Neufeld and Osendarp, 2014; Motbainor et al., 2015; Hasan et al., 2015; Olofin et al., 2013; Jiang et al., 2015; Semali et al., 2015; Chirande et al., 2015; Demirchyan et al., 2016; Kinyoki et al., 2016). These studies reported the prevalence of undernutrition among children from birth to 60 months of age. Studies have also utilized MUAC-for-age and MUAC-for-height (de Onis et al., 1997) for assessment of nutritional status.

All of the above conventional indices of nutritional status are expressed in terms of Z-scores or percentiles. The WHO recommends a comparison of these indices with an international reference population to determine undernutrition (Dibley et al., 1987). The justification for use of a reference population is the empirical finding that well-nourished children of all populations follow very similar growth patterns (Habicht et al., 1974).

Studies have highlighted the rising prevalence of undenutrition among Indian children (Measham and Chatterjee, 1999; Bamji, 2003; Bishno et al., 2004: Dolla et al., 2005). According to a recent review prevalence of undernutrition among under-five year aged children was high (under-weight: 39-75%; stunting: 15.4-74%; wasting: 10.6-42.3%) (Sahu et al., 2015). Studies have also highlighted associations of poverty, poor hygiene, illiteracy and lesser investment in public services with high prevalence of undernutrition in India, inspite of the country’s economic growth (Sen et al., 2010b; Sahu et al., 2015; Vijayaraghavan, 2016; Singh et al., 2017). Studies have shown the association of BMI with dental caries among children (Aluckal et al., 2016; Kumar et al., 2017). A large number of studies have used the conventional measures of low height-for-age, low weight-for- age, and low weight-for-height to assess the undernutrition among children below 5 years of age (Nandy et al., 2005; Bose et al., 2007; Mondal and Sen, 2010a; Sen and Mondal, 2012; Som et al., 2006; Sen et al., 2011).

Thinness based on BMI-for-age as proposed Cole et al. (2000, 2007) is considered to be more efficient in the sense it helps to interpret BMI of children and adolescents in line with adult BMI, which also facilitates direct comparison of different grade of thinness. The cut-off points were derived based on multicentre data from four developed countries (United States, Great Britain, Hong Kong, Netherlands) and one developing country (Brazil) from 2-18 years old individuals. Studies have successfully utilized these cut-offs to report the magnitude of thinness among Indian children (Medhi et al., 2006, 2007; Mishra and Mishra, 2007; Bose and Bisai 2008; Biswas et al., 2009; Chakraborty and Bose, 2009; Mandal et al., 2009; Bisai et al., 2010; Bisai and Manna, 2010; Mondal and Sen, 2010a; Das and Bose, 2011; Dorjee, 2015; Tigga et al., 2015).

Some studies were undertaken on the body composition of children were Bose et al. (2005), Sen and Mondal (2013). Studies on low birth weight infants were also reported from the country (Hirve and Ganatra, 1994; Basai et al., 2007; Sen et al., 2010b). Low birth weight related developmental delay among children was observed by Adde et al. (2016) and Mukhopadhyay et al. (2016). The associations of low birth weight with maternal nutritional status, body composition and socio-economic variables were also observed (Hirve and Ganatra, 1994; Basai et al., 2007; Sen et al., 2010b). Studies have also shown the positive impact of community base intervention on nutritional status of tribal and non-tribal children (Prasad et al., 2018; Devara and Deshmukh 2017; Jayalakshmi and Jissa, 2017).

1.2.2 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADOLESCENTS

Adolescence is a transition phase between child and adult which is accompanied by various changes in an individual’s body towards adulthood still retaining some childhood characters. Adolescence begins with pubescence, the development of secondary sexual characteristics, and continues until morphological and physiological changes near adult status (WHO, 1995). The WHO has defined individuals aged between 10-19 years as adolescents.

During this period of life individuals may suffer from substances abuse, sexually transmitted diseases, pregnancy, and accidental and intentional injuries, which could be the result of various ongoing psychosocial, morphological and biological changes. In the same phase of life growth acceleration is experienced by adolescents, known as adolescents growth spurt. In the same phase of life individual may exposed to obesity inducing environment, which make them susceptible to chronic diseases like cardiovascular diseases (CVDs), diabetes, and cancer etc in later life.

The behaviours identified by the Minnesota Adolescent Health Survey and other studies among adolescents include high prevalence rates of inadequate intake of fruits, vegetables, and dairy products; unhealthy weight-control practices; and overweight status (Neumark-Sztainer et al., 1996, 1998). A significant review by Kurz et al. (1996) conducted on nutritional status of adolescent boys and girls of Benin, Cameroon, Ecuador, India, Jamaica, Mexico, Nepal, Guatemala, and the Philippines reported high anemia and slow growth. The study further highlighted sex difference in BMI-related weight gain. Similarly, Shahabuddin et al. (2000) reported high prevalence of stunting and anaemia among rural adolescents of Bangladesh. Studies from Bangladesh, also reported correlates (poor personal hygiene, lack knowledge about nutrition and socio economic status and education) of stunting and thinness among adolescents girls along with prevalence of stunting and thinness (Rah et al., 2009; Alam et al., 2010).

Wasting along with micronutrients deficiency was reported to be higher among children aged above 12 years compared to children below 12 years of age (Sarraf et al., 2005). Undernutritions including thinness, iron, and zinc deficiencies were reported in school children and adolescent of Dakar, Senegal, West Africa (Fiorentino et al., 2013). A study from Mizan district of Ethiopia reported high prevalence of underweight and stunting among adolescent girls with significant rural-urban difference in stunting (Berheto et al., 2005). Another study reported prevalence of stunting among children, and overweight and obesity among adolescents in rural South Africa (Kimani-Murage et al., 2010).

Adolescence is a phase of rapid growth and development during which physical, physiological and behavioural changes takes place. Adolescents constitute more than 1.2 billion worldwide, and nearly 21% of Indian population (Census of India, 2011). Thinness, stunting and overweight were reported among adolescents Bengali boys by de Onis et al. (2001). The study further emphasized on the need of population specific reference data. The BMI of Khasi adolescents were compared with Indian and non-Indian populations and efforts were also made for ethnic specific references (Basu et al., 2013). Many other studies have reported stunting and thinness among the adolescents of India (Anand et al., 1999; Venkaiah et al., 2002; Das and Biswas, 2005; Deshmukh et al., 2006; Das et al., 2007; Malhotra and Passi, 2007; Medhi et al., 2007; Mondal and Sen, 2010c; Sil et al., 2011; Mondal and Terangpi, 2014; Roy et al., 2016).

A significant study observed declined stunting (11.2% to 4.9%) and thinness (50.5% to 22%), and increased overweight (4.7% to 17.2%) among adolescents of Kolkata. The factors strongly related with positive changes in anthropometric traits were maternal education and family expenditure (Dasgupta et al., 2008). Secular trend was observed among children, adolescents, and young adults of Kolkata along with influence of socio-economic status (SES) (Dasgupta, 2015). Increasing prevalence of overweight and obesity were observed among adolescents of affluent sections of Indian society (Faizi et al., 2017). High prevalence of obesity and central obesity were observed among the adolescents and young adult students (Pengpid and Peltzer, 2014). The Calcutta Childhood Obesity Study have shown the influence of family income on the study population, thinking of obesity, thinking of taking too much fast and junk foods, breakfast skipping, extra salt consumption, and spending time with computers on their BMI (Ghosh, 2014). Goyal et al. (2011) showed the association of BMI with socio-economic status. The rising prevalence of overweight and obesity were also shown among children and adolescents of Kashmir (Ganie et al., 2017). Another study from West Bengal reported rising BMI and PBF among adolescents (Chatterjee et al., 2006).

A study examined blood pressure levels, adiposity and growth of adolescent boys from high and low social classes of Indian society (Rao and Apte, 2009). A strong association of elevated blood pressure with neck circumference and BMI was reported among urban and rural adolescents of Tamil Nadu (Goel et al., 2016; Rajagopalan and Balaji, 2017). Body fat distribution was observed to be associated with hypertension in West Bengal (Ghosh and Bandyopadhyay, 2013). The association of BMI with dental caries among children and adolescents were also documented (Subramaniam and Singh, 2011; Kottayi et al., 2016). Mid Upper-Arm Circumference (MUAC) were also put forth as alternative measure of overweight and obesity among adolescents (Jaiswal et al., 2017).

Upper-arm anthropometry was used to assess body composition among children and adolescents of Assam, Meghalaya and West Bengal (Chowdhury and Ghosh, 2009; Basu et al., 2010; Sen et al., 2011; Jaswant and Nitish, 2014). Upper-arm composition utilizes MUAC and tricep skinfold measurement and is a good alternative measures of nutrition reserved in the body. Studies have also focused on body fat distribution and body composition among adolescents (Chowdhury and Ghosh, 2013; Dasgupta, 2015; Garg et al., 2016). Studies have also utilized BMI-for-age to assess the nutritional status of adolescents (Kulkarni et al., 2014; Deshmukh et al., 2006).

The prevalence of thinness and cardio-metabolic risk among adolescents of Delhi was observed (Garg et al., 2013). Rural-urban comparison of anthropometry and menarcheal status were reported among adolescence girls of Rajasthan (Choudhary et al., 2016). Association of nutritional status with menarcheal age and per capita income was also observed among young adults (Ghosh et al., 2009). The effects of nutritional programs and prevalence of stunting among south Indian tribal adolescents was documented by Thomas et al. (2013). Studies of body fat pattern and body composition were also under taken among adolescents (Mukhopadhyay et al., 2005a, 2005b; Chowdhury et al., 2008).

1.2.3 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS

The double burden of malnutrition is now one of the leading global causes of death and disability (Shafique, 2007; Winichagoon, 2013). Obesity among men has increased from 3.2% to 10.8% and among women it has increased from 6.4% to 14.9% from 1975 to 2014 (NCD-RisC, 2016). At the same time underweight remains a major problem for developing countries including India with a meager reduction from 13.8% to 8.8% in men and 14.6% to 9.7% in women from 1975 to 2014 (NCD-RisC, 2016). Obesity has increased among the population of developed countries and urban population of some developing countries. High prevalence of underweight is reported from the south Asia (men: 23.4% and women: 24.0%) followed by central and east Africa (men: 15% and women: 12%) (NCD-RisC, 2016). The rapid increase of obesity and slow decrease of undernutrition is a challenge for policy maker. Nutritional assessments have a potential role to play in formulating developmental and nutritional intervention strategies.

1.2.3.1 Undernutrition

Height and weight are the two frequently used anthropometric measurements to assess undernutrition. The body mass index (BMI) is the measure of weight relative to the height. This was first formulated by Adolphe Quetelet in the year 1832, hence also known as Quetelet index. The index is based on the concept that “the weight increases as the square of the height”. Keys (1972) compared and validated the available different indices of relative weight and confirmed the validity of Ouetelet index, terming it as Body Mass Index. The BMI is generally considered to be good indicator of both the nutritional status and socio-economic condition of the population (Ferro-Luzzi et al., 1992; Shetty and James, 1994). It has been extensively used as an indicator of undernutrition (Weiner and Lourie, 1981; James et al., 1988, 1994; WHO, 1995; Lee and Nieman, 2005).

Undernutrition can be defined in terms of chronic energy deficiency (CED). The BMI is recommended to define adult CED by the International Dietary Energy Consultative Group in the year 1992 (Norgan, 1994; Bailey and Ferro-Luzzi, 1995;

Weisell, 2002). The CED is defined as a “steady state” where an individual is in energy balance, i.e. the energy intake equals the energy expenditure, despite low body weight and low energy stores (FAO, assessed on 3-11-2016). This has been considered as adaptive with some cost, which is reduction in total energy expenditure which in turn results in lower body size and less physical activity (Khongsdier, 2005; Kurpad et al., 2005). The BMI <18.5 kg/m^2 is considered as CED which is further graded into three category such as Grade I (mild), Grade II (moderate) and Grade III (severe).

CED is caused by inadequate intake of energy accompanied by high level of physical activities and infections (Shetty and James, 1994; Shetty et al., 1994) and is associated with reduced work capacity (Pryer 1993; Durnin 1994), performance and productivity (Kennedy and Garcia, 1994). It is likely to be associated with morbidity or other physiological and functional impairments (Chakaborty et al., 2006). Supplementation during CED may lead to rapid fat accumulation in the body. This factor raises the risk of susceptibility to various deleterious consequences (Kurpad et al., 2005).

There is now clear evidence suggesting that individuals exhibiting low BMI have more sickness, a lower work capacity, limited social activity, and a low income (Rotimi et al., 1999; Bose et al., 2007; Sen et al., 2010b; Hanrahan et al., 2010). Mothers with low BMI have a greater proportion of low birth weight babies compared with those who are normal (Allen et al., 1994; Hirve and Ganatra, 1994; James 1994; Prentice et al., 1994; Karim and Mascie-Taylor, 1997; Rotimi et al., 1999; Sen et al., 2010b).

Other factors responsible for CED are low SES, education, age and gender (Khongsdier, 2002; Bharati et al., 2007). Poor sanitation and infectious diseases can also lead individuals to undernutrition (Sahn and Younger, 2009; Chantler et al., 2016 and Janmohamed et al., 2016). Studies reporting the prevalence of undernutrition using BMI from developing countries includes that of James et al. (1988), Immink (1992), Ferro-Luzzi et al. (1992), Pryer (1993), Giay and Khoi et al. (1994), Berdasco (1994), Ismail et al. (1995), Ahmed et al. (1998), Lim and Chee (1998), Rotimi et al. (1999), Winkvist et al. (2000), Nyaruhucha et al. (2001), Nube et al. (2003), Faruque et al. (2006), Azmi et al. (2009), Pei (2013), Huong et al. (2014), Asiimwe et al. (2015) and El Kishawi et al. (2016).

The Mid-Upper Arm Circumference (MUAC) is another widely used anthropometric indicator of undernutrition (James et al., 1994; Ferro-Luzzi and James, 1996). A change in MUAC tends to parallel changes in muscle mass and is a useful indicator of protein-energy starvation (Harries et al., 1984). Thus, changes in the arm circumference reflect the increase or decrease of tissue “reserves” of energy and protein (WHO, 1995). MUAC has two main advantages such as its portability and universal applicability (Sen et al., 2010a). This make MUAC better suited for emergency intervention like in famine and post conflict situations and in bed ridden patient. The combine use of BMI with MUAC can provide a better assessment of CED (Ahmed et al., 1998; Dorlencourt et al., 2000; Gartner et al., 2001; Basai and Bose, 2009; Ghosh and Bose, 2015), and recently, the target group for intervention was observed to be reduced when only BMI were used to define CED (Bisai and Bose, 2008; Ghosh and Bose, 2015).

Studies have shown the relationship between low MUAC of mother and risk for low birth weight (Assefa et al., 2012; Sebayang et al., 2012; Ramlal et al., 2012; Ververs et al., 2013; Chen et al., 2014; Hambidge et al., 2018). Studies from Vietnam, Bangladesh, India have provided cut-offs for MUAC among adults men and women (Rodrigues et al., 1994; Nguyen et al., 2014; Sultana et al., 2015). Lower MUAC was observed to be associated with higher risk of mortality among adults (Irena et al., 2013, de Hollander et al., 2013; Chen et al., 2014; Asiimwe et al., 2015; Kamiya, 2016). Similarly studies have shown the influence of SES on MUAC (Baqui et al., 1994; Suzana et al., 2002; Assefa et al., 2012; Sengupta and Sahoo, 2014). Other study conducted using MUAC among adults of developing countries has successfully shown the prevalence of undernutrition (Ahmed et al., 1998; Bose et al., 2006a; Bisai and Bose, 2009; Das and Bose, 2012; Briton et al., 2016; Tang et al., 2013; 2017).

1.2.3.2 Overweight and obesity

Studies have reported the prevalence of overweight/obesity along with undernutrition from the developing countries of the world (Shafique et al., 2007; Chhabra and Chhabra, 2007; Romaguera et al., 2008; Tuan et al., 2008; Sola et al., 2011; Gunaid 2011; Hoque et al., 2015). It has also been reported that countries in transition to westernized lifestyles are experiencing substantial increase in its prevalence. The primary environmental determinants of obesity are high calorie intake and low levels of physical activity (Poston and Foreyt, 1999; Harnack et al., 1999; Ismail et al., 2002; Partonen 2014; Rathnakaye 2014; Sartorius et al., 2015; Trivedi et al., 2015). Such prevalence of overweight/obesity makes a population highly susceptible to diseases like type 2 diabetes mellitus, cardiovascular diseases, hypertension and cancer (Freedman et al., 2010; Kee et al., 2011; Malaza, 2012; Zhao et al., 2013). This is evident from the rising premature deaths (the death under the age of 70) worldwide due to Non-Communicable Diseases (NCDs). An estimated 52% of such premature deaths were due to NCDs in the year 2012. Over three quarters of those premature deaths were caused by CVD, cancer, diabetes and chronic respiratory disease (CRD). In terms of mortality the leading NCD is CVD which claimed 17.5 million lives in 2012 which includes 7.4 million due to coronary heart disease and 6.7 million to stroke. The CVD is followed by cancer (8.2 million, with 4.3 million under age 70), and then CRD (4.0 million) and diabetes (1.5 million). Diabetes is also a risk factor for CVD, with about 10% of cardiovascular deaths caused by higher-than-optimal blood glucose level (World Health Statistics, 2016).

The World Health Organisation has defined Body mass Index (BMI) above 25 kg/m^2 as overweight and above 30 kg/m^2 as obese (WHO, 1995). It is a well accepted benchmark definition of obesity. BMI above 30 kg/m^2 usually identifies risk of ill health and metabolic syndrome. The available WHO criteria are based on the association of BMI with morbidity and mortality. These studies were mostly conducted among the European population (WHO, 1998). Similarly, association of BMI with morbidity and mortality were reported from the different population of the world (Costa, 1993; Allison et al., 1997; Calle et al., 1999; Khongsdier, 2002, 2005; Janssen, 2007; Lee, 2010; Aekplakorn et al., 2011; Aoki et al., 2014; Padwal et al., 2016).

However, obesity is by definition a condition of excess fat, not excess weight. Sport persons, athletes and fitness freak may have high weight without being fatty and their BMI usually range high (Deurenberg et al., 2002). In other word their BMI is high due to excess lean mass not fat mass. In fact BMI is a measure of general obesity and used as surrogate for body fat among adults. Thus BMI is a simple tool to screen an overweight or obese status which cannot differentiate between fat and lean body mass, especially in people with a BMI of <30kg/m^2 (Bastein et al., 2014; Lavie et al., 2009; Weig et al., 2016). Hence, BMI should be always interpreted in combination with diseases, smoking, blood pressure, serum lipids, glucose intolerance and types of fat distribution not in isolation (WHO, 1995). This is also corroborated in a recent study (Hung et al., 2017). Studies have shown high correlation between BMI and percentage body fat (Zhao et al., 2013; Gupta and Kapoor, 2014; Banik et al., 2016). Recent research reported strong correlation of BMI with BF % estimated by bioelectrical impedance among adults (Ranasinghe et al., 2013; Heo et al., 2012; Kupusinac et al., 2014; Limpawattana et al., 2014; Shaikh et al., 2016). High body fat percentage at lower BMI is usually observed to be risk factor for CVD among Asians (Deurenberg and Deurenberg-Yap, 2001; Oliveros et al., 2014). Such a low BMI and high body fat percentage were also reported among Australian aboriginals (Norgan, 1994, 1995; Piers et al., 2003). Beside, ethnic differences, age and gender also have significant influence on relation between percentage body fat and BMI (e.g., Deurenberg-Yap et al., 2000; Shah et al., 2005; Kolt et al., 2007; Shaikh et al., 2016).

Owing to general nature of BMI and the rise of studies supporting central obesity as the cause of actual obesity related morbidity, the 1997 WHO Expert Consultation on Obesity recognized the importance of abdominal fat mass (WHO, 2008). The abdominal adiposity may fall between total body fat and BMI which is also referred as abdominal, central or visceral obesity. This change in the focus from general obesity to central obesity is largely based on the rationale that increased visceral adipose tissue is associated with a range of metabolic abnormalities, including decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD (Feldstein et al., 2005; Kaplan et al., 2014; Qi et al., 2015). The alternative measures that reflect abdominal adiposity, such as waist circumference, waist–hip ratio and waist–height ratio, have been suggested as being superior to BMI in predicting CVD risk.

The waist circumference (WC) is a simple and direct measure of central adiposity. It was found associated with increase risk in hypertension and diabetes in African American women (Warren et al., 2012). WC is well considered as a metabolic syndrome along with high triglycerides, low cholesterol, high glucose levels and high blood pressure etc (Vakil et al., 2012; Takata and Fujimoto, 2013; Adedoyin et al., 2013; Despres, 2014). One of the reason behind acceptance of WC as a metabolic syndrome for clinical use could be easy to measure and no need for tedious calculations. It has been observed that both general and abdominal adiposity are associated with disability and support the use of WC in addition to BMI to assess risk of mortality in older adults (Nam et al., 2012). Studies have utilized the WC successfully to assess the prevalence of adiposity related risks (Gutierrez-Fisac et al., 2012; Bajaj et al., 2014; Khan et al., 2017).

Additional measure of body fat distribution is waist–hip ratio (WHR) which is the WC divided by the hip circumference (HC). It is consider more precise than skin folds, and it provides an index of both subcutaneous and intra-abdominal adipose tissue (Bjorntorp 1987; Al-Lawati and Jousilahti, 2008). The use of these anthropometric indicators arose from a 12-year follow-up of middle-aged men, which showed that abdominal obesity (measured as WHR) was associated with an increased risk of myocardial infarction, stroke and premature death, whereas these diseases were not associated with measures of generalized obesity such as BMI (Larsson et al., 1984). In women, BMI was associated with increased risk of these diseases; however, WHR appeared to be a stronger independent risk factor than BMI (Lapidus et al., 1984). Hence, these indices are best for complementing BMI to identify individuals at increased risk for various obesity related morbidity due to accumulation of abdominal fat (WHO, 2000a, 2008). Unlike WC the interpretation of HC is usually based on WHR rather than comparison against cut-off values. Early reports of the health effects of central adiposity based on WHR included increased risk of diabetes in women (Hartz et al., 1983) and cardiovascular disease in men (Larsson et al., 1984).

The studies evaluating different indices of adiposity indicates that waist to height ratio (WHtR), is a better predictor of diabetes, hypertension, dyslipidaemia, metabolic syndrome and other cardiovascular outcome measures than BMI or WC in both men and women (Ashwell et al., 2012). A WHtR cut-off of <0.5 can be presented as a simple public health message to keep waist circumference less than half the height (Browning et al., 2010; Ashwell et al., 2012). Studies has supported WHtR being better indicator of adiposity than BMI (Ashwell et al., 2012; Savva et al., 2013) and as sensitive as WC and WHR (Yoo, 2016). Significant associations were reported for obesity assessed by WHtR in predicting risk factors for cardiovascular diseases, metabolic syndrome and diabetes compared to other anthropometric parameters like WC and BMI (Correa et al., 2016). Other meta-analysis supported the usefulness of WHtR (Ashwell et al., 2012; Savva et al., 2013). Researchers have emphasized the usefulness of WHtR as a screening tool for obesity and related cardiometabolic risk in children and adolescents (Gamble et al., 2012; Martin-Calvo et al., 2016; Yoo, 2016).

Combined use of abdominal adiposity with BMI is suggested for intervention studies. There are differences in central fat distribution in relation to age, sex and ethnicity. Infact WHO (1995) has cautioned the interpretation of BMI in isolation. WHO (2008) presented the sex and region wise cut-offs for WC, WHR and WHtR. In this regard, Lear et al. (2010) suggested further studies. Publications after WHO (2008) have suggested cut-offs for various population (Browning et al., 2010; Katulanda et al., 2011; Zeng et al., 2014; Guo et al., 2016; Okada et al., 2016).

Other important measures of central obesity is conicity index (CI) which is a better indicator of central adiposity like WC, WHR and WHtR. Valdez et al. (1993) studied association of CI with abdominal adiposity and other related risk factors. This index is also found to be associated with cardiovascular risk factors and has clinical significance (Ruperto et al., 2013, 2017; Motamed et al., 2015; Caitano et al., 2017). Other noticeable studies are Yasmin and Mascie-Taylor (2003), Flora et al. (2009). Andrade et al. (2016) has reported inconclusive findings.

1.2.3.3 Determinants of overweight/obesity

Studies from western countries reported an inverse relationship between degree of obesity and SES. Women are affected more than men and children (Markwick et al., 2013; Bradshaw et al., 2017; Newton et al., 2017). This has also been reported from the developing countries (Monteiro et al., 2004a, 2004b; Ball and Crawford, 2005; Lee, 2010). It has also been found that gender and poverty are two major risk factors that contribute to a high prevalence of weight related problems irrespective of age (Bowen et al., 1991; de Marins et al., 2001; Gigante et al., 2013; Boylan et al., 2014). Now the situation is similar in both the developed and developing countries. The direct relationship between SES and obesity was also common in the developing countries (Gittelsohn, 1991; Stunkard, 1996; Hindin, 2000; Barker et al., 2006; Rengma et al., 2015). Number of studies has reported relationship between SES and BMI among different populations (Khongsdier, 2001, 2002, 2005; Clausen et al., 2006; Shannon et al., 2008; Gigante et al., 2013; Kim et al., 2014; Compernolle et al., 2016; Moon et al., 2017). Path ways through which SES mediate its influence on high adiposity and act as etiology of related morbidity demands different approach of investigation.

Studies have assessed the association of SES with measures of central adiposity and BMI (Baltrus et al., 2010; Blanquet et al., 2016). SES like education, occupation and residential area were found to be associated with obesity measured using WC and BMI individually (Lao et al., 2015). Associations of education, household income, employment status, marital status with WC and BMI were studied by Sarlio-Lahteenkorva et al. (2006) among Finish adults from 1992 to 2002. Another such follow up study is among the multi-ethnic Asian population conducted by Ong et al. (2009). The association between SES and annual relative change in anthropometric markers in the general German adult population was reviewed by Herzog et al. (2016). Similar trend analysis in a Chinese population with rapid economic development is published by Lao et al. (2015). There is an increasing positive association of obesity with social position among the Inuit men and women of Greenland (Bjerregaard et al., 2013). The relationship between WC with SES among Nigerian adults was also reported (Adedoyin et al., 2013).

Overweight is relatively common among Turkish and Moroccan migrants, especially women. Education and employment are relevant in explaining ethnic differences in overweight. Compared to Dutch men, migrant men seem to have a more favourable fat distribution with less abdominal fat (Ujcic-Voortman et al., 2011). High-income men and poorly-educated women were at higher risk of obesity in Zhejiang province, China where economic transformation is under process (Xiao et al., 2013). After adjustment for covariates, BMI and waist circumference increased with decreasing neighborhood socioeconomic status, especially with neighborhood education measured within 500-m radius buffers around residences; associations were stronger for women (Leal et al., 2011).

Physical activity was inversely associated with BMI and body fat percentage among adults (Du et al., 2013; Bradbury et al., 2017). Bradbury et al. (2017) reported lower body fat percentage among the more active people compared to less active people with similar BMI. In contrary co-existence of high level of physical activity and obesity was observed among Inuit adults of Arctic Canada (Hopping et al., 2010).

1.2.3.4 Other Complementary Indices

The inability of BMI to identify risk of high adiposity among various ethnic populations and individuals with a BMI of < 30kg/m^2 was major concern for researchers (Norgan, 1994; Deurenberg et al., 2002; Garrido-Chamorro et al., 2009; Rahman and Berenson, 2010). These considerations provide impetus for a more suitable direct index of adiposity which leads to the formulation of Body Adiposity Index (Bergman et al., 2011). The study claims that Body Adiposity Index (BAI) can predict Percentage Body Fat (PBF) among male and female unlike BMI without correction. The study was conducted on the Mexican-American Adults and validated on the African-American population. A gold standard of percentage body fat Dual-energy X-ray absorptiometry (DEXA), was used to derived PBF. PBF calculated using DEXA was highly correlated with BAI than BMI. The BAI is independent of weight which may provide advantage in some context. Other advantages are its formulation and validation on Non-Caucasian population as the majority of the world populations are Non-Caucasian. However, the index needs validation on other ethnic population around the world including European population. Validation of BAI in a paediatrics sample over-estimates the %BF in children and leads to development of a valid BAI for paediatrics (El Aarbaoui et al., 2013).

Consequently after Begman et al., (2011) a large number of studies have been published from around the world including India. Study conducted on Colombian adult concluded limitation of PBF assessed using newly proposed BAI among Caucasian population (González-Ruíz et al., 2015a). Metabolic syndrome components (waist circumference ≥ 90 cm; fasting plasma glucose ≥ 100 mg/dL, blood pressure ≥ 135/85 mm Hg; triglycerides ≥ 150 mg/dL and HDL-c ≤ 40 mg/dL etc) were shown to have positive correlations with BAI (González-Ruíz et al., 2015b). The study by Elia et al. (2016) compared its prognostic ability with BMI for cardiovascular diseases and its component such as hypertension, blood pressure and sub-clinical organ damage. The study is based on the Olivetti Heart Study. Statistically positive associations with cardiovascular risk factors such as levels of cholesterol, triglycerides, LDL cholesterol and glucose were observed and subsequently a high prevalence of obesity was observed based on BAI (Garcia et al., 2015). Adaptation of different BAI cut-offs for Caucasian male and female has been already emphasized (Lopez et al., 2011; Elisha et al., 2013; Zwierzchowska et al., 2013).

Over representation of females in the study of Bergman et al. (2011) was criticized as possible reason for higher correlation of HC with PBF. Even possible alternative has been suggested to consider hip for female and waist for male, as usually waist among men correlates highly with percentage body fat (Schulze and Stefan, 2011). Study by Marques-Vidal et al., (2012) has shown stronger association of BMI and waist circumference than that of BAI with CVD risk factors and cytokine. The study was conducted using CoLaus study of large sample from Switzerland. Similarly a study based on 1140 female sample drawn from SUNSET study which consisted of three ethnic groups of Netherlands concluded BMI, WHR and WHtR to better predictors of CVD risk factors (Snijder et al., 2012). A study among Xavante Indians clearly shows that BAI is not a better predictor of adiposity than waist circumference in men or BMI and waist circumference in women (Kuhn, 2014). Other important studies in this regard conclude BAI indicates only total adiposity not risk factors (e.g., Hung et al., 2012; Lima et al., 2012). Studies suggest further investigation (Hung et al., 2012; Marques-Vidal et al., 2012; Snijder et al., 2012; Gupta and Kapoor, 2014).

Neck circumference is another proxy measure of adiposity that can be used at par with waist circumference, WHR and WHtR (Ben-Noun et al., 2001; Ambady et al., 2010; Yang et al., 2010; Kee et al., 2011). Precisely it can be consider as a measure of upper body adiposity which is relatively easy to assess. Studies has reported significant and strong association of NC with conventional measure 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). Further, metabolic syndrome were 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 has investigated the cardiovascular risk, diabetes and other mortality risk based on NC (Liu et al., 2015; Dai et al., 2016; Junior et al., 2016; Yoon et al., 2016; Medeiros et al., 2011; Cho et al., 2015). The regional fat distribution has implication on obesity related morbidity especially upper body and lower body fat (Kanaley et al., 1993). Like the use of WC, WHR and WHtR as complementary to BMI in the assessment of nutritional status is well established (Norgan, 1994, 1995; WHO, 1995). The BAI and NC can be considered as additional measure of nutritional status for complementing BMI.

1.2.3.5 Body composition

There are populations and individuals who have a normal body weight based on BMI but an elevated percentage of body fat. Such metabolically obese but normal-weight (normal-weight obesity) individuals may be at a much higher risk for cardiometabolic dysregulation, endothelial dysfunction, insulin resistance and cardiovascular complications (Batsis et al., 2013; De Lorenzo et al. 2016). Even more surprising is the phenomenon known as "obesity paradox" in which obesity is seen to provide better survival in critically ill patients of CHD (Lavie and Milani, 2003, 2005; Lavie et al., 2009). The inability of BMI to discriminate between fat mass and lean mass is responsible for the "obesity paradox" (Bastein et al., 2014; Lavie et al., 2009; Weig et al., 2016). Further, studies has emphasized that visceral adipose tissue is the surrogate marker of subcutaneous adipose tissue dysfunction (Bays 2014; Smith 2015). When subcutaneous adipose tissue becomes unable to accumulate excess fat, it gets deposited as visceral adipose tissue. This phenomenon suggests imperative need for assessment body fat distribution and percentage body fat in clinical and population studies.

Percentage body fat is usually assessed using skinfolds technique based on the two-compartment model of body composition analysis and useful for field based studies. The skinfold measurement of Biceps (BSF), Triceps (TSF), Sub-scapular

(SSF) and Supra-iliac (SISF) are used to estimate subcutaneous adiposity and thus nutritional status (Hastuti et al., 2013; Temple et al., 2015; Banik et al., 2016; Madden and Smith, 2016). These skinfolds measurements are further use to derived fat mass and lean mass. The combination of MUAC and TSF provides idea about upper arm composition in terms of Upper Arm Muscle Area (UMA), Upper Arm Fat Area (UFA). UMA, UFA along with MUAC is utilized for the assessment of undernutrition or loss of weight due to infection and poor condition (Johnston, 1982; WHO, 1995; Sen and Mondal, 2013; Han et al., 2017). It is basically a marker of protein reserves and marker of arm muscle mass commonly used among children (Frisancho, 1974). Like MUAC it is suitable for nutritional assessment of hospitalized and bed ridden patients. This is an additional index of regional fat distribution. Decrease in the lean mass and fat mass is considered parallel to weight loss and undernutrition (Borzek, 1961). So, quantification of fat mass and lean mass is useful for identification of obese individuals with actual increase in fat mass rather than in lean mass (Hull et al., 2011; Lu et al., 2012; Batsis et al., 2013; De Lorenzo et al., 2016). However, few studies have used the skinfolds measurements to assess the fat mass and lean mass or arm muscle area among adults (Rao et al., 2010; Sillanpaa et al., 2013; Banik et al., 2016; Ghosh and Bose, 2018).

Age related changes were assessed among the Jat-Sikh and Bania females (Singal and Sidhu, 1983). Studies have shown the influence of age on body fatness and central adiposity and other components of body composition with change in fat free mass in women (Nassis and Geladas, 2003; Ghosh and Chaudhuri, 2005; Kaur and Talwar, 2011). Similarly other study based on NHANES III reported age related decline in fat free mass (FFM) and fat free mass index (FFMI) in older Americans is higher for African men and women compared to white men and women (Obisesan et al., 2005). The study has found similar FFM and FFMI among the males of African and European ancestry but higher among African women compared to European (Obisesan et al., 2005). Similar, difference was reported between Australian aboriginals and European Australian in percentage body fat (Norgan, 1994a,b, 1995). Due to ethnic difference in body fat distribution studies has emphasized the need for race based prediction equations (Heyward, 1996; Duerenberg and Duerenberg-Yap, 2001, 2003).

Association of indices of fat mass and lean mass with metabolic syndrome was reported (Liu et al., 2013; Rao et al., 2012). Yao et al. (1991) observed the association of body fat measured using skinfolds and other anthropometric indicator with coronary heart diseases mortality. Study based on NHANES I and II observed association of low fat free mass with mortality among males (Allison et al., 2002) and no such association was found among females (Zhu et al., 2003). Another study based on NHANES III also reported similar association (Kuk and Ardern, 2009). Other similar studies are Spataro et al. (1996) and Ducimetiere et al. (1986). In the foregoing paragraphs, the body composition variables have shown clear influence of age, sex, and ethnicity. In addition its association with metabolic syndrome has important implication in the study of nutritional assessment.

1.2.4 INDIAN STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS

In India, undernutrition and overnutrition has been observed to affect the impoverished and the affluent both at group and individual level (Subramanian and Smith 2006). Studies have been alerting about the rising prevalence of undernutrition and overnutrition in India as a result of nutritional transition (Griffiths and Bentley, 2001; Uauy et al., 2001; Shetty, 2002; Ghosh et al., 2009). The country has one of the highest burdens of undernutrition in the world and simultaneously facing the emerging problem of overweight and obesity (Vas et al., 2005; Sengupta et al., 2014; NCD-RisC, 2016). Inspite of huge economic development only modest decline can be noticed in the prevalence of undernutrition in the country (Vijayraghavan, 2016). The failure has been attributed to prevailing poverty, low socio-economic status, poor living conditions and inadequate dietary intake (Ramachandran, 2007; Antony and Laxmaiah, 2008; Mahal and Karan, 2008). The country with such a varied geography, ethnicity, culture, language and religion can provide opportunities and challenges in such endeavor.

According to National Nutrition Monitoring Bureau (NNMB) prevalence of underweight/CED (BMI < 18.5 kg/m^2) was 35% among adult men and women of rural India. Similarly, the combined prevalence of overweight/obesity (BMI > 25 kg/m^2) was 10% and 13.5%, respectively among adult men and women. The NNMB also reported the prevalence of 13.6% and 30.0% of abdominal obesity (WC > 90cm for men & > 80 cm for women) among men and women respectively (NNMB, 2012). The underweight reported by NFHS-3 (2005-06) was 34.2% and 35.5% for men and women respectively. Recently NFHS-4 reported 20.2% and 22.9% underweight among men and women respectively. The decline in underweight has come with increase in the prevalence of overweight/obesity with 18.6% and 20.7% among men and women respectively (NFHS-4, 2015-2016). However, estimated underweight prevalence by NCD-RisC (2016) is higher than that reported by NNMB (2012) and NFHS-4 (2015-2016). On the other hand prevalence of obesity is lower. Although there is difference in the reported prevalence, yet, these estimates provide general view of the prevailing nutritional status of the country.

Numbers of studies have investigated the problem of undernutrition among men and women of India. A large number of adults were found underweight in the states of Bihar, Odisha, Madhya Pradesh, Chhattisgarh and West Bengal (Das et al., 2013; Patil and Shinde, 2014; Das and Bose, 2015; Sengupta et al., 2015; Rai et al., 2018; Ghosh et al., 2018). Beside the prevalence of underweight among adults were also reported from the state of Rajasthan, Uttarakhand, (Arlappa 2005, 2009; Gautam and Thakur, 2009; Singh et al., 2008; Mandal et al., 2011). The highest prevalence of underweight men in India is 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 the young female Bengalee of Kolkata the prevalence underweight was 30.3% (Ghosh et al., 2009). A cross-sectional study reported higher underweight for female (31.7%) compared to male (23.6%) among Bengalee individuals (Bose et al., 2009).

According to the study conducted by Shukla et al., (2002) the 19% men and women of main city of Mumbai were underweight. Recently studies have reported 22.7% prevalence of underweight from rural Tamil Nadu and 38.0% from the rural areas of Andhra Pradesh (Little et al., 2016; Subasinghe et al., 2014). Such prevalence of underweight from south India was also reported by some earlier studies (Hutter, 1996; Kusuma et al., 2008). It is clear from the above discussion that the reported prevalence of underweight ranges from high prevalence (20% - 39%) to very high prevalence (above 40%), which according to WHO (1995) classification of CED prevalence the situation is serious to critical in the country.

The MUAC is a portable and less expensive measure of undernutrition suitable for emergency field situation and for bedridden patients (Sen et al., 2010b; WHO, 1995). Further it is an alternative and additional measure of thinness among children below 5 years and among adults during emergency crisis and for intervention (WHO, 1995). It is used with BMI for the assessment of thinness among adult for more refined result (James et al., 1994). The measure of BMI and MUAC was used to assess undernutrition among Indians adults Bose et al. (2006c), Banik (2008), Bisai and Bose (2009), Chakraborty et al. (2011), Datta (2011). Now a day it is frequently used to assessed the nutritional status of hospitalized patients in India (e.g., Roy et al., 2013).

The state of Kerala, Delhi and Punjab were considered as overweight province of India (Sengupta et al., 2015). The study by Bharati et al. (2007) has shown highest prevalence of obesity in Punjab and lowest in the Bihar. A recent study from rural Tamil Nadu reported 14.9%, 16.1% and 3.3% prevalence of overweight, obesity I and obesity II respectively among adults (Little et al., 2016). The prevalence of obesity reported from residents of Tamil Nadu, Maharashtra, Jharkhand and Chandigarh was 24.6%, 16.6%, 11.8% and 31.3% respectively (Pradeepa et al., 2015). Prevalence of overweight and obesity among adult Bengalee slum dwellers of Kolkata were 20.1% and 8.3% respectively (Chakraborty et al., 2011). Increase in the prevalence of both overweight and obesity from 1960 to 1999 have been noticed among Nicobarese adults in Nicobar Islands (Sahani et al., 2010). A study conducted on adult individuals of Berhampur, Odisha reported the prevalence of overweight and obesity to be 17.6% and 36.8% respectively based on revised Asian-Pacific population reference (Prasad et al., 2013). The other mentionable studies reporting prevalence of obesity using BMI were Sen et al. (2013), Pradeepa et al. (2015), Kshatriya and Acharya (2016b) , Rengma et al. (2015).

Among the adults of Tamil Nadu, Maharashtra, Jharkhand and Chandigarh the prevalence of abdominal adiposity reported was 26.6%, 18.7%, 16.9% and 36.1% respectively (Pradeepa et al., 2015). A study has found the significantly higher central adiposity among south Indians compared to US population (Bajaj et al., 2014). The prevalence of 29.8% of central obesity was found among the urban slum of Chennai, South India (Anuradha et al., 2012). Prevalence of central obesity using the cut-offs of 102 cm, 90 cm and 80 cm were 0.46%, 5.08% and 24.7%, respectively among the adult slum dweller of Kolkata (Chakraborty et al., 2011). These studies were conducted using waist circumference.

The tribal population of the country constitutes 8.6% of the total population. Of them, 89.97% live in rural areas and 10.03% in urban areas (Census of India, 2011). Generally tribal people of India inhabit two distinct region of the country – the Central India and the Northeast India. The Gonds, Bhils and the Minas of the central and western region of India, and the Santals and the Oraons of eastern and central region, are the major tribes of India. Though the Indian tribal are a heterogeneous group, most of them remain at the lowest stratum of the society due to various factors like geographical and cultural isolation, low levels of literacy, primitive occupations, and extreme levels of poverty. Their nutritional status is still poor and influence health outcomes inspite of constitutional safeguard. Studies conducted among the tribes of northeast India are discussed in a different section later.

A review among the tribal populations by Bisai and Bose, (2008) reported the highest prevalence of CED to be in West Bengal (64.2%) and lowest in Sikkim

(4.8%). According to a previous study, the prevalence of CED was the lowest in Arunachal Pradesh and highest in Odisha. East zone of the country including West Bengal, Odisha and Jharkhand were at the bottom of the list with the highest degree of malnutrition (Bharati, 2007). The prevalence of CED was also reported to be high among the tribes of Maharashtra, ranging from 16.82 kg/m^2 - 18.33 kg/m^2 (Adak et al., 2006). However, a recent study observed high prevalence of undernutrition among Koras (51.9%), Bathudis (51.3%), and Oraons (49.6%) (Kshatriya and Acharya, 2016). Another study by Datta Banik (2011) has reported the prevalence of very high percentage of CED among Oraon and Saraks, 62.50% and 46.36% respectively. Similarly, 41.0% and 42.0% CED among men and women of Chenchu tribal population of Telangana and Andhra Pradesh were reported (Rao et al., 2015). More women (64.7%) then men (54.4%) based on MUAC and women (59.4%) then men (34.6%) based on BMI were undernourished among Santals of Purulia (Das and Bose, 2012). Studies have also reported 55.3% undernutrition based on BMI and 51.2% based on MUAC (Bisai and Bose, 2009). Prevalence of MUAC based undernutrition was 35.1% among Oraon adults of Jharkhand (Chakraborty et al., 2011) and 33.7% among Santals men of Odisha (Bose et al., 2006c). Other studies in the field of adult nutritional assessment include that of Mittal and Srivastava, (2006) among the Oraon and Banik et al. (2007) among the Dhimal. In a subsequent study, Banik et al. (2009) further documented high prevalence of undernutrition and poor health condition among the Dhimals, Meches and Rajbanshis. In yet another study, Banik (2011) validated arm span as a surrogate measure of nutritional status.

A single study have observed overweight among Bhumijs (17.7%), Dhodias (23.8%), Kuknas (15.8%), Santals of West Bengal (12.2) and Santals of Odisha (15%) (Kshatriya and Acharya, 2016). The prevalence of overweight/obesity in adult tribal men and women was 7% and 8%, respectively (NNMB, 2009). The proportion of adult tribal men (waist circumference ≥90 cm) and women (waist circumference ≥ 80 cm) with abdominal obesity was 2.4% and 7.6%, respectively (NNMB, 2009).

The access to good quality life which ensures health, optimum diet and hygienic living are main determinants of desired nutritional health and fitness. Such accessibility is facilitated by number of socio-economic factors like age, sex, education, residence, income etc. 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 and income (Khongsdier, 2002, 2005; Arlappa, 2005, 2009; Barker et al., 2007; Chakraborty et al., 2009a; Das and Bose 2010; Das et al., 2013; Patil and Shinde, 2014; Sengupta et al., 2015). Further, study by Subasinghe et al. (2014) has found association farming and low income with CED.

Studies have concluded BMI and other measure of central adiposity reflects on the economic and social condition of a population (Kusuma et al., 2008; Pradeepa et al., 2015; Meshram et al., 2016b). Studies conducted on India reported influence of age, sex, income, education, residence, social status and rural-urban migration on the prevalence of obesity among Indian adults (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 population of south India (Gaiha et al., 2010; Adinatesh et al., 2013; 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 Agarwal et al., 2014). Incidence of obesity was noted higher even among rural people of some states and in some states its incidence was confined to urban people only (Sengupta et al., 2015). The trends noted elsewhere have been started to appearing in India (Stunkard, 1996; Ball and Crawford, 2005).

General obesity, central adiposity and sedentary life style were found to be related among the inhabitants of Trivandrum, Kolkata, Mumbay, Moradabad and Nagpur (Singh, 2007). Lack of physical activity was found to be associated with adiposity (Pradeepa et al., 2015; Little et al., 2016). Similar obesogenic environment within the family was also reported responsible for prevalence of obesity (Swaminathan et al., 2013). Increase television viewing was related with increase WC among women of Santiniketan, West Bengal (Ghosh and Bhagat, 2014). Bus drivers of Karnataka were more overweight and obese than their conductor (Joshi et al., 2013). Tobacco use, alcohol use and unhealthy diets lacking fruits and vegetables were found to be related with diseases factor such as hypertension and obesity among adults from Assam and Gujarat (Bhagyalaxmi, 2013; Misra, 2014).

In India, non-communicable diseases caused an estimated 50% of all deaths and 60% of total disease burden in the year 2004 excluding different types of cancers (Patel et al., 2011). The obesity measured by BMI and central obesity was found to be associated with a range of metabolic abnormalities, including decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD. Studies from India have reported clustering of these risk factors among young adults (Ghosh, 2007; Gupta et al., 2010; Nag and Ghosh, 2016; Naval et al., 2016). A frequently reported CVD risk factor associated with overweight and obesity among Indian adult is hypertension (Chakraborty et al., 2011; Prasad et al., 2013; Midha et al., 2014; Pal et al., 2014; Shukla et al., 2014; Panda et al., 2017).

Hypertension was strongly associated with BMI, WC, WHR, WHtR (Midha et al., 2014; Panda et al., 2017; Chakraborty and Bose, 2012). Studies have concluded the steady increase of hypertension from underweight to normal and then to overweight/obese individuals (Pal et al., 2014; Datta Banik, 2014). Similar, risk of hypertension was reported among overweight and obese tribes of Kerala. Less increase in hypertension with age was observed among educated and high SES group (Meshram, 2012). High BMI along with high blood glucose and abnormal serum cholesterol were also found to be responsible for non-communicable diseases (Patel et al., 2011). A study conducted among the youth of Hyderabad and nearby rural area reported significantly high WC, WHR, diastolic blood pressure, blood glucose, total cholesterol and LDL among the urban youth (Bhongir et al., 2011).

Indian studies have also supported the validity of indices abdominal obesity (WHR, WHtR, WC) as risk factor of metabolic syndrome and related morbidity (Gopinath et al., 2012; Naval et al., 2016; Panda et al., 2017). Some studies have shown WC as better CVD risk factor (Kurpad et al., 2003; Chakraborty et al., 2011; Ghosh and Bandyopadhyay, 2012) and useful screening measure for hypertension and high BMI (Chakraborty et al., 2011; Chakraborty and Bose, 2012; Gupta and Kapoor, 2012). There has been efforts to give valid regional cut-offs for Indian population (Misra et al., 2006; Singhal et al., 2011; Chakraborty et al., 2011; Gupta and Kapoor, 2012).

Association of CI and the above discussed central adiposity measures with various metabolic syndrome, diabetes and CVD risks were also studied (Ghosh et al., 2000;Venkatramana and Reddy, 2002; Mamtani and Kulkarni, 2005; Ghosh, 2006, 2007, 2009; Ghosh and Bandyopadhyay, 2007). Studies also reported influences of age, sex and ethnicity on CI (Das and Bose, 2006; Kusuma et al., 2008).

Neck circumference (NC) is a marker of upper body subcutaneous adipose tissue distribution. Its correlation was high with other anthropometric study makes it a reliable and easy measure regional adiposity. NC was found higher among diabetics compared to non-diabetics (Aswathappa et al., 2013). Correlation of metabolic syndrome was higher among the individuals with high NC (Kumar et al., 2014). NC was good predictors of Metabolic Syndrome and cardiovascular risk factors among Asian Indians (Selvan et al., 2016). It can serve as screening measure for efficient detection of metabolic syndrome (Duki and Naidoo, 2016). Association of NC, abdominal obesity and obstructive sleep apnea is estabalished (Sharma et al., 2004; Krishnan et al., 2012). The NC and WC were compared between normal and overweight/obese adolescents to validate these measures with BMI (Patnaik et al., 2017). NC is now a established measure of regional body adiposity. Recently study by Mondal et al. (2016) has published cut-offs for defining NC to diagnose obesity.

A study reported from Haryana, found negative correlation between BAI with PBF assessed using bio-impedance analyzer in contrast to other measure of adiposity (Verma et al., 2016). Gupta and Kapoor (2014) found BAI to be a not much reliable as BMI, however suggest the possible use of BAI among the populations. Study among three endogamous population of south Bengal found higher correlation of PBF assessed using bio-impedance analyzer with BMI than BAI (Datta Banik and Das, 2015). However, BAI is not found suitable for predicting and screening hypertension compared to measure WC, WHtR and BMI (Chakraborty and Bose, 2012).

Studies from India have utilized skinfolds to define body adiposity among children and adults (Mukhopadhyay et al., 2005, Khatoon et al., 2008, Banik 2011, Rao et al. 2012; Sen and Mondal, 2013). Impact of undernutrition on the body composition variables were documented (Bose et al., 2006a; Khatoon et al., 2008; Datta Banik, 2011). The Oraon and Sarak tribal adult of Ranchi, India suffering very high CED were characterized with very low body fat mass (FM) and high fat free mass (FFM) (Datta Banik, 2011). The increase in the body adiposity was observed with increase of regional adiposity in the upper arm, triceps skinfold and mid upper arm circumference among Muslims females (Khatoon et al., 2008).

Higher arm muscle area and FFM was reported among the rural men compared to women from West Bengal (Nag and Ghosh, 2016). Similarly, Das and Bose (2006) reported higher FFM among men and higher PBF, FMI, mid upper arm muscle area of among women Marwaris of Howrah. Both studies used skinfolds, central obesity measures, height and weight. Similarly, among young Bengalee women of Kolkata, the mean BMI and skinfolds were significantly high (Bhadra et al., 2002). There were significant sex differences in these measures of adiposity among Bathudis, tribal people of Odisha (Bose et al., 2005). Body composition and fat distribution among rural and urban Jat females were compared (Kaur and Talwar, 2011).

Studies have investigated age related changes in the body compostion variable among Indian tribal and non-tribal (Singal and Sidhu, 1983; Ghosh et al., 2001; Bose and Das Chaudhuri, 2003; Ghosh, 2004; Ghosh and Das Chaudhuri, 2005; Bose et al., 2006a, 2005; Kaur and Talwar, 2011). Age related change was assessed among the Jat-Sikh and Bania females (Singal and Sidhu, 1983) and among Jat females of

Haryana (Kaur and Talwar, 2011). Study by Ghosh and Chaudhuri (2005) observed the impact of age, age at menopause, age at first conception, educational level and frequency of walking on PBF, FFMI and FMI of elderly women of Calcutta (Kolkata). Age had significant negative association with all anthropometric body composition measures such as PBF, FM, MUAC, UMA and UFA in both sexes (Ghosh, 2004). Age had significant negative association with most variables and indices in both sexes. In general, the associations were much stronger in men (Ghosh et al., 2001). Similar, negative impact of increasing age was observed on the body adiposity and composition among elder Bengalee women (Bose and Das Chaudhuri, 2003). Significant negative correlation of age with body composition variables were also noted among the Bathudis tribal men of Odisha (Bose et al., 2006a).

Metabolic syndrome like hypertension was also found to be associated with body composition. In this regard study by Ghosh and Bala (2011), Rao et al. (2012), Chowdhury and Roy (2016) among tribal and non-tribal are mentionable. There are studies of body composition in India which uses various reference methods like Dual-energy X-ray absorptiometry (DEXA), densitometry etc (Satwanti et al., 1980; Kuriyan et al., 1998; Josehp et al., 2011; Singhal et al., 2011; Nigam et al., 2013; Kuriyan et al., 2014; Marwaha et al., 2014a, b). Studies conducted using such complex methods which are not feasible for field based studies are outside the scope of the present work.

1.2.5 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS OF NORTHEAST INDIA

Northeast India is home to a large number of ethnic groups with distinct customs and traditions. All three main type of physical features like East Asian, European type and Australoid can be encounter in this part of the country. In India, Northeast region occupy a distinct place due its geographical, historical, social, cultural and political features. Northeast India comprises of Assam, Nagaland, Mizoram, Manipur, Meghalaya, Tripura, Arunachal Pradesh and Sikkim. Of which Sikkim was included in North Eastern Council in the year 2000. All these Indian states are frontier states. A long narrow passage in the west connects the regions with mainland India. Northeast India occupies an area of 255,000 sq km which comprises of hilly area and Bramhaputra valley. This ecological setting has profound impact on their subsistence as they can be divided into hill dwelling and valley dwelling. Hinduism is the major religion with Hindu Caste and Hinduised Tribals. Islam is the other major religion followed by Christianity and Buddhists (Irshad Ali and Das, 2003). Population professing animistic religion small and mostly located in Arunachal Pardesh. Some of the tribes of this region are Bodos, Khasis, Khynriams and Pnars, Garos, Mizos, Karbis, Mishings, Konyak Naga, Ao Naga, Sema Naga and Angami Naga, Tangkhul, Kabui, Thado and Hmar, Galong, Nishi, Wancho, Adi, Bodo Kacharis, Rabhas and Mishings.

According to NFHS-3 the prevalence of CED among the Northeast states was below 20% except Assam where the prevalence is 20-34%. Similarly, prevalence of overweight and obesity was below 10% among the Northeast states except Manipur and Mizoram where prevalence is 10-14% (NFHS-3, 2005-2006). This is also supported by an earlier study by (Bharati et al., 2007). The prevalence of chronic energy deficiency (CED) was also lower in the tribal (19%) than in the Hinduized (49%) and caste (52%) populations (Khongsdier, 2001). The mean values of BMI reported from tribal populations of Northeast India were significantly higher than the caste groups (Khongsdier, 2001, 2002, 2005). The prevalence of CED among male

Dibongiya Deoris of Assam was 21.43% (Gogoi and Sengupta, 2002). The prevalence of CED was higher among tribal (20.45%) than non-tribal (7.43%) college students of Tripura (Datta et al. 2015). Based on NFHS-3 data highest prevalence of male undernutrtion was reported from Tripura (Patil and Shinde, 2014).

A recent study conducted among the Nyishi tribal women of Arunachal Pradesh reported simultaneous prevalence of underweight (10.50%), overweight (9.94%) and obesity (9.57%), which is a suggests nutritional transition (Bharali et al., 2017). Another recent study among Rengma Naga observed the prevalence of 32.57% (males: 39.34%; females: 25.50%) and 10.77% (males: 9.95%; females: 11.63%) overweight and obesity respectively (Rengma et al., 2015). Trend was also observed among Tangkhul Naga tribal women of Manipur where the prevalence of overweight and obesity was 25.1% and 2.0%, respectively (Mungreiphy and Kapoor, 2010). The measure of abdominal adiposity like waist hip ratio is successful in predicting pre-diabetes/diabetes among the tribes of northeast (Mungreiphy and Kapoor, 2014).

Age, education occupation and income appear to have higher associations with overweight and obesity among adults Rengma Naga (Rengma et al., 2015). Similarly, changing life style among Tangkhul Naga tribe with improve SES are the contributing factor for increasing prevalence of overweight and obesity and related morbidity like diabetes (Mungreiphy and Kapoor, 2014).

Urban and tribal difference on CVD risk factors was assessed among adults of Tripura using anthropometry, biochemical tests and lifestyle variables (Saha et al., 2013). Serum lipid concentrations were strongly influenced by anthropometric indices of obesity like high WC and BMI in both sexes of Gauhati Assam (Bora et al., 2015). Tobacco use, alcohol use and unhealthy diet habits were high among men and women of Mishing tribes of Assam which predisposed them to various non-communicable diseases (Misra et al., 2014). There was non-significant relation between BMI and self reported morbidity. Similarly non-significant relation of BMI with self reported morbidity was reported by later studies however, it was found that Body Fat Mass Index was significantly associated with self reported morbidity after adjusting for age, income and FFMI (Khongsdier, 2002, 2005).

Some of the recent study among children has highlights on the nutritional scenario of Northeast India (Sikdar, 2012; Singh and Mondal, 2014). The prevalence of thinness varies from 17.18% to 27.73% among the boys and from 19.21% to 28.23% among the girls. On the other hand the prevalence of overweight varies from 1.95% to 7.81% among the boys and 1.96% to 9.41% among the girls. Such prevalence of overweight despite a persistently high burden of thinness suggests existence of nutrition transition among the Mising population (Sikdar, 2012). Study conducted among the children and adolescents of Sonowal Kacharis shown thinness using upper-arm composition (Singh and Mondal, 2014).

Other significant study conducted among the children and adolescents of northest are (Khongsdier et al., 2005; Khongsdier and Mukherjee, 2003a, b). The overall prevalence of CED was significantly greater in boys than in girls among the Khynriam Khasis, War Khasis and Hmars, respectively. The patrilineal and matrilineal forms of society were not reflected in the prevalence of CED among adolescents. This could be the interest of further research (Khongsdier et al., 2005). A study also reported difference in growth and body size among the three exogamous group of Khasi society such as Niam Khasi, Muslim Khasi and Christian Khasi (Khongsdier and Mukherjee, 2003a). Similar finding was reported among the Khasi girls. Such effect of heterosis on growth is subject of further research (Khongsdier and Mukherjee, 2003b). The rising epidemic is not restricted to highly urbanized societies but now has penetrated even to traditional and transitional tribes owing to their changing lifestyle (Mungreiphy and Kapoor, 2014).

1.2.6 STUDIES IN THE DIFFERENT FIELDS OF BIOLOGICAL ANTHROPOLOGY, INCLUDING NUTRITION AMONG ADULTS FROM SIKKIM

Studies in the different research areas of biological anthropology among the populations of Sikkim are relatively less in number. There are some studies on dermatoglyphic patterns among the Lepchas by Miki et al. (1960, 1961) and Miki and Hasekura (1961). A recent study by Dorjee et al. (2015) has investigated dermatoglyphic variation among the Limboos of Sikkim. Comparative evaluation of growth patterns among different caste and tribal groups of Sikkim was reported by Bhasin et al. (2008). Sporadic studies have been found on the life style and genetic influences on the metabolic syndrome (Sarkar et al., 2005), affects of perceived stress on CVD risk factors (Sarkar and Mukhopadhyay, 2008a), age related changes in blood pressures, influence on obesity and relation with anthropometric indices (Sarkar and Mukhopadhya, 2008b) and the possible seasonal variation (summer and winter) in blood pressures (Sarkar and Mukhopadhya, 2009) among the Bhutias. A study among the Bhutia and Rai populations reported a significant correlation of hypertension with use of tobacco and alcohol consumption, level of education and activity patterns (Mishra et al., 2010). Other studies investigated eating and weight concern among adolescent girls and their biocultural correlates (Mishra and Mukhopadhya, 2011). Prevalence of obesity, overweight, and hypertension was 2.04%, 14.5% and 5.62%, respectively among the adolescents of urban areas of Gangtok, Sikkim. The average fast food intake, screen time and limited outdoor activities were significantly associated with obesity (Kar and Khandelwal, 2015).

Sikkim is a state where fundamental studies on nutritional assessment appear to be almost non-existent, except the NFHS-3 (2005-2006) and NFHS-4 (2015-2016) reports.

1.3 OBJECTIVES OF THE PRESENT STUDY

Given the above, the present study is an attempt to document the prevalence of undernutrition or overnutrition among adult individuals belonging to an ethnic population from Sikkim using anthropometry. The objectives are as follows:

- To assess the nutritional status and body fat distribution using anthropometric measurements and derived indices using internationally accepted cut-off points.
- To document the association of different socio-economic variables with nutritional status and body fat distribution.
- To assess the age and sex related changes in nutritional status and body fat distribution.
- To compare the findings of present study with other available international and national data.

The present study is basically fundamental in nature and has the potential to provide the basic data on undernutrition, overweight and obesity along with body composition that is sorely lacking for the ethnic populations of Sikkim.

Chapter 2

MATERIALS AND METHODS

2.1 THE POPULATION

The state of Sikkim is ethnically rich and appealing for anthropological research and other field of studies related to humans. Some knowledge of history is necessary before moving to the discussion of various ethnic populations residing in the state. The erstwhile kingdom of Sikkim joined Indian union through popular memorandum to become its 22nd state on 16 May 1975. Until then it was ruled by a righteous king, supported and nurtured by Tibetan Theocracy. In Sikkimese Bhutia language righteous king is known as Chogyal, which can be translated in *Dharma Raja* in Nepali and Hindi languages. The annexation of Sikkim on 16 May 1975 brought down the 300 year old Namgyal dynasty. The first king of the dynasty was Chogyal Phuntsog Namgyal. He was the descendent of Khe Bumsa, prince's son of Minyak kingdom of eastern Tibet, celebrated as having strength equals to 1 lakh warriors. This fame was conferred to him when he alone erected gigantic pillars in the chapel of a Sakya Monastery when the monks repeated efforts were not successful. He was invited to remain in Sakya where he married the hierarch's daughter. Eventually, he settled in Chumbi Valley and one of his sons Mipon Rab, later moved to Gangtok, Sikkim. Phuntsog was son of Mipon Rab and consecrated as the first Chogyal of Sikkim by three monks namely Gyalwa Lhatsun Chenpo, Gnadag Sempo Chenpo and Kathog Rigzing Chenpo in Yuksom in the year 1641. Simultaneously these monks inducted Ningmapa sect of Buddhism among the Sikkimese people, Lepchas and Limboos, including people who accompanied them during the trek to Sikkim (Gyamtso, 2011). However, religious influence upon Limboos was meagre.

The Bhutia people of Sikkim claim their affiliation to Namgyal dynasty. The author from the same community have emphasised that there could be cultural, traditional and lifestyle similarities with other Himalayan groups like Lopas, Menpas, Denpas, Sherpas who are also referred by generic term Bhutia actually like to be known as Sikkimese Bhutia (Gyamtso, 2011). They speak a dialect of Tibetan Language. So, Bhutias of Sikkim were ruling class of the state. A majority of them are still found in bureaucracy. The last Chogyal of Sikkim was Palden Thondup Namgyal.

The consecration of King Phunstog Namgyal is believed as the result of prophecy and boon of Thekong Tek, the Lepcha Patriarch to Khe Bumsa a generation ago in a place called Kabi Longtsok in North Sikkim. Simultaneously, Thekong Tek and his wife Nekung Nyal inter into a blood brotherhood treaty with Khey Bhumsa in the same place. According to which Lepcha and Bhutia should be considered as brothers and equal under new Buddhist monarchy (White 1909; Gyamtso, 2011). However, there are claims and believes about the existence of Lepcha kingdom and rivalry with before and after the establishment of Buddhist monarch (Chattopadhaya, 1990).

The Lepcha, which is also an East Asian population like Bhutia and Tibetan, is considered to be one of the prominent indigenous populations of the state. Their built is slightly smaller than Bhutia and Tibetan. They called themselves Rongpa or dweller of mountain ravine valley. There are speculations about their origin in the literature, one of which says they migrated through Assam and Burma. However, they do not subscribe to this view (White, 1909). They believe that they are the original inhabitants of the region. This view is also supported by the accounts of pioneers like Hooker (1854), White (1909) and Risley (1891). They have their own language, which has been praised for having names for all animals, insects and plants found in

Sikkim. This also reflects their close association with nature in the past. It is well known the Lepcha language is distinct from Tibetan and other Kiraties language of the vicinity. They were actually nature worshiper and later under the Buddhist ruler many of them converted first into Buddhist and other were converted to Christian by missionaries. Hence, there are animist Lepcha, Buddhist Lepcha and Christian Lepcha. Beside Sikkim, they are found in Kurseong, Darjeeling and Kalimpong districts of West Bengal, Southern Bhutan and Eastern Nepal bordering Sikkim. The means of subsistence in the past among the Lepcha were slash and burn shifting cultivation. Dzongu, in North Sikkim was their first permanent settlement in the record (White, 1909). At present, they practice all kind of possible agriculture and cattle farming in the villages. Young generation are engaged as bureaucrats and professionals in the government of Sikkim.

In 1889, the British appointed Sir J. C. White as the first political officer in Sikkim. White during his administration raised the revenue of Sikkim from ₹ 8000 per annum to ₹ 22,00,000 per annum with the introduction of terrace farming. People from nearby Nepal were encouraged to settle with purpose of terrace farming on the steep slopes where virtually farming was impossible (White, 1909). However, even during the consecration of Phuntsog Namgyal, presence of Manger people has been mentioned (Chattopadhaya, 1990). Further, forts belonging to Manger King were also reported from the place called Mangerjong and other places of Sikkim (Bhattacharyya-Panda, 2015). It is well documented the word Lepcha itself was first used by Nepali people to address their new kinfolks (White, 1909). Hence, presence of Nepali people in the erstwhile kingdom of Sikkim before 19th century cannot be denied. The fact can also be supported by geographical continuity with adjoining Himalayan country. However, most of the accounts on Sikkim and its people consider

Nepali as 19th century migrants, which has harm the image of Nepali speaking people of Sikkim and Darjeeling region.

The Anthropological Survey of India has identified twenty-five ethnic communities in Sikkim. These are classified into four ethnic stocks (Lepcha, Limboo, Bhutia and Nepali). While the first three are homogenous entities, the Nepali is composed of a number of castes and sub-castes. They constitute a major chunk of the population in Sikkim. Among them, Bhaun, Chettri, Kami, Damai, and Sarki are similar in physical features. They are Hindu by religion and society is structure according to Varna system. First two are higher castes and the later three are service castes. However, between the higher caste and service caste, other Himalayan tribes were fitted by the erstwhile king of Nepal during his regime, that structure still prevails in Sikkim and still dominates the day to day life among Sikkimese Nepali. These "caste-tribe" people are Rai, Dewan, Newar, Gurung, Tamang, Mangar, Sunwar, Bhujel, Thami, Thakuri etc with East Asian features. They are referred to as caste-tribe people because they have both caste and tribal characteristics. Interestingly there is no word for "tribe" in Sikkim and the word *jat* is widely used which translates into English word caste. The elements of caste were adopted by them from their higher caste Nepali neighbour and tribal characters were their own. As a result, belief system among them is neither Hindu proper nor animist in total. Most of them are strong shamanistic and follow oral tradition. The Gurungs and the Tamangs among them profess Buddhism. Many of the above mentioned Nepali caste and communities of Sikkim were converted to Christianity during the time of British. Still Hinduism is a major religion of the state of Sikkim numerically (Sikkim Human Development Report, 2014). In general people are very tolerant of each other beliefs and culture. Their day to day life is so closely interwoven to each other.

2.1.1 THE LIMBOO

Popularly known as Limbu or Subba, the Limboo is one of the original ethnic people of Sikkim and are referred as “Tsong” by the Bhutias. The Limboo population, according to Risley (1891), originated from the Tsang Province of Tibet from where they migrated to Sikkim via East Nepal. However, Subba (1999) was of the opinion that Limboos were the original inhabitants of a region called “Limbuwan”, which was composed of parts of West, South and a part of North Sikkim along with some districts of East Nepal. The Limboos exhibit East Asian features and are similar to that of the Lepchas and Rais. They have their own script called Sirijonga script and language called Limboo language. The Limboo language is a member of the eastern sub-group of Himalayan languages with complex pronominalizing features. It is one of the members of Tibeto Burman sub family (Kainla, 1992).

They are found in Sikkim, Nepal and West Bengal. In Sikkim, their major concentration is in West Sikkim. The total population of Limboo in Sikkim according to the census of India (2011) was 53,703, with more people residing in the rural area.

They were pastoralist in the past and practiced slash and burn cultivation, like other tribals of northeast India. Their past was constructed by Subba (2010), on the basis of occasional mentions of high altitude flora and fauna, including yak (*Bos frontalis*) in their oral tradition and allegory. Their preference to be called as Yakthungba, meaning ‘yak herders’ and possession of yak tail as auspicious household item were also considered. Further inferences were made based on the deities they worshiped, the rituals they performed, the places of worship, the materials used for all of these, and *kipat* system of communal land ownership. The practice of settled cultivation by them is about two centuries old (Subba 2010). The majority of them own land and practice terrace farming and cattle rearing as a humble means of livelihood. Among the people residing in higher elevation, cardamom farming is more popular compared to traditional paddy farming. Many of them are engaged in government jobs, army and recently village based tourism industry.

The earliest mention of Limboo in Sikkim can be trace back to the “Lho-Men-Tsong-Sum” a tripartite treaty signed between the ministers of the king on one side and the leaders of Lepcha and Limboo on the other side (Subba, 1999), following the consecration of Phunstsog Namgyal in the year 1642. The main reason behind this agreement was to strengthen Namgyal rule and ensure co-operation among Lhopas (Bhutias), Menpas (Lepchas) and Tsongpas (Limboos) who inhabited Sikkim at that time (Kazi, 1983; Basnet, 1974). This suggests the presence of Limboos long before the establishment of Namgyal dynasty in Sikkim.

With the passage of time, behaviours of the king towards the Lepcha and Limboo subjects changed and deteriorated. Such attitude towards Limboo may be due to cultural differences and revenue related issues, as a result they were also clubbed with Nepalis (Subba, 1999). Even after coming of democracy, they suffered a lot, with non-representation in the assembly. Of late, the Limboos have been accorded the status of Scheduled Tribe in the state. According to Article 366 of the Constitution of India, ‘Scheduled Tribes’ are those communities who are scheduled in accordance with Article 242 of this constitution. This article states that only those communities who have been declared as such by the President of India through an initial public notification or through a subsequent amending Act of Parliament will be considered as ‘Scheduled Tribes’. The essential features for a community to be identified as a ‘Scheduled Tribe’ first laid down by the Lokur Committee, are indications of primitive traits, distinctive culture, shyness of contact, geographical isolation, and backwardness.

Limboo people possess some Hindu and Buddhist characters in their culture, which could be the result of them being ruled by Gorkha Hindus in Nepal and Tibetan Buddhists in Sikkim. The Limboo profess Yumaism as their religion, where Yuma means grandmother and Tagera Ningwaphuma is their supreme goddess or grandmother, also known as Yuma Mang. The different forms of deity Tagera Ningwaphuma are Yuma Sam and Thoba Pa-Sam or Hangsam are transcendental forms in the earth (Subba, 2012). Risley (1981) has stated that Limboo religion is similar to Pon or Bon religion of pre-Buddhist Tibet. Later on, Subba (2010) has shown the conceptual evidence to show the similarity between pre-Buddhist religion of Pon and Limboo religious practices and concluded Limboo religion as animism. However, a different author, Subba (2012), is reluctant to accept Limboo religion as animistic religion and consider Yumaism as a monotheist religion. The previous author is anthropologist by training while the later is not. In the present day Sikkim any Limboo children can say their religion is Yumaism, which was not the case 20 years ago. No place of worship like temple or monastery were known among Limboos, although of late they have constructed one at Martam and other is coming up at Darap, West Sikkim. Their place of worship is called Mangkhim. In the village of Lingchom an open space with rising steps on two sides for people to sit during rituals ceremonies is another Mangkhim or sacred place considered by villagers. The Mangkhim look like small amphitheatre. It shows the Limboo are moving towards larger religious philosophy away from mere animism, irrespective of conflicting motives behind.

The different deities of Limboo mentions here are propitiate with blood sacrifice and offerings of alcohols and meats. Legends and philosophies surrounding these deities are found in *Mundum*. Socio-cultural activities of Limboo people are defined and guided by *Mundum.* It is oral tradition handed down the generations which is a collection of rich myths and beliefs. Recitation of *mundum* takes place in every ritual as it is powerful and mystical, through which shamans can contact with the supernatural being. The *Mundum* can even trace the origin of a single family back to the ancestral place. In the different stages of life, ritual and recitation of *mundum* is indispensible. Nowadays Limboos have started writing *Mundum* in the forms of books for preservation. Such as *phedangmas*, *Sambas* and *Yeba* are their religious specialists who preside over particular types of rituals and ceremonies. However, such specialities are on the verge of extinction, as result, any senior individuals with such knowledge are expected to preside over such events. This is possible because there is a tradition of debate between shamans and onlooker who are usually village elders (Subba, 1999).

Beside above mentioned deities of Yuma religion, they also hold high regards for Teyongsi Srijanga, pioneer Limboo poet and saint who advocated, preserved and revived Limboo language. Every household hangs the hand painted picture of Srijanga. Reverend Teyongsi Srijanga and his eight disciples killed by Buddhist monks in the bank of the river, *kolej khola* angst against his revival of culture, language and script among the Limboos. The birth anniversary of Teyongsi Srijanga is celebrated every year with cultural performances, poetry reading, story reading etc.

The Hindu festivals like Dashain and Tihar, which coincides with Durga Puja and Diwali elsewhere, use to celebrate by all ethnic communities of Sikkim excluding Bhutia and Lepcha. These festivals for caste people have religious significance and for Limboos it is primarily a get-together and a social occasion. They have abandoned these festivals in North Bengal, Sikkim and Nepal since 1991. Subba (1999) finds no plausible reason for abandoning these festivals claiming as Hindu festivals. Some of the Limboo festivals listed by Dr B.L. Khamdhak in his blog (www.buddhilkhamdhak.blogspot.com/p/struggle-of-sikkimese-limboos-for.html) are *Kokfekwa Tongnam, Sisekpa Tongnam, Bolihang Tongnam, Tongsum Tongnam and Ingmang or Yokwa* few of which coincides with the Hindu festivals of Nepali caste (Assessed on 11-09-2017).

They are divided into Kasi gotra and Lhasa gotra, which are further divided into several clan/sept. The Limboos of Sikkim practice clan/sept exogamous marriage and marriages outside the tribe are not rare phenomena in Sikkim. Since the historical time, the Limboos have marital relationship with the Lepchas, the Rais and the Bhutias. However, marriage with other Himalayan caste and tribes can also be observed. Some commonly found clans of Limboos in Sikkim are Khamdhak, Kewa, Nebang, Lingden, Muringla, etc. Some clans like Youngmu, Sitling, Lucksom and Mangmu among Lepchas and Limboos are common. These clans are considered Lepcha if they are in Lepcha country and Limboo if they are in Limboo area (Subba, 2010). Shared cultural traits among the Kiratis and other Hindu Nepalis suggested the long co-existence of people together. Gotra system of lineage indicates influence of Hinduism and nothing to do with marriage as among Hindus (Subba, 1999). A majority have disregarded gotra as it is a Hindu concept. They live with parents of bridegroom event after marriage which is a patrilocal system of residence. The Limboo marriage is usually arranged marriages that take place in the house of the bridegroom. Nowadays elopement is more popular than the arranged marriage. The Limboo believe in physical chastity and do not cohabit before marriage. The study has shown the absolute supremacy over the marriage and choice of spouse enjoy by Limboo women. They can even divorce their husbands and get married with other men. In such cases, the other man along with his wife has to come to the wife's previous husband for ceremonial exchange called *Jari* (Subba, 1999). Marriages among close relatives are strictly avoided.

Limboo descent is traced patrilineally and the rule of inheritance is male ultimogeniture with regard to immovable property and female equigeniture about movable properties. Immovable property means land and house, while moveable properties are cattle, gold/silver ornaments, brass or copper utensils, clothes, and so on (Subba, 1999).

The Limboo have a custom of adopting members of other clan or tribe which is followed by feast and rituals. However, they hardly allow caste Nepali to take such membership. They also have a system of bond-friendship with member of other ethnic community, which is established through rites performed by a Brahmin priest and called Mith-sino. Such bond-friendship also found among the other community of Sikkim. There is restriction on the marriage between the families of fictive kins for four generation. Yet, such kins have no property right (Subba, 1999).

The Dhan Nach or Yalang (paddy dance) performed by a group of male and female Limboo during the time of paddy harvesting. During the time when the use of oxen to thrash the rice grain was not known, they used to thrash rice grains by trampling over the dried paddy plants. It was a hard job and they had to spend day and night. So, throughout the process they used to sing while trampling over the paddy plants. This way of thrashing paddy turned into a dance while singing. Nowadays it can be performed in any kind of ceremonies and festivals. In Sikkim, it is performed on the cultural festivals like *Bhanu jayanti*, *Panglabsol* and *Maghe Mela* etc.

Another popular dance of Limboos of Sikkim is Kelang or Chyabrung dance. This is a typical Limboo Drum made out of huge hollow trunk of a tree with processed leather on both sides. This dance is performed after the completion of new house to free it from various kind of insect that dwell on wooden pillars of the house, to wade off evil spirits, to save house from natural calamities such as wind, storm, earthquake and fire. This dance is also performed in the marriage ceremonies, for well coming revered guests and for other special occasions.

They are non-vegetarian in their food habits and alcoholic beverages constitute an integral part of their cuisine until recently. Rice is the staple crops and is the main source of energy. Other food products like fermented foods, maize, millets and roots also are rich in energy. They consume animal food excluding their totem animal, which is specific for different clans/septs. Consumption of alcoholic beverages was part and parcel of Limboo life, which is discredited by the younger generation and look down upon. Globalized food and beverages have also made ways into the life of this Himalayan folks. Snacks for guest, agriculture labour and family mostly consist of fizzy drinks (coca cola, pepsi), instant noodles and potato chips beside sugar tea. Otherwise it used to be, ripe squash and its roots, pumpkin, potato and other roots boiled etc.

The Limboo community of Sikkim can be considered as most successful in preserving their culture and ethnic identity compared to Lepcha and Bhutia. There are groups within Limboo community who are working towards social reforms and successful in bringing major changes. Major cultural changes are abandoning of excess alcohols used and animal sacrifices in ritual and ceremonies followed by simplification of expensive and elaborative rituals. They are also checking consumption of alcohols and alcoholic beverage among the tribe members. Further impetus is provided by raising living cult of Yuma, which also teaches non-violence and love. Their members have to follow different sets of rituals and rites for all the events from birth to death, which emphasizes the use of milk and vegetables in place of alcohol and meat.

The facts and analysis discussed, made it is clear that they were successful in preserving their cultural practices such as religion, language and cultural traits even in presence of hegemonic monarch. Invent of modern education in Sikkim has the major impact in their society and overall development. Until recently may be due of modern education and modernisation youth among them were really confused about their religion and ethnic affiliation and culture. They were lately recognised as a tribal group by the constitution of India compared to Lepcha and Bhutia, can be regarded as positive result of them being educated. Diminishing agriculture land and agricultural practices are some problems faced by community are directly related to changing traditional food habits. The market economy has, even more, influence upon their food habits. All this may have bearing on their health and nutritional status.

2.2 THE AREA

As already noted, that Sikkim was ruled by righteous king till the date of its annexation with the Indian union. The state of Sikkim has an area of 7096 km^2 and located between 27°04'46" to 28°07'48" North latitudes and 88°00'58" to 88°55'25" East longitudes. It is surrounded by Tibet, a country under Chinese occupation, on the north and east, Bhutan on south-east, Nepal on west and districts of West Bengal

(Darjeeling and Kalimpong) on the south. This is depicted by the map given in Figure 2.1. The total population of the state is 6, 10,577 according to census of India (2011). The state is the 2nd smallest state of India only after Goa in size and population. The landlocked mountain state is connected to rest of India via a national highway NH 10 (earlier NH31 A), which passes from Darjeeling hills, ultimately leading to Siliguri, a bustling town and major business hub of the region on the foothill of Darjeeling District (see Figure 2.2). The national highway NH 10 becomes a lifeline and Siliguri town a major supply centre for all kind of commodities for life in Sikkim. As it is clear that only means of transport are roads in the state. Although there is helicopter service from Bagdogra to Gangtok the capital city.

Since the state of Sikkim is dependent on the Siliguri town for all necessary supplies supporting lives, to reach Siliguri one has to drive 3 to 6 hours on hilly roads on the bank of river Teesta. This connecting road falls under the newly formed Kalimpong district which was originally a part of Darjeeling district and share similar topography and climate. This passage to Siliguri also remains disrupted due to frequent landslides and agitation strike in the neighbouring Darjeeling in the past. There was concern for the direct and alternative mode of communication between Sikkim and other states of India. Initiative by the state government in this regard has been the construction of a fully operational airport in Pakyong, East Sikkim. As of now the other nearest airport is located in Bagdogra and the only railway connection to Sikkim is New Jalpaiguri station both in the periphery of Siliguri town.

This mountainous state is home to the world third highest peak Mt. Kanchandzonga (8,586m) situated partly in Sikkim and in Nepal on the western border. Sikkim is separated by the Singalila range from Nepal in the west and Chola range from Tibet in the north-east and Bhutan in the south-east. Teesta and

Rangit rivers form the borders with the Indian state of West Bengal in the south. The state has 10 mountain peaks that rise above 7,000 metres, 84 glaciers and 315 glacial lakes (including the Tsomgo, Gurudongmar and Khecheopalri). Its unique geographical position, high annual rainfall, varied topography, rich flora and fauna make it a biodiversity hotspot (Sikkim Human Development Report, 2014). The vegetation of Sikkim is broadly classified into tropical, sub-tropical, temperate and alpine types (Singh and Chauhan, 1998).

Teesta and Rangit are two major rivers of the state with its innumerable tributaries which flows southward makes drainage system of the state. In addition, there is great variation in elevation, ranging from 270 mm to 8580 mm from sea level. Seasons in Sikkim are winter, spring, autumn, summer and monsoon. The heavy rainfall is a phenomenon in Sikkim with the mean annual rainfall of 82 mm to 3494 mm. The combination of drainage systems, varied elevation of land mass and heavy rainfall makes the state prone to soil erosion and landslides. As a consequence some remote villages remain isolated during the monsoon. Soil type and composition of rock are also responsible for frequent landslides. The capital town of Gangtok and other places with similar altitude usually have the mean temperature ranging from 1°C to 25°C. In the lower altitude it ranges between 4°C and 35°C, in contrast the range for mean temperature never rises above 15° C and go down to freezing point in winter (Gazetteer of Sikkim, 2013).

Above 4500 species of angiosperms, 424 medicinal plants, 16 species of conifers, 480 species of ferns and allies, 527 species of orchids, 11 species of oaks, 144 species of mammals, 58 species of primulas, 23 species of bamboos, 574 species of birds, over 689 species of butterflies and moths are reported from the state (Rahman and Karuppaiyan, 2011). The forests are abundance in *Alnus nepalensis*

(Uttis), *Castanopsis* (Kattus), *Macaranga* (Malata), *Engelhardtia spicata* (Mahua), *Toona ciliate* (Tooni), *Machilus* (Kawla), *Cinnamomum* (Sinkoli), *Symplocos* (Kharane) etc. along with some shrubs *Rhododendrons*, *Juniper*, *Rosa* (Rose), *Barberries* (Paewu), *Rubus* (Aiselu), *Daphne* (Algeri), *Leucosceptrum* (Ghurpis). Some carnivores and herbivores of the state are Red fox, Tibetan fox, Tibetan wolf, Himalayan brown bear, Snow leopard, Pallas's cat, Tibetan gazelle, Tibetan Argali and Blue sheep etc (Lachungpa, 2009; Gazetteer of Sikkim, 2013).

The state of Sikkim is divided into four districts such as North, South, West and East. The districts are further divided into subdivisions and blocks. These are shown in Figure 2.3 and Figure 2.4. The villages under the present study fall under the Geyzing or Gyalshing Block, which is also a district, headquarter (Figure 2.4). The Gyalshing is situated at 27^{o} 17' 41.88" North latitude and 88^{o} 15' 12.31" East longitude. The names of the study villages are Langang, Tikjek, Lingchom, Darap, Singpheng and Nambu. These villages are situated at the altitude of 4831feet (Gyalshing) and above from the sea level. All the villages are connected to Gyalshing through metalled road. Houses or settlements of people are upto far above and down below the roads connecting one village to another. Hence, means of communication upto road is following narrow footpaths or village roads passing through farming fields and jungle on foot.

Figure 2.1: Location map of Sikkim showing rivers, districts, and sub-divisions surrounded by neighbouring countries and a state of India (Source: ENVIS Sikkim centre http://sikenvis.nic.in/Database/NaturalResources_790.aspx. Accessed on 27-10-2017).

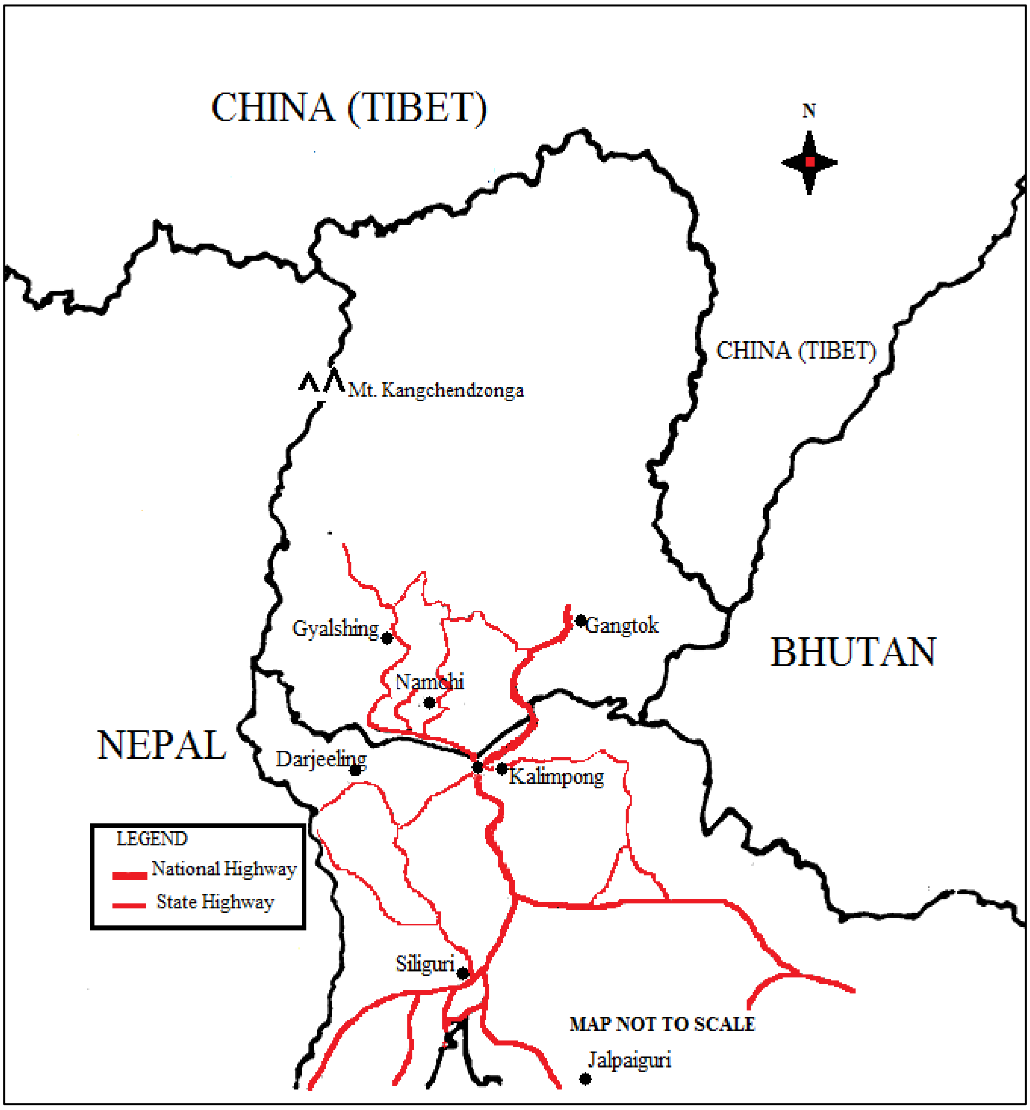

Figure 2.2: Map showing the National Highway 10 only connection to rest of the country and Siliguri, Subdivision of Darjeeling District.

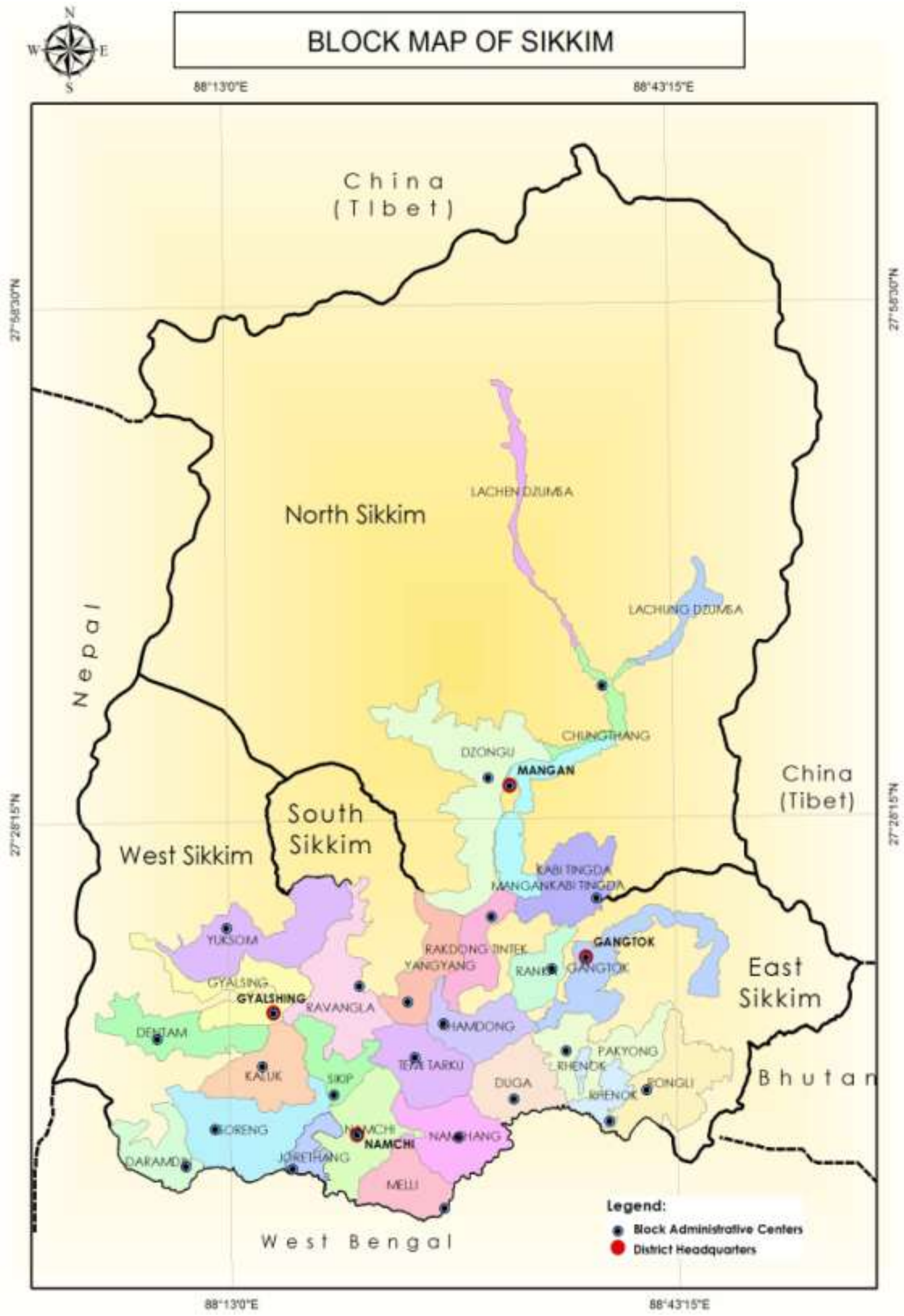

Figure 2.3: Block map of Sikkim with respective Block Administrative Centres (BACs) and District Headquarters (Source: Government of Sikkim Portal <u>https://www.sikkim.gov.in/portal</u> Accessed on 27-10-2017).

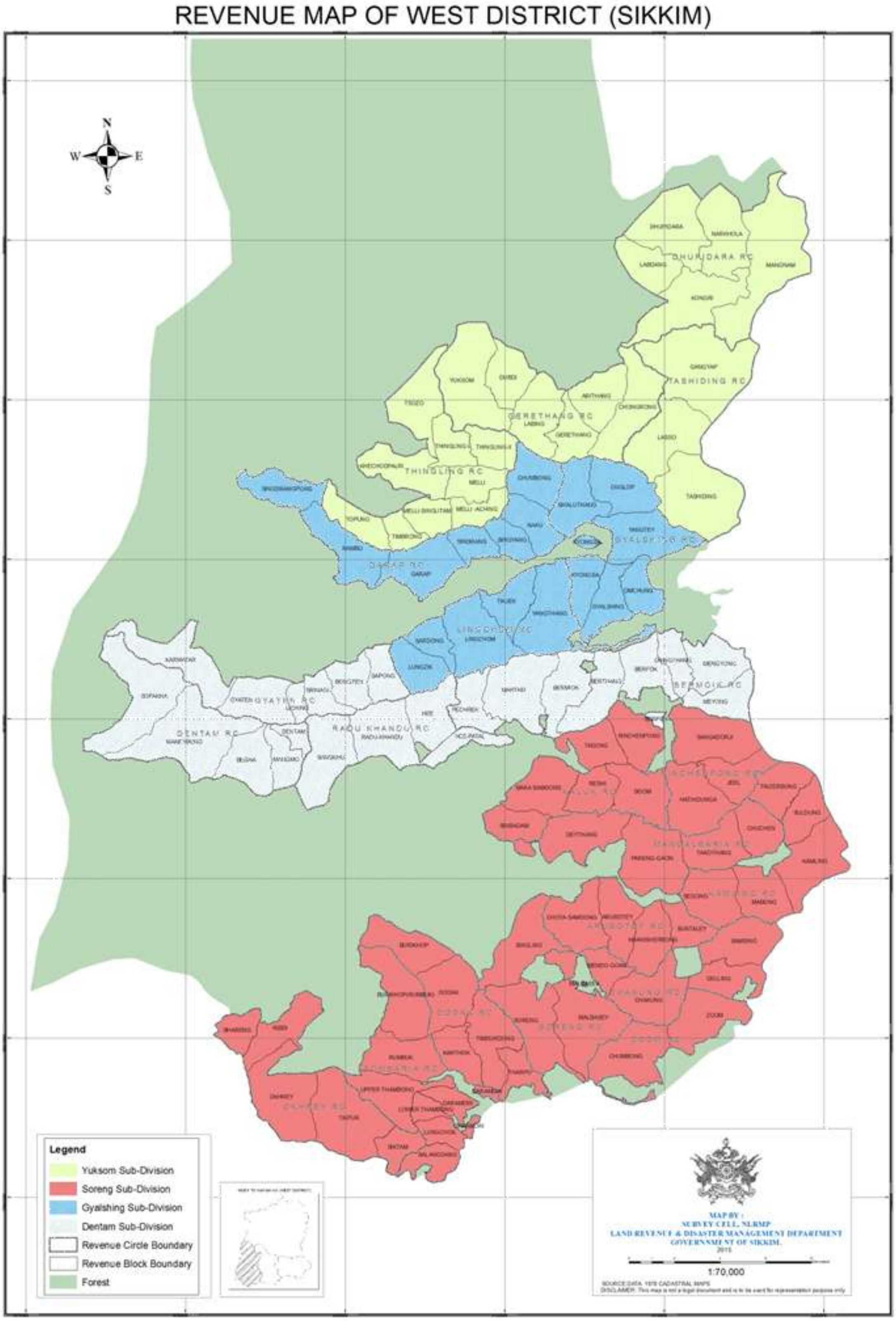

Figure 2.4: Map showing revenue blocks of West District of Sikkim including studied villages of the present study falling under Gyalshing Sub-division (Source: Government of Sikkim Portal https://www.sikkim.gov.in/portal Accessed on 27-10-2017).

2.3 NATURE OF SAMPLING AND SAMPLE SIZE

The individuals are selected using a multistage sampling method. West district of Sikkim has the high concentration of Limboo population, which is also explicit on the account of its proximity with east Nepal or erstwhile Limbuwan (Limboo kingdom). In the process, senior resourceful people were consulted for advice on the Limboo dominated villages. Through this process, 15 villages were listed and further it is reduced to 6 village base on the distance from the main urban centre Gyalshing. The six villages are Langang, Tikjek, Linghom, Darap, Singpheng, and Nambu. The villages were selected based on the predominance of Limboo individuals. The populations of the villages were confirmed by utilizing voter-list available online and some collected by meeting with panchayats. The data was collected during the period from January 2014 to April 2016 from above mentioned six villages. The villages named Langang, Tikjek and Linghom are within 9 km from Gyalshing, a district town and other villages like Darap, Singpheng and Nambu are 20 km away from the town towards north uphill. In Figure 2.4, the studied villages are shown in blue colour.

From the Limboo dominated villages, only Limboo individual willing to take part in the study were approached. Adults belonging to the Limboo community were identified by utilizing their surnames, physical features and language. The anthropometric, demographic, socio-economic and lifestyle related information were collected and recorded by visiting them at their homes and sometime all the individuals of a neighbourhood were call up on a neighbour’s house. Opinion of the senior and respected persons of village was also taken into consideration. The non-Limboo individuals were simply excluded from the study.

After verification of the initial information related to ethnicity and age, 1080 Limboo individuals (males: 530; females: 550) were approached for taking part in the study. None of the women were pregnant or lactating. The objectives of the present study were then explained them prior to data collection. Of these 1080 individuals, 76 of them (7.04%) refused to take any further part in the study. Later on, 7 individuals were found to be a fitness freak and 5 individuals were not available to provide their SES information of including the date of birth. Hence, the final sample comprised of 992 adult Limboo individuals (males: 496; females: 496) aged 18 years to 64 years. Age of the individuals was collected from available official records like birth certificates, and in some cases, voter cards and Aadhaar cards were utilised. A bearer of voter cards in India is an eligible individual citizen who can cast his/her vote in elections thereby ensures participation in making of government. Similarly, Aadhaar is a recently initiated scheme which uses fingerprints and retina as unique identification marks and used for identification purpose. Informed consent was taken from each Limboo individual prior to collection of the data.

2.4 PROCEDURES OF DATA COLLECTION

In order to achieve the objective of the present study, standard procedures of data collection were taken into consideration to obtain data from the field situation. The data collection procedures are briefly described below. The study has been conducted in accordance with ethical guidelines about human experiments as laid down in Helsinki Declaration (Touitou et al., 2004).

2.4.1 DEMOGRAPHIC, SOCIO-ECONOMIC AND LIFE STYLE FACTORS

The demographic, socio-economic and lifestyle variables taken in this study has important bearings on the different stages of human life. It also influences the nutritional status and the diseases out comes directly and indirectly. To obtain the demographic, socio-economic and lifestyle related data of the Limboo individuals, a questionnaire was structured and tested. The data on demographic, socio-economic and life-style related factors were collected using this structured and tested schedule (Annexure I) for the present field simultaneously with the anthropometric measurements.

2.4.1.1 Demographic variables

The explanatory variables that summarize the demographic behaviour of a population are considered as demographic variables. The demographics variables examined in the present study were age, sex, marital status, family size. Usually, individual can be identified as male and female and a third gender or transgender based on their biological endowment. In the present study biological sex was considered for the study and accordingly it was recorded.

Researches in the different fields have already identified differences in the physical, mental and social maturity among the human beings. However, the general tendency is physical, mental and social maturity is considered parallel with chronological maturity or age of an individual and difference as a deviation. Different age groups have different nutritional requirements. On the other hand different age groups have dependency and responsibility to one another. Unavailability or excess of nutrients according to age to an individual can impact the diseases out come. As already mention age was collected by asking the date of birth, if known, otherwise by asking about 'the age completed on the last birthday'. In some cases official documents like birth certificates, voter cards and Aadhaar card were also utilised.

Individuals were categorised into three age categories for further analysis viz. 18-29 years; 30-49 years and 50-64 years.

The information on marital status was obtained by asking the person whether he or she is married. Marriage is the most important aspect of human life and has a positive bearing on individuals as it fulfils the biological and social needs. Though, it brings responsibilities and predisposed individuals to various kinds of stress and depression which is widely regarded as the by-products of modern lifestyle and culture. Usually, information comes out on simple conversations, yet, whether the person is married or not was confirm by asking the individual.

The numbers of family members or individuals sharing a common kitchen as a family constitute family size in the present study. They are mutually dependent upon one another by some social obligations. They share common resource or means of procuring such resources as result family also forms a basic economic unit of a society. It has a huge influence on social accessibility and economic attainment which in turn has bearings on nutritional status as well. It has edge over family type, which is hindered by impractical definition like nuclear family, joint and extended family at least in the present study. For the ease of analysis, the family type in the present study is defined as small and large with 0 – 4 members and above 5 members respectively. This information was obtained directly by asking the respondent.

2.4.1.2 Socio-economic variables

The variables which reflect the social and economic status of any population or group are known as socio-economic variables. These variables are also important for understanding the impact of nutritional status on health. The socio-economic variables utilized in the present study were education, occupation, family monthly income, and land holding pattern.

The socio-economic characteristic like educational status, in general, is used as the degree of familiarity with culture and receptivity to new ideas and information on the part of individuals. At the same time, in this modern world, its importance is itself evident. In this sense, educational status has direct bearings on nutritional status and overall health of an individual. Those individuals who can read and write at least one vernacular language of the reason were considered literate. People with formal education were inquired about years of life spend on school and higher education institute.

Occupation gives measures of economic development attained by individuals and families as in the case of comparing societies. It also indicates the social position of individuals and families. The occupation category for the present study is based on the nature of the jobs, which is broadly classified into the manual occupation, non-manual occupation and the remaining as others. The manual occupation mostly consists of non-salaried jobs involving manual labour. In contrast the non-manual occupation category is consists of salaried jobs which involve less physical endurance. Category termed as 'others' consists of students and few unemployed individuals.

In the cash based market economy education and occupational status may not adequately highlight the economic attainment of a family and individuals. Families may have secondary sources of income which add to their purchasing power. The family monthly income helps us to understand their living standard. This parameter was calculated by adding the yearly incomes from all the sources as most of the responded were farmers and they sold their agricultural products once in a year. This yearly sum was divided by 12 to get family monthly income. For people with government service, their monthly salary was considered as family monthly income. Both the methods were combined to derive family monthly income of families with one or two family member with salaried jobs.

Table 2.1: Kuppuswami socio-economic scale proposed by Mishra and Singh (2003) updated for year 2015

Sl. No.	Education	Score
1	Professional or Honours	7
2	Graduate or post graduate	6
3	Intermediate or post high school diploma	5
4	High school certificate	4
5	Middle school certificate	3
6	Primary school certificate	2
7	Illiterate	1
	Occupation	
1	Professional	10
2	Semi-professional	6
3	Clerical, shop owner and farmer	5
4	Skilled worker	4
5	Semi-skilled worker	3
6	Unskilled worker	2
7	Unemployment	1
	(C) Income per month in Rupee	
1	≥ 40,315	12
2	20,158 – 40, 314	10
3	15,118 – 20,157	6
4	10,079 – 15,117	4
5	6,047 – 10,078	3
6	2,036 – 6,046	2
7	≤ 2,035	1
	Socio-economic status	Total score
1	Upper (I)	26-29
2	Upper-middle (II)	16-25
3	Lower-middle (III) (Middle)	11-15
4	Upper lower (Lower)	10-5
5	Lower	< 5

The information on land holding pattern was taken as the additional parameter for understanding their living standard and economic status. Ownership of land which is a natural resource can give individuals and families extra viability. This was recorded by asking each individual about the amount of their land. This was further confirmed by land deeds certificates issued by the government of Sikkim.

In addition, the Socio-economic Status (SES) of the population under study was also assessed utilizing the modified scale of Kuppuswami proposed by Mishra and Singh (2003). The scale was updated for the year 2015 using real time calculator available online from www.scaleupdate.weebly.com (Accessed on 2016-05-10) which is developed by Dr R. Sharma (Sharma, 2012). The calculator has been utilised by different studies (Reddy et al., 2014; Thakur et al., 2014; Bhansali, 2015). The updated Kuppuswamy socio-economic scale is presented in Table 2.1. This scale utilises the level of education, occupation and monthly income of the individual to identify his or her socio-economic status.

2.4.1.3 Life style variables

The lifestyle variables have added influences on nutritional status of an individual or population. The variables recorded in the present study were sources of drinking water, toilet facility and house type.

Until recently most of the houses in Sikkim were Assam-type cottages. Nowadays concrete buildings are the norms. In the present study, mud plastered houses and wooden houses were considered as “kacha” house, Assam-type houses with cement plastered wall were taken as “semi-pakka” house and concrete building were taken as “pakka” house. All the kacha and semi-pakka houses in the study area were found with metal sheet roofs.

Availability of drinking water was also assessed of household visits and recorded accordingly. In Sikkim there are two sources of drinking water, one is government supply and other is managed by individual households or group of households from source directly using rubber pipes in their own expenses. The common sources are springs and small streams. Hence, the terms “supply” and “piped” has been used respectively in the present study.

Households in Sikkim are equipped with commode toilets or at least proper pit toilets. Information recorded for this study is the presence of commode and pit toilets. Pit toilets are relatively unhygienic. Except for concrete building most of the houses have toilets outside the home within premises and clearly visible.

2.5 ANTHROPOMETRIC MEASUREMENTS

Aims, objectives and procedures of the present study were explained to individual participants before obtaining the anthropometric measurements. Subsequently a verbal consent was taken and then only measurements were recorded. Participants were healthy and not suffering from any diseases at the time of measurements. People with any kind of physical deformity and abnormality were not included in the study.

2.5.1 PROCEDURES OF TAKING MEASUREMENTS

Anthropometric measurements of stature, weight, arm span, arm length and mid-upper arm circumference (MUAC) were recorded following the standard procedures as outlined by Weiner and Lourie (1981). Similarly, waist circumference (WC) and hip circumference (HC) were recorded following the guidelines of WHO stepwise approach to surveillance (WHO, 2008) and recommended by WHO (2008). The measurement of neck circumference (NC) was recorded following Ben-Noun et al. (2001). Standing height, arm span, arm length and sitting height were measured using a standard anthropometer to the nearest 0.10 cm. Specially for measuring arm length and sitting height, 1^{st} and 2^{nd} segments of anthropometer (rod compass) were used. All the measurements were recorded in minimum clothes and bare feet on the left side of the subject. All the circumferences were measured using flexible nylon tape.

The skinfolds (BSF, TSF, SSF and SISF) were measured following Weiner and Lourie (1981) using a Holtain skinfold calliper on the left side of each individual to nearest to 0.2 mm. The skinfold calliper is designed to exert a pressure of 10 mm^2 during measurements. Precaution was taken to only include a double layer of skin and adipose tissue beneath but not muscles. The calliper was applied at the right angle to the fold. The reading was taken 2 seconds after the release of the trigger to exert full pressure.

In measuring obese subjects, firm pressure of the thumb and index finger were used to reduce excessive movement of the indicator. For difficult to raise skinfolds thickness, the caliper was forced to the muscle level and then slightly withdrawn when the fold is controlled by the grasp. Measurement was taken to the nearest 0.1mm. The three measures were taken on each individual and the mode value was considered.

The detail procedures of each measurement are briefly described below:

2.5.1.1 Height

Standing height was measured with the anthropometer rod (GPM type, Galaxy Informatics, New Delhi) to the nearest 0.10 cm. The adult subjects were made to stand on a flat surface with both heels together. The head was kept stretched upward to the fullest extent in the Frankfurt horizontal plane. The horizontal arm of the anthropometer was brought down lightly to touch the vertex in the mid-sagittal plane of the subject.

2.5.1.2 Weight

Body weight of the individuals was recorded using a portable digital weighing machine. The individuals were instructed to remove their slipper or shoes and extra clothes before stepping into the measuring scale. They were also instructed to place their foot properly on the scale and stand still facing forward until asked to step off with hands hanging on the sides. Body weight was recorded to the nearest 0.1kg.

2.5.1.3 Sitting height (SH)

To measure SH the participants were instructed to sit on a table with legs hanging from the edge of the table with hands resting on thighs in a cross. The body posture should be erect with ear-eye plane. Then SH was recorded from the surface of table to vertex with the anthropometer positioned on back of the participants parallel to spinal cord.

2.5.1.4 MUAC

The MUAC was measured on the left arm of each individual with arms hanging relaxed and palm of hand facing forward. It was measured midway between the tip of the acromion and the olecranon process. The measurement points were marked by a marker and the measurement was recorded without compressing the tissue. The subjects were asked to stand erect throughout the process.

2.5.1.5 Neck circumference (NC)

The neck circumference was measured in the midway of the neck, between the midcervical spine and the midanterior neck, to within 1 mm, with flexible nylon tape. In men with a laryngeal prominence (Adam's apple), it was measured just below the prominence (Ben-Noun et al. 2001).

2.5.1.6 Waist Circumference (WC)

The waist circumference was measured at the midpoint between lower margin of last palpable rib and the top of the iliac crest while the subject is in standing position. The measurement was recorded at the end of normal expiration with arms relaxed on the sides. The measurement was taken with the help of a flexible nylon tape to nearest 1 mm. The measurement of female participants was measured and recorded by a female investigator in a separate room. The measurement was conducted on light clothing.

2.5.1.7 Hip Circumference (HC)

This measurement was taken immediately after the waist circumference. The hip circumference was measured as maximum circumference or elevation of the buttocks with the individuals standing straight with the heels touching and arms relaxed on the sides. The measurement was taken using flexible nylon tape to nearest 1mm. The measurement on female participants was measured and recorded by a female investigator in a separate room. The measurement was conducted on light clothing.

2.5.1.8 Arm span

Arm span measurement was taken from the tip of the middle finger of one arm to the tip of middle finger of another arm (dactylion to dactylion) with arm outstretched at right angles to the body, on a level concrete floor. In the process participants was standing straight with heels closed to each other.

2.5.1.9 Arm length

Left arm length (LAL) was taken from the tip of the humerus (acromion) bone to tip of the middle finger (dactylion) of left arm while the subject was standing erect in the Frankfort plane with arms hanging down wards lateral to the body and heels closed to each others. Same steps were repeated for right arm length (RAL).

2.5.1.10 Biceps Skinfold (BSF)

The participants were asked to stand straight and relaxed with arms hanging on sides. The midpoint of the acromion process and the olecranon process was measured and marked. The marked was extended to encircle around the arm and another point was marked 1cm. above the circular line on the anterior surface of the biceps muscle for BSF measurement.

The skin and the subcutaneous tissue fold was picked approximately 2 cms above the circular line with the help of thumb and index finger and then the jaw of the caliper was placed in the marked point. The measurement was recorded as mentioned above.

2.5.1.11 Tricep skinfold (TSF)

The participants were asked to stand straight with arms relaxed and hanging on sides. The left hand of the participant was marked in the midpoint between the acromion and the olecranon processes in the posterior surface of the tricep muscle. The skin and the subcutaneous tissue fold was picked 1 cm above the marked point with the help of thumb and index finger and then caliper was applied to the pinch at the marked point. The measurement was recorded as mention before.

2.5.1.12 Sub-scapular Skinfold (SSF)

The participant was asked to stand straight with arms hanging on sides and relaxed. The inferior angle of the scapula was located by palpating the posterior spine of the scapula with fingertips and marked. The skin and subcutaneous tissue fold was picked obliquely just below the inferior angle of the scapula. The caliper was applied 1 cm away from the left thumb and index finger on the marked point.

2.5.1.13 Suprailiac Skinfold (SISF)

The participant was asked to stand straight with arms relaxed and hanging on sides. The suprailiac skinfold was marked about 1 cm above and 2 cm medial to the anterio-superior iliac crest. The skin and subcutaneous tissue fold were lifted accordingly to measure suprailiac skinfold.

2.5.2 TECHNICAL ERROR OF MEASUREMENT

To achieve intra-observer precision, three widely used precision estimates were calculated: the technical error of measurement (TEM), the relative technical error of measurement (rTEM) and the coefficient of reliability (R) (Ulijaszek and Kerr, 1999; Goto and Mascie-Taylor, 2007). For the calculation of intra-observer

TEM of height, weight, armspan, arm length, MUAC, NC, WC, HC, BSF, TSF, SSF and SISF were recorded from 30 adult male and female Limboo individuals. Anthropometric measurement is conducted by the male investigator for male participants and by a female investigator for female participants.

TEM was calculated as the square root of the squared difference between two corresponding measurements divided by twice the sample size (Ulijaszek and Kerr, 1999; Goto and Mascie-Taylor, 2007). The relative technical error of measurement (rTEM) was calculated by dividing the TEM for the given variable by the mean for that variable and multiplying the result by 100. The coefficient of reliability or R was calculated using the following equation: $R = 1 - \left[\frac{TEM^2}{SD^2}\right]$, where SD is the standard deviation of all measurements.

Table 2.2: Intra-observer technical error of measurement (TEM) for the male investigator (n=30).

Measurement	TEM	rTEM (%)	R
Height (cm)	0.2384	0.1508	0.9975
Weight (kg)	0.4111	0.7312	0.9972
Armspan (cm)	0.3717	0.2315	0.9962
LAL (cm)	0.3638	0.5434	0.9793
RAL (cm)	0.3730	0.5530	0.9959
MUAC (cm)	0.3274	2.3951	0.9813
NC (cm)	0.2299	0.6492	0.9876
WC (cm)	0.3435	0.4263	0.9974
HC (cm)	0.3490	0.4176	0.9992
SH (cm)	0.2696	0.3173	0.9986
TSF (mm)	0.2121	3.0878	0.9929
BSF (mm)	0.1879	4.8908	0.9802
SSF (mm)	0.2556	2.2382	0.9972
SISF (mm)	0.2359	2.7856	0.9964

Table 2.3: Intra-observer technical error of measurement (TEM) for the female investigator (n=30).

Measurement	TEM	rTEM (%)	R
Height (cm)	0.2342	0.1560	0.9971
Weight (kg)	0.7888	0.3371	0.9998
Armspan (cm)	0.4187	0.2732	0.9940
RAL (cm)	0.5241	0.8060	0.9685
LAL (cm)	0.5252	0.8110	0.9615
MUAC (cm)	0.6434	2.5193	0.9645
NC (cm)	0.1708	0.5455	0.9957
WC (cm)	0.5295	0.6340	0.9994
HC (cm)	0.3875	0.4176	0.9992
SH (cm)	0.3243	0.3968	0.9995
TSF (mm)	0.2338	2.0390	0.9961
BSF (mm)	0.2129	3.7093	0.9926
SSF (mm)	0.2323	1.8102	0.9982
SISF (mm)	0.2033	1.9265	0.9984

Since the R values are above the cut off value of 0.95 as proposed by Ulijaszek and Kerr (1999), the measurements recorded by both investigators (male and female) are reliable and reproducible. Subsequently all the measurements in the present study were recorded by both of them (male for the male subjects and female for the female subjects).

2.5.3 ASSESSMENT OF NUTRITIONAL STATUS

The nutritional status of the 992 adult Limboo individuals (males: 496; females: 496), in the age of 18 years to 64 years was assessed using standard anthropometric indicators and body composition indicators. These are described as follows:

2.5.3.1 Body Mass Index (BMI)

BMI is a suitable indicator to estimate the intensity of under-nutrition or CED and over-nutrition (overweight and obesity) of an individual or a population. BMI has been calculated using the following standard equation of WHO (1995):

$$BMI(kgm^{-2}) = \frac{Weight\ (kg)}{Height^2\ (m^{2)}}$$

Nutritional status has been assessed using the internationally accepted BMI cut-off points as suggested by WHO (WHO, 1995) and Asian cut-offs recommended by WHO (2000). For the screening of undernutrition, CED grades of BMI were used (WHO, 1995). The cut-off point value of <18.50 kg/m^2 for underweight was retained in recommended Asian cut-offs as well. New points for public health action for Asian adults are 23 kg/m^2 or higher considered as at risk. In addition to Obese I and II were formulated at 25 kg/m^2 and 30 kg/m^2 respectively. BMI is a well established proxy for undernutrition and high adiposity (James et al., 1988; Gibson, 1990; Ferro-Luzzi et al., 1992; Sengupta et al., 2014; Mondal et al., 2017). The classification of CED according to BMI as suggested by the WHO Expert Committee (WHO, 1995) and Asian cut-offs (WHO, 2000) are presented in Table 2.4 and Table 2.5 respectively.

Table 2.4: Cut-off points for assessing nutritional status of adult individuals as recommended by WHO (1995)

Category	BMI value (kg/m^2)
CED Grade III	< 16.00
CED Grade II	16.00 – 16.99
CED Grade I	< 17.00 – 18.49
Normal	18.50 – 24.99
Overweight	≥ 25.00 – 29.99
Obese	≥ 30.00

Table 2.5: Specific Asian cut-off points recommended by WHO (2000)

Category	BMI value (kg/m^2)
Underweight	< 18.50
Normal	18.50 – 22.99
Overweight	≥ 23.00
At risk	≥ 23.00 – 24.99
Obese I	25.00 – 29.99
Obese II	≥ 30.00

Table 2.6: Classification of CED based on BMI for adult individuals as recommended by WHO (1995)

Prevalence of CED	BMI value (kg/m^2)
Low prevalence	Warning sign: 5-9% of population with BMI < 18.50
Medium prevalence	Poor situation: 10-19% of population with BMI < 18.50
High prevalence	Serious situation: 20-39% of population with BMI < 18.50
Very high prevalence	Critical situation: > 40% of population with BMI < 18.50

2.5.3.2 Mid Upper arm circumference (MUAC)

Nutritional status was also evaluated in the present study using the internationally accepted cut-off points of MUAC. The individual values of MUAC found below 23 cm and below 22 cm were characterized as under-nutrition among the males and females respectively (James et al., 1994). These cut-offs value was recommended as a useful indicator of protein energy starvation (Harries et al. 1984; WHO 1995).

2.5.3.3 Waist Circumference (WC)

The cut-offs for WC given by International Diabetes Federation (Alberti et al., 2007) is 80 cm and 90 cm for female and male respectively and also recommended by WHO (2008) has been utilised to identify the individuals at risk of adiposity related morbidity. This criteria is used by WHO (2000) and WHO/FAO (2003) and specifically recommended for Asians (WHO, 2008). In India, it is adopted by NNMB (2009) for its national surveys.

2.5.3.4 Waist-Hip Ratio (WHR)

The WHR has been calculated using the measurements of WC and HC using the following equation:

$$WHR = \frac{Waist\ Circumference\ (cm)}{Hip\ Circumference\ (cm)}$$

A high WHR was defined as >0.9 in males and >0.8 in females by Web *et al.* (2002) and Huxley *et al.* (2008) and recommended by WHO (2008). These cut-offs are used to assess the amount of higher regional adiposity among the individuals studied.

2.5.3.5 Waist-Height Ratio (WHtR)

The WHtR was calculated from the measurements of WC and height using the following equation:

$$WHtR = \frac{Waist\ Circumference\ (cm)}{Height\ (cm)}$$

A cut-off value of 0.5 was proposed by Hsieh and Muto (2004) to assess higher level of adiposity for both sexes. This cut-off has also been validated on the Kayastha population of North Bengal, India (Sarkar et al., 2009) and also recommended by WHO (2000). The present study has used this cut-off to assess adiposity among the Limboo individuals.

2.5.3.6 Cormic Index (CRI)

Cormic Index is also known as the index of body shape is calculated as ratio of sitting height to height. It is usually studied to observed ethnic differences and for correction of influence of long leg in relation to trunk in the BMI of an individual and population (WHO, 1995; Norgan, 1995).

$$CRI = \frac{Sitting\ Height}{Standing\ Height}$$

2.5.3.7 Conicity index (CI)

CI was also worked out in the present study to assess body composition following the equation of Valdez et al. (1993). Mostly this index is studied in association with cardiovascular diseases and other indicators of adiposity. Cut-offs points used for the Conicity index are 1.25 for males and 1.18 for females above which cardiovascular diseases and related risk increases. The formula to calculate CI is given below:

$$CI = \frac{Waist\ Circumference\ (m)}{0.109\sqrt{\frac{Weight\ (kg)}{Height\ (m)}}}$$

2.5.3.8 Neck Circumference (NC)

The NC has been put forth by Ben-Noun et al. (2001) as a culture free measure of adiposity of upper trunk which may well correlated with BMI and the related morbidity. In the present study it was used to compare with other established measures of adiposity such as BMI, WC, WHtR, WHR and BAI and CI.

2.5.3.9 Body Adiposity Index (BAI)

BAI was proposed by Bergman et al. (2011) to overcome the limitations of BMI in accessing PBF. The formula put forth by Bergman et al. (2011) is utilised to calculate BAI which is shown below.

$$BAI = \frac{Hip\ circumference\ (cm)}{Height\ (m)^{1.5}} - 18$$

Further, it has been utilised to compare with adiposity indicators like BMI, WHtR, WHR, WC, and NC based on the PBF derived from skinfolds.

2.5.4 ASSESSMENT OF BODY COMPOSITION

2.5.4.1 Upper Arm Composition

Combination of MUAC and TSF is useful for the assessment upper arm composition as suggested by Frisancho (1974, 1981, and 1989). The given method of upper arm composition is recommended by WHO (1995) and also corroborated by Singh and Mehta (2009). It enhances the utility of MUAC and TSF. In the present study the upper arm composition of the individuals was evaluated using the equations of Total Upper Arm Area (TUA), Upper Arm Muscle Area (UMA), Upper Arm Fat Area (UFA) and Arm Fat Index (AFI) which is given below:

$$TUA\ cm^2 = \frac{(MUAC)^2}{4\pi}$$

$$UMA\ cm^2 = \frac{\{MUAC - (TSF \times \pi)\}^2}{(4 \times \pi)}$$

$$UFA\ cm^2 = TUA - UMA$$

$$AFI = \frac{UFA}{TUA} \times 100$$

The standard equations of Frisancho (1989) were also utilized to assess the corrected Bone Free Muscle Area (BFMA) among the Limboo male and female individuals. The equations are as follows:

$$BFMA_{MALE} cm^2 = (UMA - 10.0)$$

$$BFMA_{FEMALE} cm^2 = (UMA - 6.5)$$

2.5.4.2 Body Density (BD) Assessment

In order to assess PBF utilizing skinfold thickness (e.g., BSF, TSF, SSF, SISF) calculation of body density is a mandatory step. Sex specific standard equations of Durnin and Womersely (1974) were utilized for the purpose. These equations assumed a logarithmic relationship between obesity or higher level of adiposity and sum of BSF, TSF, SSF and SISF skinfolds among the individuals. These equations have been validated in different Indian populations by Chakrabarty and Bharati (2010), Kaur and Talwar (2011), Chowdhury and Roy (2016), Banik et al. (2016), Ghosh and Bose (2018). The equations of Durnin and Womersely (1974) utilized to assess the body density is given below:

$$Male\ body\ density = 1.1765 - 0.0744 \times \log_{10}(BSF + TSF + SSF + SISF)$$

$$Female\ body\ density = 1.1567 - 0.0717 \times \log_{10}(BSF + TSF + SSF + SISF)$$

2.5.4.3 Assessment of Percentage Body Fat (PBF)

After the calculation of body density, the standard equation of Siri (1956) was used to assess PBF for both male and female individuals of the present study. Indian studies have utilized Siri’s equation in order to estimate the body fat content in different ethnic populations (Chakrabarty and Bharati, 2010; Kaur and Talwar, 2011; Chowdhury and Roy, 2016; Banik et al., 2016; Ghosh and Bose, 2018).

$$PBF = \left(\frac{4.95}{Body\ density} - 4.50\right) \times 100$$

2.5.4.4 Assessment of Fat mass (FM) and Fat free mass (FFM)

The body mass consists of both fat mass (FM) and fat free mass (FFM). The standard equations of Van Itallie et al. (1990) and Eckhardt et al. (2003) have been utilized to assess the amount of FM and FFM among the Limboo individuals. Several researchers have utilized these equations to assess the FM and FFM among different Indian populations (Chakrabarty and Bharati, 2010; Kaur and Talwar, 2011; Chowdhury and Roy, 2016; Banik et al., 2016; Ghosh and Bose, 2018). The equations are as follows:

$$Fat\ Mass\ (kg) = \left(\frac{PBF}{100}\right) \times Weight\ (kg)$$

$$Fat\ Free\ Mass\ (kg) = Weight\ (kg) - \ FM\ (kg)$$

2.5.4.5 Assessment of Fat mass index (FMI) and Fat free mass index (FFMI)

The indices of fat mass index (FMI) and fat free mass index (FFMI) were calculated from the equations of Van Itallie et al. (1990). The indices are given below:

$$Fat\ Mass\ Index\ (kgm^{-2}) = \frac{FM}{Height^2\ (m^2)}$$

$$Fat\ Free\ Mass\ Index\ (kgm^{-2}) = \frac{FFM}{Height^2\ (m^2)}$$

The proposed classification for FMI and FFMI for Caucasian men by Kyle et al. (2003), modified by Khongsdier (2005) for males of the Northeast, India was used in the present study. The cut-offs of FFMI was 15.1, 15.1-18.0 and 18.0 kg/m^2 for low, normal and high FFMI, respectively. Similarly, FMI was 2.9, 2.9-5.0 and 5.0 kg/m^2 was categorised as low, normal and high, respectively (Khongsdier, 2005). As Khongsdier (2005) has not presented the cut-offs for women, the cut-offs of FMI given by Liu et al. (2013) for Chinese men (7.00) and women (7.90) were utilised further in the present study.

2.5.4.6 Assessment of status of body fatness

The percentage body fat classifications of Nieman (1995) and Muth (2009) were used to determine the fitness level among the individuals of the present study. The detail of their classification is presented in the Table 2.7 and 2.8. Classification given by Muth (2009) was sex specific and classification of Nieman (1995) was general.

2.5.4.7 Assessment of related risk factor with PBF

There is no recommended cut-offs to assess the risk level of PBF (WHO, 1995; Lavie et al., 2009). The often used cut-offs points of PBF for male and female are 25% and 35%, respectively. Increasing use of these cut-offs point for PBF was purported from the unavailability of a reliable cut-offs. On the other hand the increasing use of these cut-offs is generating evidence in favour of these PBF cut-offs per se (Deurenberg, 2002; Lavie et al. 2010) etc. Another widely used cut-offs points of PBF are 25% for male and 30% female individuals which are utilized in the present study (Dudeja et al. 2001; Zeng et al. 2012).

Table 2.7: Classification of Percentage Body Fat (PBF) given by Nieman (1995)

Body weight status	Fat %
Lean	< 13%
Optimal fat	13-23%
Fat	24-32 %
Over fat	>33%

Table 2.8: Sex specific cut-off values for assessment of related risk factor with PBF after Muth (2009).

Classification	Male %	Female %
Essential fat/Underweight	2-5	10-13
Normal	6-17	14-24
Acceptable/ Overweight	18-24	25-31
Obese/Morbid	25	32

2.6 STATISTICAL ANALYSIS

The data obtained in the present study were statistically analyzed using statistical constants and relevant statistical tests. The statistical analyses were performed utilizing the Statistical Package for Social Sciences (IBM SPSS; version 20). A p-value of <0.05 and <0.01 was considered to be statistically significant.

The anthropometric variables recorded have been described using descriptive statistics (mean ± standard deviation). Some variables were log transformed owing to normal distribution. Sex differences and age specific differences within sexes in the anthropometric variables were analysed using one-way analysis of variance (ANOVA). The Pearson correlation coefficient analysis was done to understand the association between the anthropometric variables. Linear regression analysis was done to assess the dependency of the sex, age and BMI on the anthropometric variables.

Chi-square (χ^2) analysis was utilized to assess sex differences in socio-economic, demographic and life style related factors (population size, education, occupation, family monthly income, family size, marital status, drinking water facility, toilet facility, landholding pattern, house type, and socio-economic status). Further, χ^2 analysis was also done to assess the sex differences and difference within sex in the prevalence of undernutrition and overnutrition based on various anthropometric indices taken in the study. The Fisher's exact test was utilised for a cell/category with less than 5 individuals. This correction term adds to the accuracy of the χ^2 analysis when the numbers of classes are small. The χ^2 analysis was also utilized to assess sex differences in nutritional indices related to fatness, body composition, overnutrition and regional adiposity measurements between male and female individuals. The differences in BMI, WHR, WHtR with respect to the different socio-economic, demographic and lifestyle related variables were also assessed using χ^2 analysis.

The logistic regression models were fitted to estimate the odds of being affected by undernutrition and overnutrition in case of BMI, WC, WHR, WHtR and CI among the Limboo individuals. Multinomial logistic regression was used to compare being affected by underweight, overweight and obesity against normal weight. Similarly, binary logistic regression analysis was conducted to compare the chances of being affected by high WC, WHR, WHtR and CI. The model with the calculation of Wald χ^2-square, corresponding adjusted odds (ORs) and 95% confidence interval (CIs) was used to examine possible differences between the individuals in the category of under-nutrition or overnutrition. The predictor variables or independent variables were socio-economic, demographic and life style related factors such as sex, age, marital status, education, occupation, income, socio-economic status (based on Kuppuswamy Scale), family size, land holding, house type, drinking water and hygienic toilet. The multinomial regression model allows controlling effects of these variables to create dependency in selective variables. Therefore, individuals affected by undernutrition and overnutrition were categorized into different levels by using different sex specific cut-offs points for BMI (WHO, 1995), WC (WHO 2008), WHR (WHO, 2008), WHtR (Hsieh and Muto, 2004) and C-Index (Valdez et al., 1993). Cases of undernutrition, overweight and obesity were coded as 3, 4, 5 and normal cases were coded as 0 for BMI respectively. The parameters of central obesity such as WC, WHR, WHtR and C-Index were coded as 0 for the cases below the cut-offs and coded as 1 those above the given cut-offs. These dummy variables were entered in the regression model as response variables. Similarly, the predictor variables were coded separately and entered in the regression model as a set of dummy variables. The variables used as predictors for the multinomial regression model includes sex (male; female), age (18-29 years; 30-49 years;50-64 years), marital status (unmarried; married), education (illiterate; upto 8^{th} grade; ≥ 9^{th} grade), occupation (non-manual; manual; others), income (≤ ₹4999/=; ₹5000/= - ₹9999/=; ≥ ₹10000/=), Socio-economic status based on Kuppuswamy Scale (upper lower; lower middle; upper middle), family size (large; small), land holding (≥ 1 acre; 0-0.99 acre), house type (semi-pakka; pakka; kacha), drinking water (piped from spring; supply) and hygienic toilet (pit; commode). The words in the brackets are categories of the each variable and coded keeping in view that SPSS automatically assigned last or higher number as reference so that first category of each of these variables gets set as the reference category for the logistic regression models.

Receiver operating curve (ROC) analysis was utilised to compare the available indices of adiposity. Best indices were identified based on area under curve (ROC-

AUC). The same analysis was utilised to define appropriate cut-offs for different variables of obesity and fatness including body composition variables taken in the present study. The cut-off points were defined at the equal sensitivity and specificity of ROC-AUC using highest value of Youden Index (J). The J is equal to sensitivity + specificity. The skinfolds derived PBF with cut-offs of 25% (male) and 30% (female), and the BMI (WHO 2000) classifications were utilized as a reference for ROC-AUC.

Chapter 3

RESULTS

3.1 DISTRIBUTION OF DEMOGRAPHIC, SOCIO-ECONOMIC, AND LIFE STYLE RELATED VARIABLES AMONG THE LIMBOO INDIVIDUALS

3.1.1 POPULATION SIZE AND STRUCTURE

The present study comprised of 992 adult Limboo individuals, of which 496 were males and 496 were females. The selected age group was 18 – 64 years with mean age of 34.73 years (±12.37). The individuals in the present study were further categorised into three categories such as 18 – 29 years, 30 – 49 years and 50 – 64 years. Each of the age groups comprised of 405 (40.83%), 421 (42.44%), 166 (16.73%) adult Limboo individuals of both sexes (Figure 3.1). In the first age group males and females was 46.67% and 53.33%, respectively. It was 51.31% males and 48.69% females in the second age group. Further the last age group have 54.82% males and 45.18% females. The χ^2 test between sex was not significant in the age categories (χ^2 – value 3.63; d.f.2; $p>0.05$). The sex-specific distribution is presented in Figure 3.2.

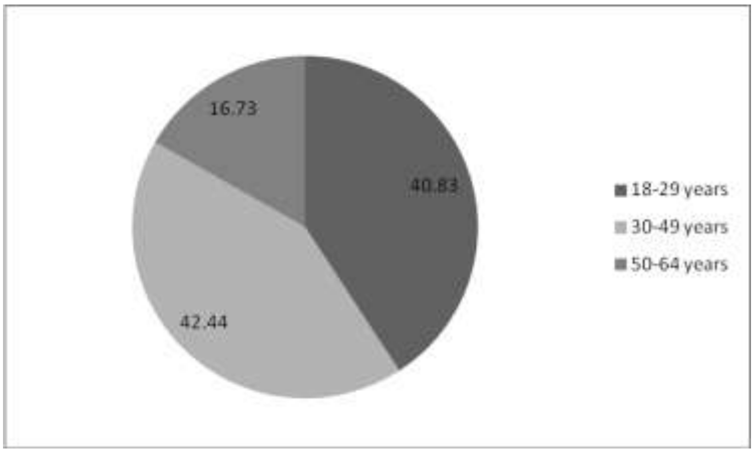

Figure 3.1: Age distribution of the Limboo individuals.

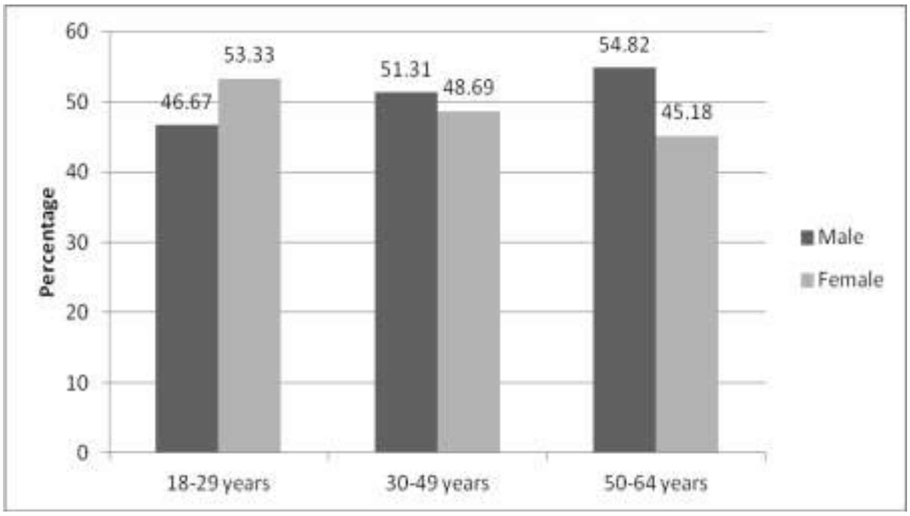

Figure 3.2: Age and sex distribution of the Limboo individuals.

3.1.2 MARITAL STATUS

As depicted in Figure 3.3 there were 75.10% married and 24.90% unmarried Limboo individuals. Unmarried males were 54.66% and females were 45.34%. The remaining 48.46% males and 51.54% females were married. The χ^2 test on marital status for sex difference yields non-significant result (χ^2 – value 2.85; d.f.1; p>0.05). The sex specific distribution is presented in Figure 3.4.

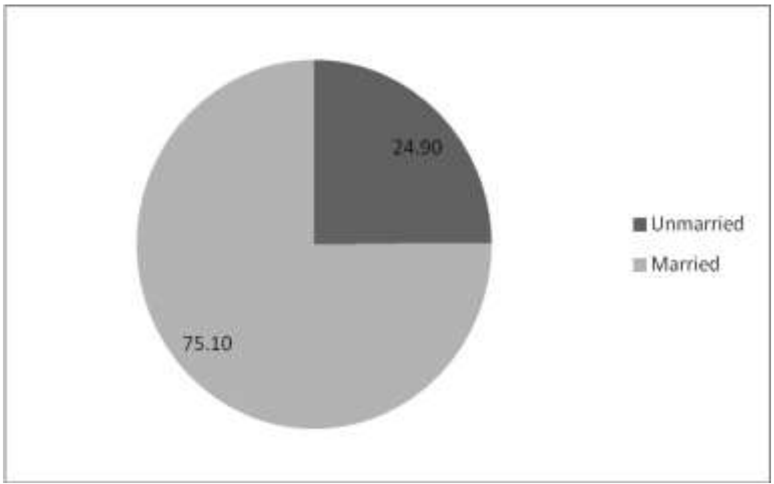

Figure 3.3: Distribution of marital status of the Limboo individuals.

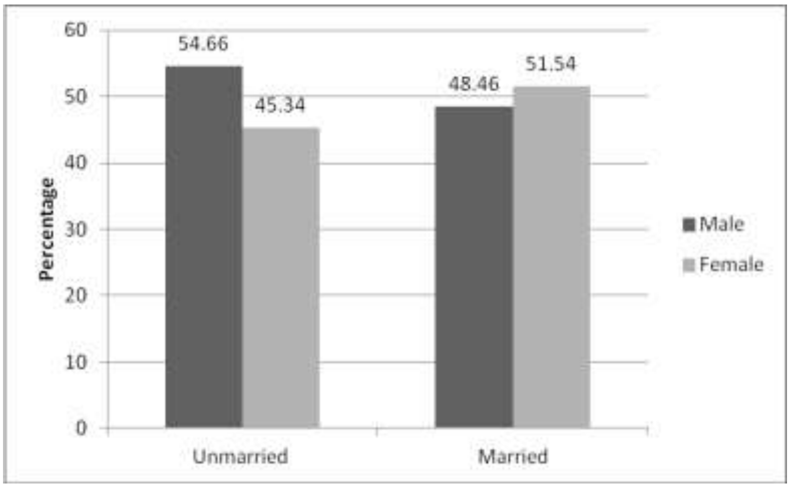

Figure 3.4: Sex specific marital status of the Limboo individuals.

3.1.3 EDUCATION

The educational attainment of the Limboo individuals irrespective of sex is presented in Figure 3.5. The categorization are illiterate, upto 8^{th} grade and above 9^{th} grade which consists of 245 (24.70%), 387 (39.01%) and 360 (36.29%) individuals respectively. The sex difference in these categories of educational attainment were significant (χ^2 – value 61.61; d.f.1; $p<0.001$). Among the individuals who never went to school, males were 28.57% and females were 71.43%. Those who studied only up to 8^{th} grade were 59.43% males and 40.57% females. Finally educational category of above 9^{th} grade consists of 54.44% males and 45.56% females. The sex specific distribution is presented in Figure 3.6. Along with senior secondary education the above 9^{th} grade category consists of diploma, graduation and post graduation degree holders.

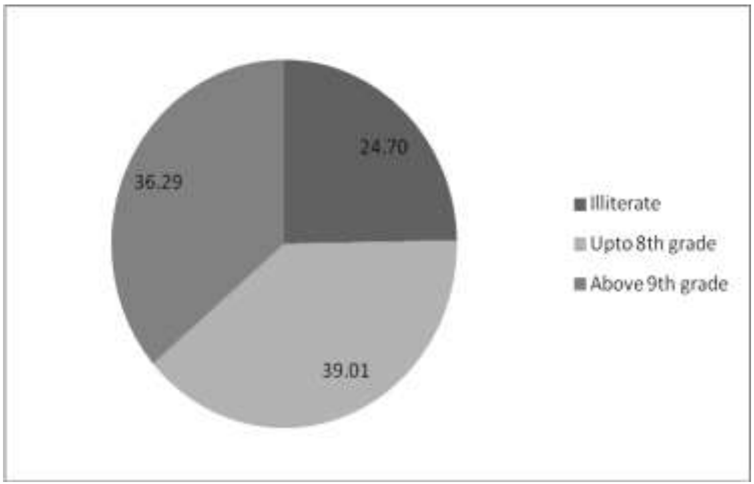

Figure 3.5: Distribution of educational attainment of the Limboo individuals.

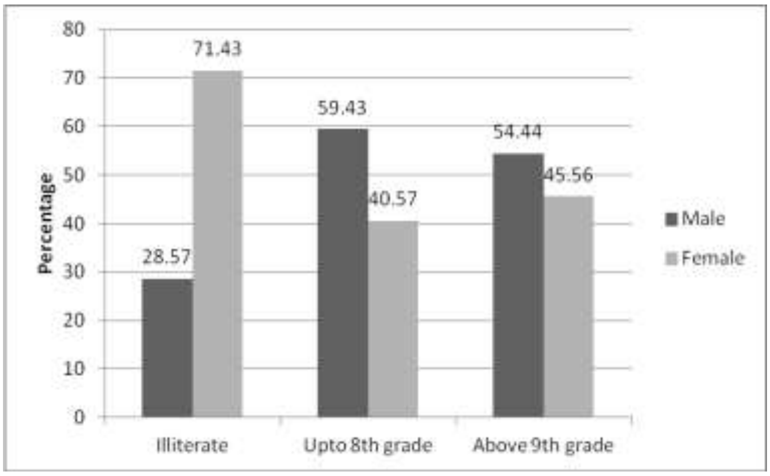

Figure 3.6: Sex specific educational status of the Limboo individuals.

3.1.4 OCCUPATION

There were total 71.77% of individuals involved in occupations which demands manual labour, among them 46.49% and 53.51% were males and females respectively. On the other hand individuals dependent on non-manual occupations were 15.83%, of which males were 66.24% and females were 33.76%. The category termed "others" has 123(12.40%) individuals of the total sample population, which comprised of 49.59% and 50.41%, males and females respectively. The overall and sex specific distribution is given in Figure 3.7 and 3.8, respectively. The χ^2 test for sex difference was significant (χ^2 – value - 63.79; d.f.5; P<0.001).

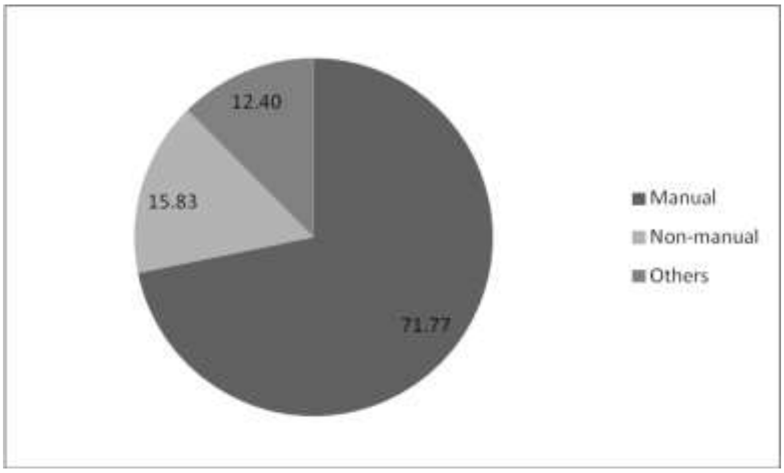

Figure 3.7: Distribution of occupation of the Limboo individuals.

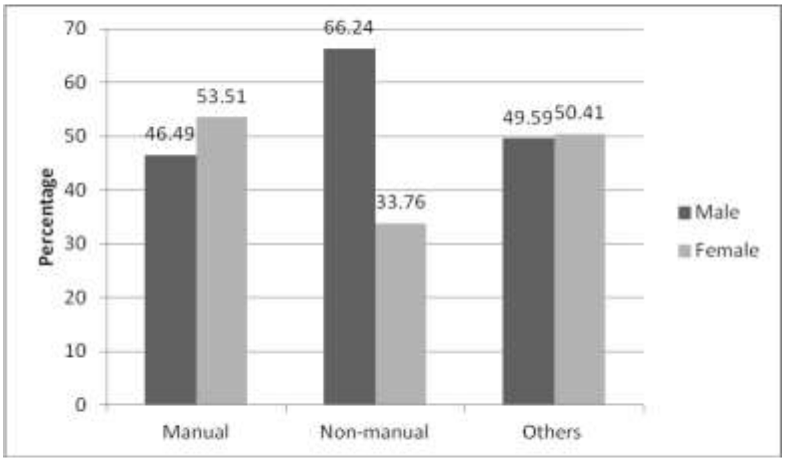

Figure 3.8: Sex specific occupations of the Limboo individuals.

3.1.5 FAMILY MONTHLY INCOME

The family monthly income of the present study population range from ₹500/= – ₹80,000/=. As shown in Figure 3.9 the individuals belonging to lower income group with family monthly income of ₹4999/= and below constitute 11.49% of the study population. The middle income group with family monthly income of ₹5000/= – ₹9999/= were 38.0% and then individuals of high income group with family monthly income above ₹10000/= were 50.50% of the total sample. Sex specific distribution of the income group is depicted in Figure 3.10. In the lower income group (≤ ₹4999/=) males and females constitute 50.88% and 49.12% respectively. In the middle income group (₹5000/= – ₹9999/=) males and females constitute 48.01% and 51.99%, respectively. The high income group (₹10000/= and above) was comprised of 51.30% males and 48.70% females. The χ^2 test between sexes and income groups (χ^2 – value 0.96; d.f.2; p>0.05) was not significant.

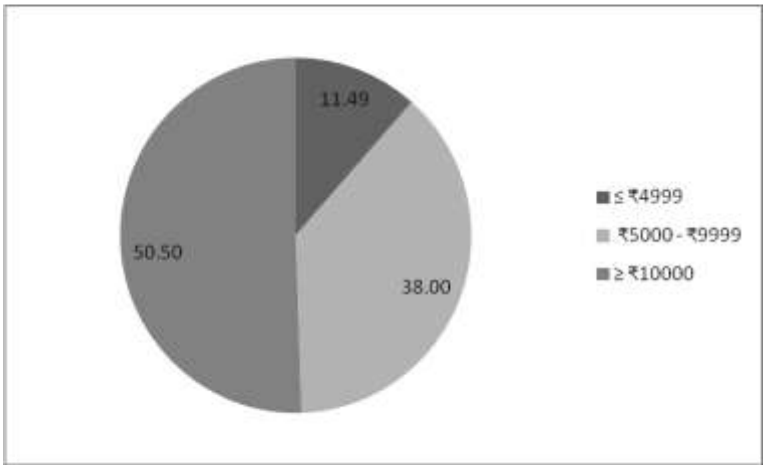

Figure 3.9: Distribution of monthly family income of the Limboo individuals.

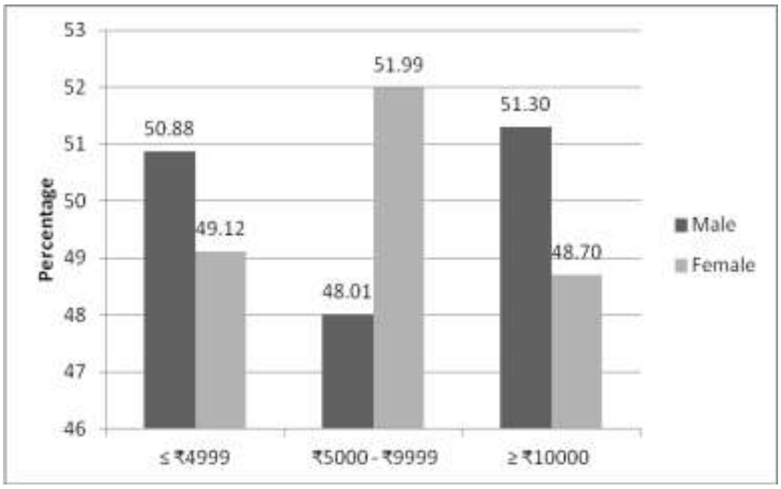

Figure 3.10: Sex specific family monthly income among the Limboo individuals.

3.1.6 SOCIO-ECONOMIC STATUS (SES)

The Kuppuswamy socio-economic status scale indentified only three socio-economic statuses among the Limboos of present study. These are Upper Middle (UM), Lower Middle (LM) and Upper Lower (UL). The overall distribution is presented in Figure 3.11. The highest number of individuals were under the UL (52.32%) which was followed by LM (30.44%) and then UM (17.24%). The sex specific pattern is given in Figure 3.12 and Table 3.1. The UM group consists of 47.95% and 52.05%, males and females, respectively. The LM group consists of 46.36% males and 53.64% females. The UL group consists of 47.21% males and 52.79% females. The sex difference between the above SES categories was not significant (χ^2 – value 3.51; d.f.1; p>0.05).

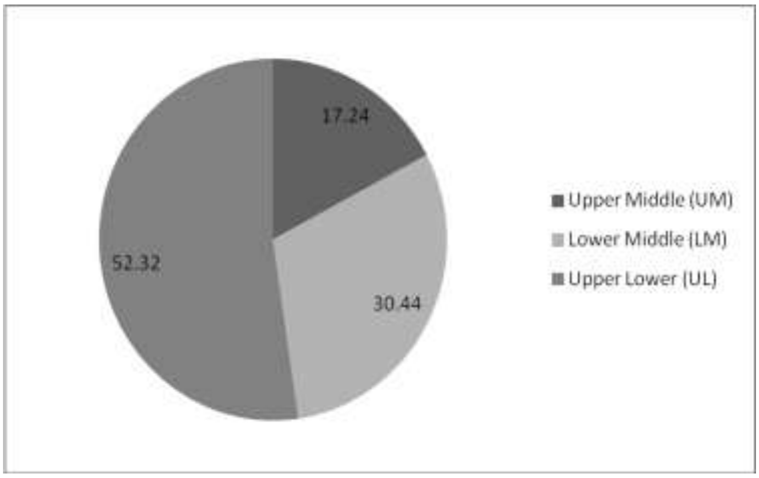

Figure 3.11: Distribution of Socio-economic status (SES) of the Limboo individuals.

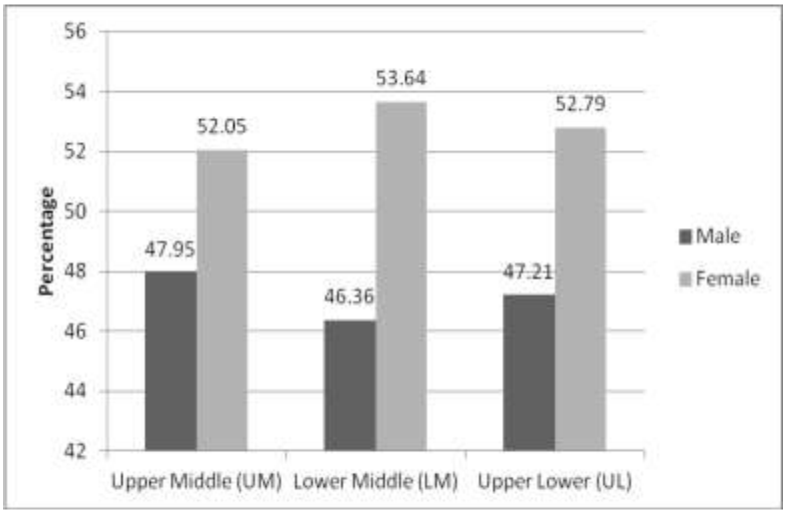

Figure 3.12: Sex specific SES of the Limboo individuals.

3.1.7 FAMILY SIZE

The distribution of small (1-4members) and large (5 and above members) family is shown in Figure 3.13. The individuals coming from small family were 333 (33.57%) and large family were 659 (66.43%). The individuals of small family consist of 50.15% males and 49.85% females (Figure 3.14). On the other hand, large family consists of 49.92% males and 50.08% females (Figure 3.14). The sex difference between above family sizes was non-significant (χ^2 – value 0.01; d.f.1; $p>0.05$).

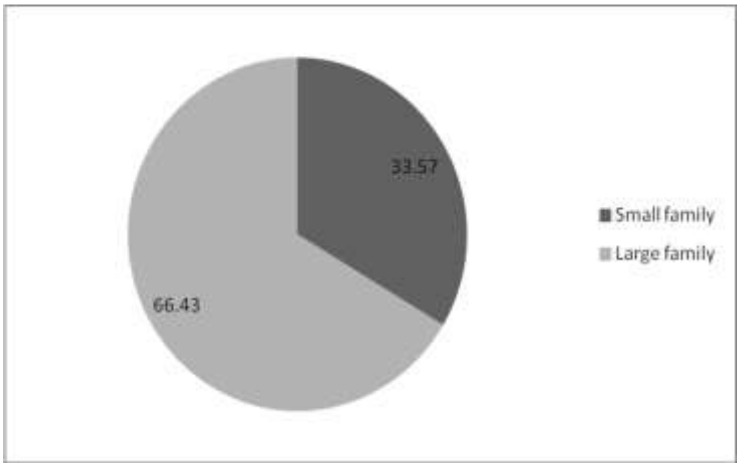

Figure 3.13: Distribution family size of the Limboo individuals.

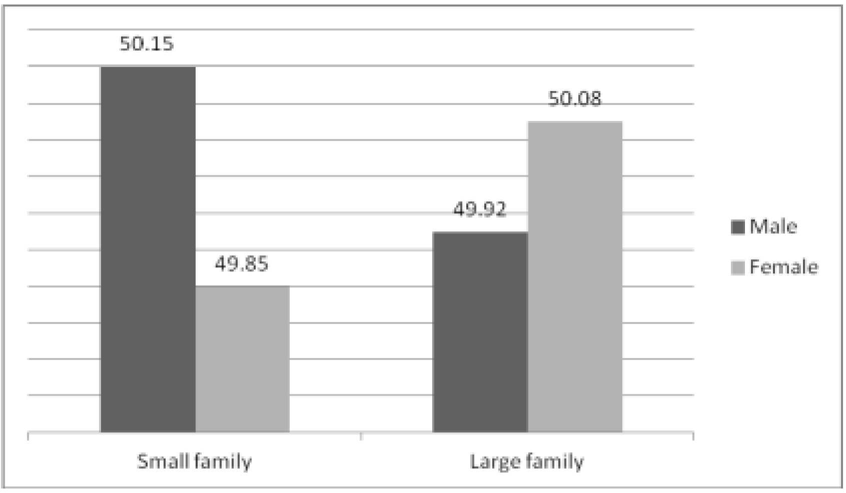

Figure 3.14: Sex specific family size of the Limboo individuals.

3.1.8 LAND HOLDING PATTERN

The two categories of land holding pattern considered in the present study were 0 – 0.99 acres and above 1 acre (≥ 1 acre). The first category consists of landless people, people with the only house and people with land below 0.99 acres and the second category consists of people with land ≥ 1 acre. The percentages of individuals with landholding 0 – 0.99 acres and ≥ 1 acre were 32.86% and 67.14%, respectively (Figure 3.15).

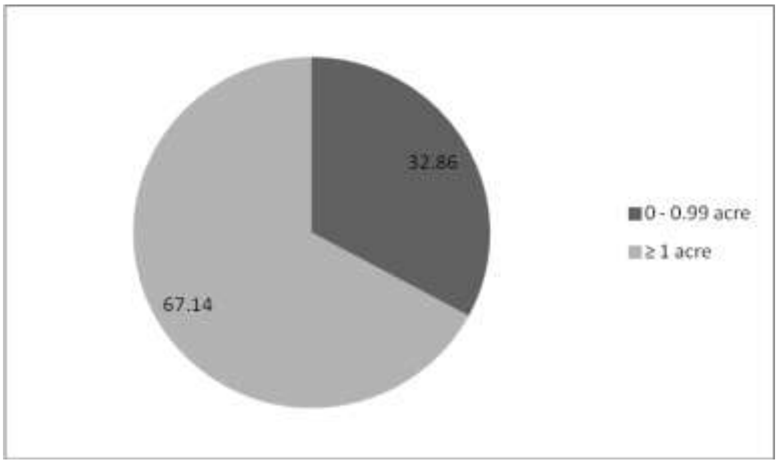

Figure 3.15: Distribution of land holding pattern of the Limboo individuals.

The sex specific distribution of the land holding pattern is shown in Figure 3.16. About 53.60% and 46.40%, males and females, respectively have land holding of 1 acre and above. On the other hand, 42.64% and 57.36%, male and female individuals were observed in the category with land holding 0 – 0.99 acres, respectively. The χ^2 test result was significant for the sex difference in land holding pattern (χ^2 – value - 10.53; d.f.1; p<0.05).

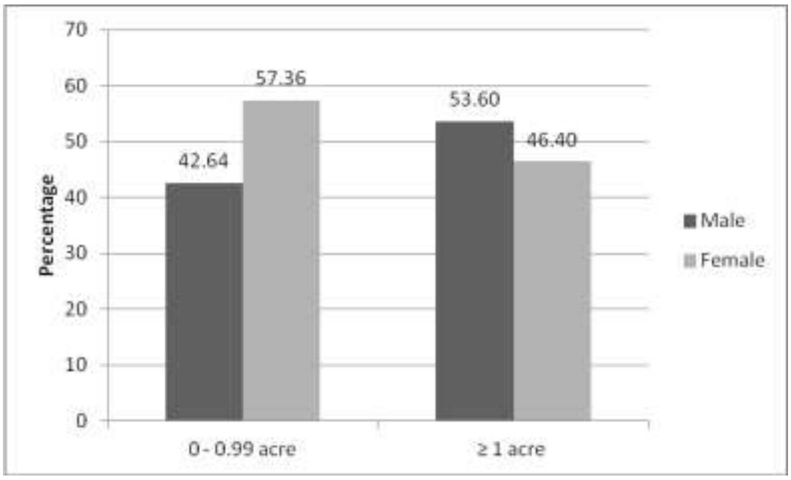

Figure 3.16: Sex specific land holding pattern of the Limboo individuals.

3.1.9 HOUSE TYPE

The pie diagram (Figure 3.17) shows the distribution of house type among the Limboo individuals of the present study. The majority houses were "pakka" (55.14%) followed by "kacha" (26.41%) and "semi-pakka" (18.45%). The sex specific distribution is given in Figure 3.18. Among the individuals staying in pakka house 50.09% were females and 49.91% were males. Among the kacha house dwellers 52.67% were males and 47.33% were females. The semi-pakka house dwellers comprised of 46.45% males and 53.55% females. The χ^2 test yield non-significant result (χ^2 – value 1.67; d.f. 2; p>0.05).

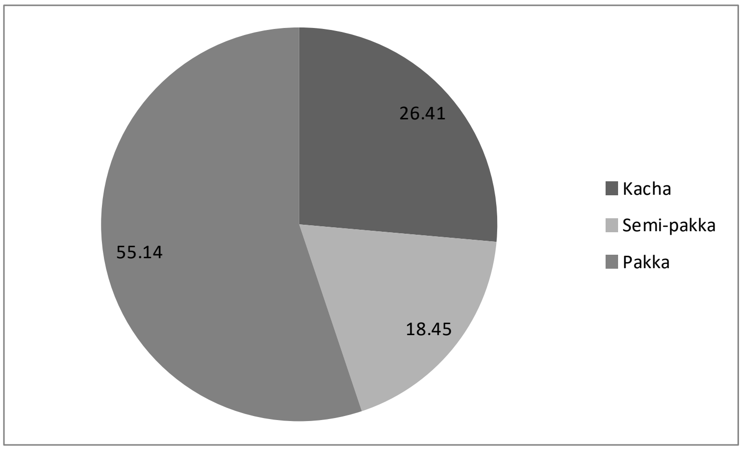

Figure 3.17: Distribution of house type of the Limboo individuals.

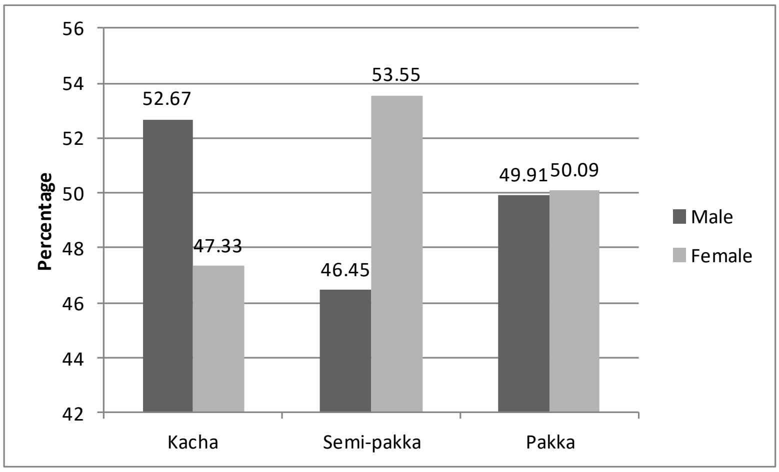

Figure 3.18: Sex specific house type of the Limboo individuals.

3.1.10 DRINKING WATER

There were mainly two type of drinking water source in Sikkim, one is government supply as a part of its welfare system and the other is piped from spring and nearby natural sources of water by people with their own effort. For this the terms supply and piped has been used respectively in the present study. Total numbers of individuals from households with the piped source of drinking water were 58.37% and those with supply source of drinking water were 41.63%. The distribution is depicted in Figure 3.19. Among the individuals with piped source of drinking water facility 46.25% were males and 53.75% were females. Similarly, among the individuals of household with supply source of drinking water 52.68% were males and 47.32% were females. The sex specific distribution is presented in Figure 3.20. The sex difference between the sources of drinking water was significant (χ^2 – value - 3.98; d.f.1; $p<0.05$).

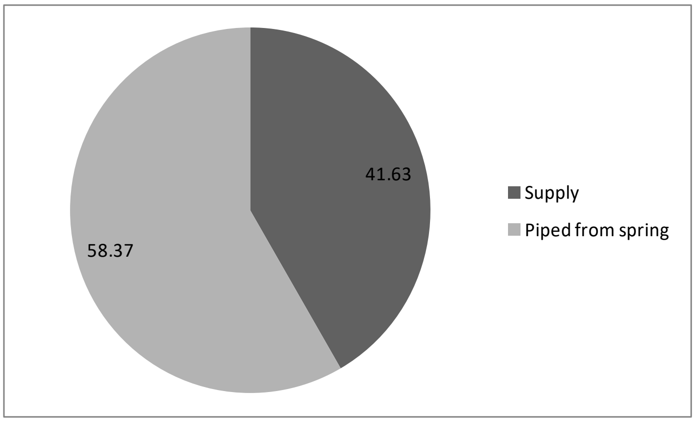

Figure 3.19: Distribution of available drinking water source of the Limboo individuals.

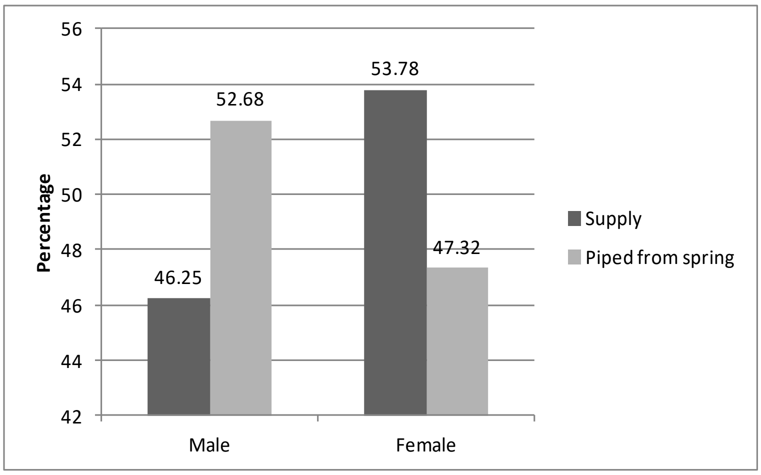

Figure 3.20: Sex specific source of drinking water of the Limboo individuals.

3.1.11 TOILET

In the present study no households were found without toilet. The two types of toilets differ in structure only not on hygienic condition with few exceptions. Overall 858 (86.49%) individuals belonged to households with commode toilet and remaining

134 (13.51%) individuals were from the households with pit toilet (Figure 3.21). The individuals from the commode toilet households consist of 50.35% males and 49.65 % females. Further 47.76% were males and 52.24% were females from the households with pit toilet. The sex difference was not significant for the individuals of households with commode and pit toilets (χ^2 – value 0.31; d.f.1; p>0.05). The sex specific distribution was presented in Figure 3.22.

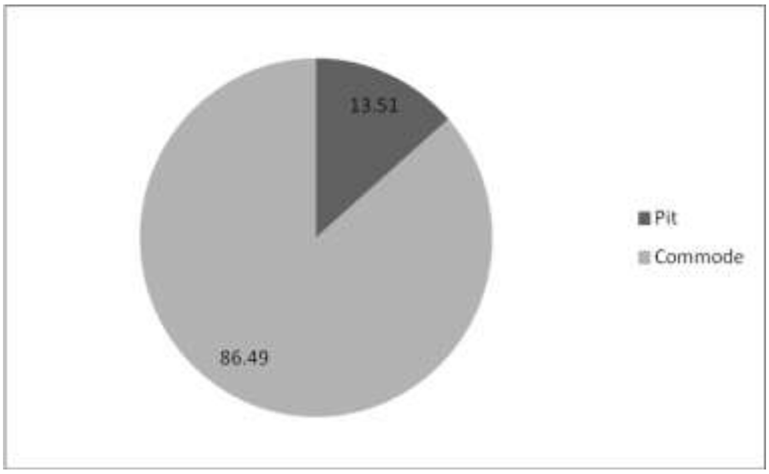

Figure 3.21: Distribution of types of toilet of the Limboo individuals.

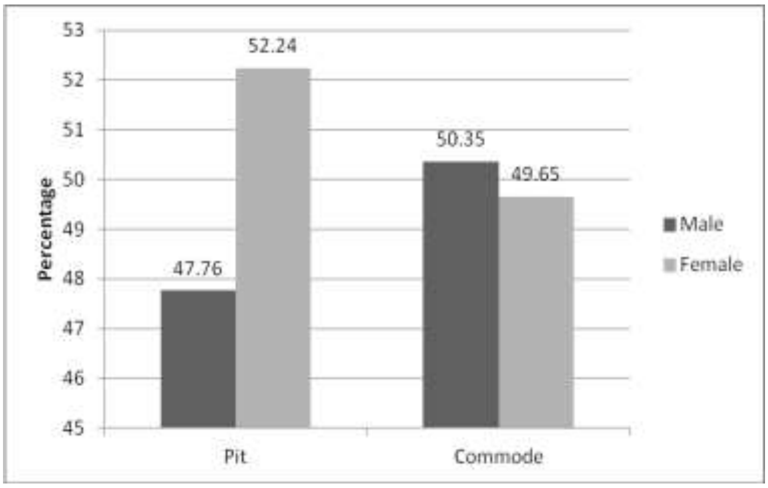

Figure 3.22: Sex specific break-ups of types of toilet of the Limboo individuals.

Table 3.1: The sex wise distribution of socio-economic, demographic, and life style variables of the Limboo individuals

Variables	Categories	Male	Female	χ^2-value
Age group	18-29 years	189 (46.67)	216 (53.33)	3.63; d.f.2; p>0.05
	30-49 years	216 (51.31)	205 (48.69)	
	50-64 years	91 (54.82)	75 (45.18)	
Marital status	Unmarried	135 (54.66)	112 (45.34)	2.85; d.f.1; p>0.05
	Married	361 (48.46)	384 (51.54)	
Education	Illiterate	70 (28.57)	175 (71.43)	61.61; d.f. 2; P<0.001
	Upto 8th grade	230 (59.43)	157 (40.57)	
	≥ 9th grade	196 (54.44)	164 (45.56)	
Occupation	Manual	331 (46.49)	381(53.51)	20.09; d.f. 2 p<0.001
	Non-manual	104 (66.24)	53 (33.76)	
	Others	61 (49.59)	62 (50.41)	
Income	≤ ₹4999	58 (50.88)	56 (49.12)	0.96; d.f.2; p>0.05
	₹5000 – ₹9999	181 (48.01)	196 (51.99)	
	≥ ₹10000	257 (51.30)	244 (48.70)	
SES	Upper Middle (UM)	82 (47.95)	89 (52.05)	3.51; d.f.1; p>0.05
	Lower Middle (LM)	140 (46.36)	162 (53.64)	
	Upper Lower (UL)	245 (47.21)	274 (52.79)	
Family size	Small	167 (50.15)	166 (49.85)	0.01; d.f.1; p>0.05
	Large	329 (49.92)	330 (50.08)	
Land holding	0 – 0.99 acre	139 (42.64)	187 (57.36)	10.53; d.f. 1; p<0.05
	≥ 1 acre	357 (53.60)	309 (46.40)	
House type	Kacha	138 (52.67)	124 (47.33)	1.67;d.f. 2; p>0.05
	Semi-pakka	85 (46.45)	98 (53.55)	
	Pakka	273 (49.91)	274 (50.09)	
Drinking Water	Supply	191 (46.25)	222 (53.75)	3.98; d.f.1; p<0.05
	Piped from spring	305 (52.68)	274 (47.32)	
Toilet	Pit	64 (47.76)	70 (52.24)	0.31;d.f.1; p>0.05
	Commode	432 (50.35)	426 (49.65)	

Figures in the parentheses are percentage

3.2 ASSESSMENT OF NUTRITIONAL STATUS USING ANTHROPOMETRY AND BODY COMPOSITIONS CHARACTERISTICS

3.2.1 GENERAL DESCRIPTIVE STATISTICS OF AGE AND ANTHROPOMETRIC VARIABLES

The sex specific and overall mean and SD of the studied anthropometric variables and age are given in Table 3.2. The overall (n = 992) mean age of the study population was 34.73 years (±12.47) with range of 18 to 64. The age of male individuals ranged from 18-64 with mean (SD) of 35.71 years (±12.78) and the mean age of females ranged from 18-63 with mean (SD) of 33.74 years (±12.09). The anthropometric measurements taken in the present study were height, weight, arm span, RAL, LAL, MUAC, NC, SH, WC, HC, TSF, BSF, SSF and SISF.

The overall (sex-combined) mean and SD of height, weight, arm span, RAL, LAL, MUAC, NC, SH, WC, HC, TSF, BSF, SSF and SISF were 154.12 cm ± 7.66, 54.32 kg ± 9.56, 156.96 cm ± 8.95, 65.38 cm ± 3.82, 65.16 cm ± 3.82, 25.44 cm ± 2.71, 33.35 cm ± 2.92, 83.80 cm ± 4.40, 81.62 cm ± 9.25, 88.95 cm ± 7.02, 8.90 mm ± 4.12, 4.89 mm ± 2.36, 11.38 mm ± 4.53, and 9.14 mm ± 4.35, respectively in the present study. The sex specific mean and SD values of 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 ± 2.23), and SH (86.92 cm ± 3.10 vs. 80.67 cm ± 3.09) were higher among males. In contrast the sex specific mean and SD 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), 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 higher among females.

The ANOVA was utilised to assess sex differences in mean values of age and anthropometric variables taken in the study (Table 3.2). The results of ANOVA between sexes in height (F = 920.17; d.f.1; p<0.001), weight (F=97.54; d.f.1; p<0.001), arm span (F= 860.41; d.f.1; p< 0.001), RAL (F= 597.19; d.f.1; p<0.001), LAL (F = 616.95; d.f.1; p<0.001), MUAC (F=78.95; d.f.1; p<0.001), NC (F=624.82; d.f.1; p<0.001), SH (F= 1013.49; d.f.1; p<0.001), WC (F=30.36; d.f.1; p<0.001), HC (F= 20.52; d.f.1; p<0.001), TSF (F= 344.13; d.f.1; p<0.001), BSF (F=177.19; d.f.1; p<0.001), SSF (F= 32.41; d.f.1; p<0.001), and SISF (F=112.35; d.f.1; p<0.001) were significant (p<0.001).

3.2.2 GENERAL DESCRIPTIVE STATISTICS OF DERIVED INDICES OF NUTRITIONAL STATUS AND BODY COMPOSITION

Table 3.3 depicts the overall and sex-specific mean (SD) of various derived indices of nutritional status and body composition. The indices of nutritional status derived for the present study from above mention anthropometric variables are BMI, BAI, WHtR, WHR, CI and CRI. The overall mean (SD) of BMI (22.85 kg/m^2 ± 3.53), BAI (28.68% ± 4.82), WHtR (0.53 ± 0.07), WHR (0.91 ± 0.07), CI (1.27 ± 0.09) and CRI (0.54 ± 0.01), TUA (52.10 cm^2 ±11.20), UMA (48.51 cm^2 ±10.32), AFI (6.82 ± 2.87), UFA (3.59 cm^2 ±1.85) and BFMA (40.26 cm^2 ± 9.84), PBF (18.48% ± 7.56), FM (10.21 kg ± 5.04), FFM (44.12 kg ± 7.76), FMI (4.38 kg/m^2 ± 2.26) and FFMI (18.45 kg/m^2 ± 2.25).

The indices significantly high among the female Limboo individuals were 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) compared to male Limboo individuals. The CRI (0.55 ± 0.01 vs. 0.54 ± 0.02) was significantly high among the male Limboo individuals. Further, the mean of 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), FFM (49.55 kg ± 5.73 vs. 38.68 kg ± 5.35) and FFMI (19.49 kg/m^2 ± 1.92 vs. 17.45 kg/m^2 ± 2.10) were high among the male Limboo individuals (Table 3.3). On the other hand indices and body composition 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), 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 high among the female Limboo individuals compared to male individuals. Using ANOVA, sex differences in the means of body composition indices and its components were found significant ($p < 0.001$) for the Limboo individuals. The respective ANOVA results obtained were as follows for BMI (F = 10.51; d.f.1; p < 0.001), BAI (F= 575.35; d.f.1; p<0.001), WHtR (F= 225.84; d.f.1; p<0.001), WHR (F= 11.88; d.f.1; p<0.001), CI (F= 205.86; d.f.1; p<0.001), CRI (F= 11.26; d.f.1; p<0.001), TUA (F= 72.58; d.f.1; p<0.001), UMA (F= 142.24; d.f.1; p<0.001), UFA (F= 183.15; d.f.1; p<0.001), AFI (F= 595.26; d.f.1; p<0.001), BFMA (F= 38.67; d.f.1; p<0.001), PBF (F= 1325.25; d.f.1; p<0.001), FM (F= 349.80; d.f.1; p<0.001), FFM (F= 952.12; d.f.1; p<0.001), FMI (F= 589.80; d.f.1; p<0.001), FFMI (F= 253.01; d.f.1; p<0.001).

Table 3.2: Descriptive statistics of age and anthropometric characteristics of the Limboo individuals

Variables	Overall (n = 992)	Male (n = 496)	Female (n = 496)	*F*-value
	Mean ± SD	Mean ± SD	Mean ± SD	
Age (years)	34.73 ± 12.47	35.71 ± 12.78	33.74 ± 12.09	6.535*
Height (cm)	154.12 ± 7.66	159.43 ± 5.89	148.81 ± 5.11	920.17**
Weight (kg)	54.32 ± 9.56	57.18 ± 8.86	51.46 ± 9.38	97.54**
Armspan (cm)	156.96 ± 8.95	163.06 ± 6.53	150.86 ± 6.57	860.41**
RAL (cm)	65.38 ± 3.82	67.72 ± 3.00	63.04 ± 3.03	597.19**
LAL (cm)	65.16 ± 3.82	67.52 ± 2.99	62.79 ± 3.01	616.95**
MUAC (cm)	25.44 ± 2.71	26.18 ± 2.46	24.70 ± 2.77	78.95**
NC (cm)	33.35 ± 2.92	35.16 ± 2.34	31.53 ± 2.23	624.82**
WC (cm)	81.62 ± 9.25	80.03 ± 7.44	83.22 ± 10.54	30.36**
HC (cm)	88.95 ± 7.02	87.95 ± 5.66	89.95 ± 8.04	20.52**
SH (cm)	83.80 ± 4.40	86.92 ± 3.10	80.67 ± 3.09	1013.49**
TSF (mm)	8.90 ± 4.12	6.81 ± 2.95	10.99 ± 4.07	344.13**
BSF (mm)	4.89 ± 2.36	3.97 ± 1.56	5.81 ± 2.65	177.19**
SSF (mm)	11.38 ± 4.53	10.57 ± 4.42	12.18 ± 4.50	32.41**
SISF (mm)	9.14 ±4.35	7.76 ± 3.63	10.53 ± 4.56	112.35**

** p<0.001; * p<0.05; d.f . = 1, SD = Standard deviation

Table 3.3: Descriptive statistics of derived nutritional and body composition indices of the Limboo individuals

Variables	Overall (n = 992)	Male (n = 496)	Female (n = 496)	*F*-value
	Mean ± SD	Mean ± SD	Mean ± SD	
BMI (kg/m^2)	22.85 ± 3.53	22.48 ± 3.17	23.21 ± 3.83	10.51**
BAI (%)	28.68 ± 4.82	25.75 ± 3.08	31.60 ± 4.47	575.35**
WHtR	0.53 ± 0.07	0.50 ± 0.05	0.56 ± 0.07	225.84**
WHR	0.92 ± 0.07	0.91 ± 0.06	0.93 ± 0.09	11.88**
CI	1.27 ± 0.09	1.23 ± 0.06	1.30 ± 0.10	205.86**
CRI	0.54 ± 0.02	0.55 ± 0.01	0.54 ± 0.02	11.26**
TUA (cm^2)	52.10 ± 11.20	55.02 ± 10.47	49.18 ± 11.15	72.58**
UMA (cm^2)	48.51 ± 10.32	52.17 ± 9.54	44.85 ± 9.77	142.24**
UFA (cm^2)	3.59 ± 1.85	2.86 ± 1.43	4.32 ± 1.94	183.15**
AFI	6.82 ± 2.87	5.06 ± 1.86	8.57 ± 2.61	595.26**
BFMA (cm^2)	40.26 ± 9.84	42.17 ± 9.54	38.35 ± 9.77	38.67**
PBF (%)	18.48 ± 7.56	12.76 ± 5.09	24.20 ± 4.80	1325.25**
FM (kg)	10.21 ± 5.04	7.63 ± 4.04	12.78 ± 4.60	349.80**
FFM (kg)	44.12 ± 7.76	49.55 ± 5.73	38.68 ± 5.38	952.12**
FMI (kg/m^2)	4.38 ± 2.26	3.00 ± 1.57	5.76 ± 1.99	589.80**
FFMI (kg/m^2)	18.45 ± 2.25	19.49 ± 1.93	17.45 ± 2.10	253.01**

** p<0.001; * p<0.05; d.f. = 1, SD = Standard deviation

3.2.3 AGE SPECIFIC DESCRIPTIVE STATISTICS OF AGE AND ANTHROPOMETRIC VARIABLES

The individuals have been categorised into three age group viz. 18-29 years, 30-49 years and 50-64 years. The mean (SD) and ANOVA results of anthropometric variables of each age groups mention above are presented in Table 3.4. The mean values of age within the age groups 18-29 years, 30-49 years and 50-64 years were 23.33 years (± 3.57), 38.15 years (± 6.23), and 55.65 years (± 4.23), respectively for Limboo males. Among the female individuals mean of age within age groups were 22.76 years (± 3.34), 37.71 years (± 5.77), and 54.52 years (± 3.76), respectively. The observed mean value of weight, arm span, RAL, LAL, MUAC, NC, WC, HC, TSF, BSF, SSF and SISF were high among 30-49 years age group compared to 18-29 years and 50-64 years adult males except height and SH which were high among males of 18-29 years. Similarly, among females the observed mean value of weight, MUAC, NC, WC, HC, TSF, BSF, SSF and SISF were high among 30-49 years age group compared to 18-29 years and 50-64 years adult females except height, SH, and arm span, which were higher among 18-29 years female adults. In contrast to males among females the mean values of RAL and LAL were higher among 50-64 years age group.

The result of ANOVA between above mention age groups showed significant ($p<0.05$) effect of age on the anthropometric variables used in the present study except for arm span, RAL and LAL among male and female Limboo individuals. The decreasing trend with increasing age in case of the height and SH among the Limboo individuals of both sexes were observed to be significant ($p < 0.001$). The results of ANOVA between age groups of males and females Limboo individuals are presented in Table 3.4.

However, post hoc analyses have revealed the significant difference between 30-49 years and 50-64 years age group in height, SH, TSF of males and height, SH, TSF, BSF, and SISF of females in the present study. The measurements like NC, WC, and HC were observed increased in 30-49 years age group from 18-29 years based on post hoc analyses. The measurements observed rising during 30-49 years and declining in 50-64 years of age were MUAC, BSF, SSF, and SISF among males and weight, MUAC, and SSF among females of the present study. Irrespective of sex, the decline in height, SH, skinfolds and MUAC during 50-64 years was observed. Similarly, the increase in NC, WC and HC was observed during middle age around 30-49 years.

3.2.4 AGE SPECIFIC DESCRIPTIVE STATISTICS OF DERIVED ANTHROPOMETRIC AND BODY COMPOSITION INDICES

As mentioned earlier the samples has been categorised into three age groups viz. 18-29 years, 30-49 years, and 50-64 years. The mean (SD) of derived anthropometric and body composition indices with results of ANOVA of each age groups are presented in Table 3.5. Among the male Limboo individuals mean of indices like BAI, WHtR, WHR, and CI were observed to be increasing across the age groups from 18-29 years to 50-64 years age group. Instead, among female Limboo individuals mean of BMI, BAI, WHtR and WHR were high for 30-49 year age adults compared to 18-29 years adults and 50-64 year adults, which also holds for mean BMI among male individuals (Table 3.5). The observed F values for BMI ($F= 16.90$; d.f.2; $p<0.001$), BAI ($F= 14.72$; d.f.2; $p<0.001$), WHtR ($F= 34.82$; d.f.2; $p<0.001$), WHR ($F= 23.16$; d.f.2; $p<0.001$) and CI ($F= 28.69$; d.f.2; $p<0.001$) were significant among male Limboo individuals. Similarly observed F values of BMI ($F= 23.70$; d.f.2; $p<0.001$), BAI ($F= 11.99$; d.f.2; $p<0.001$), WHtR ($F=24.37$; d.f.2; $p<0.001$) and

WHR ($F= 12.91$; d.f.2; $p<0.001$) were significant among female Limboo individuals. Among female Limboo individuals the mean of CI was observed increasing significantly ($F= 7.43$; d.f.2; $p<0.001$).

However, post hoc analyses revealed the significant difference between 18-29 years and 30-49 years age group in the indices like BMI, BAI, WHtR, WHR, CI, FFM and FFMI among males. Similarly, these indices excluding BMI were significantly different between the 18-29 year and 30-49 years age groups females. The change in mean BMI values across the age group among females was supported by post hoc analysis.

The mean values of CRI remained stable across the age groups among both male and female Limboo individuals which were statistically significant ($p<0.05$) among females. The observed mean values of TUA, UMA, UFA, AFI, BFMA, PBF, FM, and FMI of male and female Limboo individuals were higher among middle age group (30-49 years) compared to young adults (18-29 years) and old adults (50-64 years). The ANOVA results between age groups were significant for these indices as shown in Table 3.5. On the post hoc analyses the indices like TUA, UMA, BFMA, FM, and FMI was observed significantly different across each age groups of both male and female Limboo individuals. Similar, post hoc analyses results were obtained for UFA, BD and PBF among male Limboo individuals. AFI among male and CRI, UFA, AFI, BD, and PBF among female Limboo individuals have observed difference between the 30-49 years and 50-64 years of age groups on post hoc analyses in the present study.

Table 3.4: Age and sex specific descriptive statistics (mean ± SD) of anthropometric measurements of the Limboo individuals

Variables	Male			F-value	Female			F-value
	18-29 yrs	30-49 yrs	50-64 yrs		18-29 yrs	30-49 yrs	50-64 yrs	
Age (years)	23.33 ± 3.57	38.15 ± 6.23	55.65 ± 4.23	1327.36 **	22.76 ± 3.34	37.71 ± 5.77	54.52 ± 3.76	1484.09**
Height (cm)	159.94 ± 6.11	159.67 ± 5.49	157.81 ± 6.12	4.38*	149.41 ± 5.10	148.55 ± 5.06	147.81 ± 5.12	3.20*
Weight (kg)	54.98 ± 7.58	59.24 ± 9.09	56.88 ± 9.66	12.29**	49.18 ± 8.11	54.15 ± 9.70	50.70 ± 10.13	15.94**
Arm span (cm)	162.70 ± 6.54	163.68 ± 6.45	162.33 ± 6.62	1.82	151.15 ± 6.52	150.56 ± 6.27	150.80 ± 7.53	0.42
RAL (cm)	67.54 ± 3.12	67.89 ± 2.97	67.70 ± 2.84	0.72	63.10 ± 2.89	62.92 ± 3.03	63.20 ± 3.43	0.30
LAL (cm)	67.33 ± 3.07	67.70 ± 2.96	67.52 ± 2.90	0.75	62.88 ± 2.81	62.64 ± 3.07	62.92 ± 3.41	0.41
MUAC (cm)	25.66 ± 2.20	26.78 ± 2.47	25.86 ± 2.64	12.00**	23.98 ± 2.49	25.65 ± 2.69	24.22 ± 3.02	22.36**
NC (cm)	34.63 ± 1.99	35.61 ± 2.57	35.21 ± 2.25	9.05**	30.84 ± 1.92	32.20 ± 2.29	31.68 ± 2.35	21.25**
WC (cm)	76.88 ± 6.31	82.01± 7.19	81.85 ± 8.00	30.62**	80.08 ± 9.05	86.31±10.63	83.8 ± 11.71	19.95**
HC (cm)	86.48 ± 5.11	89.18 ± 5.59	88.11± 6.25	12.06**	88.49 ± 6.48	91.44 ± 8.68	90.12 ± 0.52	7.25**
SH (cm)	87.19 ± 3.25	87.06 ± 2.82	86.05 ± 3.26	4.63*	81.20 ± 3.29	80.58 ± 2.87	79.41 ± 2.69	9.78**
TSF (mm)	6.69 ± 2.78	7.25 ± 3.13	6.02 ± 2.66	5.92**	11.22 ± 3.62	11.38 ± 4.24	9.27 ± 4.39	8.25**
BSF (mm)	3.76 ± 1.37	4.29 ± 1.71	3.65 ± 1.43	8.28**	5.65 ± 2.33	6.23 ± 2.93	5.10 ± 2.51	5.76**
SSF (mm)	9.70 ± 3.65	11.64 ± 5.02	9.83 ± 3.80	11.78**	11.73 ± 4.03	13.29 ± 4.72	10.44 ± 4.44	13.58**
SISF (mm)	7.17 ± 3.14	8.51 ± 3.91	7.20 ± 3.63	8.38**	10.81 ± 4.06	10.78 ± 4.87	9.03 ± 4.77	4.85*

** p<0.001; * p<0.05; d.f. = 2, SD = Standard deviation

Table 3.5: Age and sex specific descriptive statistics (mean ± SD) of nutritional status and body composition indices of the Limboo individuals

Variables	Male			F-value	Female			F-value
	18-29 yrs	30-49 yrs	50-64 yrs		18-29 yrs	30-49 yrs	50-64 yrs	
BMI (kg/m^2)	21.48 ± 2.61	23.23 ± 3.34	22.79 ± 3.27	16.90**	22.01 ± 3.28	24.47± 3.77	23.20 ± 4.36	23.70**
BAI (%)	24.83 ± 3.00	26.25 ± 2.95	26.49 ± 3.09	14.72**	30.51 ± 3.65	32.51± 4.52	32.24 ± 5.69	11.99**
WHtR	0.48 ± 0.04	0.51 ± 0.05	0.52 ± 0.05	34.82**	0.54 ± 0.06	0.58 ± 0.07	0.57 ± 0.08	24.37**
WHR	0.89 ± 0.05	0.92 ± 0.06	0.93 ± 0.06	23.16**	0.90 ± 0.07	0.95 ± 0.09	0.93 ± 0.10	12.91**
CI	1.21 ± 0.06	1.24 ± 0.05	1.25 ± 0.06	28.69**	1.28 ± 0.08	1.31 ± 0.09	1.32 ± 0.13	7.43**
CRI	0.55 ± 0.01	0.55 ± 0.01	0.55 ± 0.01	0.00	0.54 ± 0.02	0.54 ± 0.01	0.54 ± 0.01	4.20*
TUA (cm^2)	52.76 ± 9.21	57.54 ± 10.60	53.74 ± 11.38	11.84**	46.23 ± 9.76	52.93 ± 11.21	47.40 ± 11.88	21.80**
UMA (cm^2)	50.02 ± 8.36	54.43 ± 9.60	51.25 ± 10.57	11.80**	41.96 ± 8.39	48.30 ± 9.89	43.77 ± 10.29	24.83**
UFA (cm^2)	2.75 ± 1.32	3.11 ± 1.52	2.50 ± 1.32	7.07**	4.27 ± 1.74	4.63 ± 2.02	3.63 ± 2.11	7.66**
AFI	5.08 ± 1.81	5.25 ± 1.96	4.55 ± 1.72	4.59*	9.03 ± 2.30	8.55 ± 2.71	7.32 ± 2.75	12.55**
BFMA (cm^2)	40.02 ± 8.36	44.43 ± 9.60	41.25 ± 10.57	11.80**	35.46 ± 8.39	41.80 ± 9.89	37.27 ± 10.29	24.83**
BD (cm^3)	1.07 ± 0.01	1.07 ± 0.01	1.07 ± 0.01	9.33**	1.04 ± 0.01	1.04 ± 0.01	1.05 ± 0.01	12.06**
PBF (%)	12.06 ± 4.45	13.86 ± 5.48	11.62 ± 4.90	9.42**	24.34 ± 4.17	24.91 ± 5.00	21.84 ± 5.24	11.93**
FM (kg)	6.86 ± 3.40	8.59 ± 4.36	6.97 ± 4.05	11.16**	12.22 ± 3.99	13.85 ± 4.88	11.47 ± 4.92	10.54**
FFM (kg)	48.11 ± 5.11	50.65 ± 5.11	49.91 ± 6.40	10.48**	30.96 ± 4.56	40.30 ± 5.41	39.23 ± 5.83	22.80**
FMI (kg/m^2)	2.68 ± 1.32	3.37 ± 1.70	2.77 ± 1.53	11.18**	5.46 ± 1.71	6.24 ± 2.08	5.26 ± 2.20	11.40**
FFMI (kg/m^2)	18.80 ± 1.59	19.86 ± 1.98	20.01 ± 2.05	21.15**	16.55 ± 1.76	18.22 ± 1.95	17.95 ± 2.38	42.09**

** $p<0.001$; * $p<0.05$; d.f. = 2, SD = Standard deviation

3.2.5 CORRELATIONS OF ANTHROPOMETRIC VARIABLE AMONG THE MALE LIMBOO INDIVIDUALS

The Pearson correlation values between different anthropometric variables of male Limboo individuals are shown in Table 3.6. The age was positively and significantly correlated with weight (r = 0.156, p<0.01), MUAC (r = 0.112, p<0.01), NC (r = 0.144, p<0.01), WC (r = 0.327, p<0.01), HC (r = 0.164, p<0.01), SSF (r = 0.090, p<0.01), BMI (r = 0.234, p<0.01), BAI (r = 0.250, p<0.01), WHtR (r = 0.370, p<0.01), WHR (r = 0.319, p<0.01), CI (r = 0.339, p<0.01), TUA (r = 0.117, p<0.01), UMA (r = 0.131, p<0.01), FM (r = 0.088, p<0.05), FFM (r = 0.178, p<0.01), FMI (r = 0.102, p<0.05) and FFMI (r = 0.303, p<0.01) among the male Limboo individuals. The negatively and significantly correlated variables with age were height (r = -0.130, p<0.01) and SH (r = -0.114, p<0.05) among the male Limboo individuals. The observed strength of association was low.

The height was positively and significantly correlated with weight (r = 0.411,p<0.01), arm span (r = 0.788, p<0.01), RAL (r = 0.794, p<0.01), LAL (r = 0.787, p<0.01), MUAC (r = 0.100, p<0.05), NC (r = 0.197, p<0.01), WC (r = 0.145, p<0.01), HC (r = 0.330, p<0.01), SH (r = 0.783, p<0.01), CRI (r= -0.381, p<0.01), TUA (r = 0.098, p<0.05), UMA (r = 0.102, p<0.05), FM (r = 0.160, p<0.01), and FFM (r = 0.523, p<0.01) among the male Limboo individuals. The negatively and significantly correlated variables with height beside age were WHtR (r = -0.253, p<0.01), WHR (r = -0.134, p<0.01), and FFMI (r = -0.139, p<0.01) among the male Limboo individuals. The height was correlated strongly with only linear measurements among male Limboo individuals.

The weight was positively and significantly correlated with arm span (r = 0.392, p<0.01), RAL (r = 0.341, p<0.01), LAL (r = 0. 343, p<0.01), MUAC (r =

0.770, p<0.01), NC (r = 0.740, p<0.01), WC (r = 0.838,p<0.01), HC (r = 0.860, p<0.01), SH (r = 0.453, p<0.01), TSF (r = 0.612, p<0.01), BSF (r = 0.693, p<0.01), SSF (r = 0.700, p<0.01), SISF (r = 0.657, p<0.01), BMI (r = 0.876, p<0.01), BAI (r = 0.456, p<0.01), WHtR (r = 0.653, p<0.01), WHR (r = 0.346, p<0.01), CI (r = 0.172, p<0.01), TUA (r = 0.769, p<0.01), UMA (r = 0.742, p<0.01), UFA (r = 0.680, p<0.01), AFI (r = 0.499, p<0.01), PBF (r = 0.746, p<0.01), FM (r = 0.864,p<0.01), FMI (r = 0.814, p<0.01), FFM (r = 0.935, p<0.01) and FFMI (r = 0.777, p<0.01) among the male Limboo individuals. The correlations of weight with other anthropometric variables were strong except for BAI, WHR, and CI.

The armspan was positively and significantly correlated with RAL (r = 0.900, p<0.01), LAL (r =0.910, p<0.01), MUAC (r = 0.100, p<0.05), NC (r = 0.181, p<0.01), WC (r = 0.181, p<0.01), HC (r = 0.319, p<0.01), SH (r = 0.540, p<0.01), CRI (r= -0.408, p<0.01), TUA (r = 0.097, p<0.05), UMA (r = 0.102, p<0.05), FM (r =0.131, p<0.01), and FFM (r = 0.513, p<0.01) among the male Limboo individuals. The negatively and significantly correlated variables with armspan were BAI (r = -0.333, p<0.01) and WHtR (r = -0.134, p<0.01) and. The arm span was observed strongly correlated with only linear anthropometric measurements such as RAL and LAL.

Similarly, RAL was positively and significantly correlated with LAL (r =0.977, p<0.01), NC (r = 0.149, p<0.01), WC (r = 0.159, p<0.01), HC (r = 0.280, p<0.01), SH (r = 0.516, p<0.01), UMA (r = 0.090, p<0.05), FM (r = 0.099, p<0.05), and FFM (r = 0.457, p<0.01) among the male Limboo individuals. The negatively and significantly correlated variables with RAL were BAI (r = -0.375, p<0.01), WHtR (r = -0.158, p<0.01), and CRI (r= -0.454, p<0.01), among the male Limboo individuals. The strong correlation was only observed with LAL. The LAL itself was positively and significantly correlated with MUAC (r = 0.094, p<0.05), NC (r = 0.165, p<0.01), WC (r = 0.166, p<0.01), HC (r = 0.277, p<0.01), SH (r = 0.499, p<0.01), TUA (r = 0.093, p<0.05), UMA (r = 0.100, p<0.05), FM (r = 0.103, p<0.01) and FM (r = 0.458, p<0.01). The negatively and significantly correlated variables with LAL were BAI (r = -0.372, p<0.01), WHtR (r = -0.148, p<0.01), and CRI (r= -0.469, p<0.01).The correlations of LAL with the remaining anthropometric measurements and indices were low.

Among the male Limboo individuals, MUAC was positively and significantly correlated with NC (r = 0.636, p<0.01), WC (r = 0.699, p<0.01), HC (r = 0.681, p<0.01), SH (r = 0.170, p<0.01), TSF (r = 0.567, p<0.01), BSF (r = 0.602, p<0.01), SSF (r = 0.632, p<0.01), SISF (r = 0.627, p<0.01), BMI (r = 0.789, p<0.01), BAI (r = 0.540, p<0.01), WHtR (r = 0.640, p<0.01), WHR (r = 0.328, p<0.01), CI (r = 0.151, p<0.01), CRI (r= 0.095, p<0.01), TUA (r = 0.998, p<0.01), UMA (r = 0.992, p<0.01), UFA (r = 0.684, p<0.01), AFI (r = 0.392, p<0.01), PBF (r = 0.683,p<0.01), FM (r = 0.739, p<0.01), FMI (r = 0.735, p<0.01), FFM (r = 0.667, p<0.01), and FFMI (r = 0.699, p<0.01). The most of the observed correlation were strong except with SH, CI, CRI, WHR, and AFI.

The NC was positively and significantly correlated with WC (r = 0.658,p<0.01), HC (r = 0.651, p<0.01), SH (r = 0.258, p<0.01), TSF (r = 0.460, p<0.01), BSF (r = 0.530, p<0.01), SSF (r = 0.638, p<0.01), SISF (r = 0.574, p<0.01), BMI (r = 0.706, p<0.01), BAI (r = 0.435, p<0.01), WHtR (r = 0.563, p<0.01), WHR (r = 0.301, p<0.01), CI (r = 0.161, p<0.01), TUA (r = 0.626, p<0.01), UMA (r = 0.609, p<0.01), UFA (r = 0.523, p<0.01), AFI (r = 0.355, p<0.01), PBF (r = 0.618, p<0.01), FM (r = 0.693, p<0.01), FFM (r = 0.654, p<0.01), FMI (r = 0.671, p<0.01), and FFMI (r = 0.615, p<0.01). All correlations of NC were strong except with SH, TSF, BAI, WHR, CI, and AFI.

The WC was positively and significantly correlated with HC (r = 0.765,p<0.01), SH (r = 0.198, p<0.01), TSF (r = 0.631, p<0.01), BSF (r = 0.678, p<0.01), SSF (r = 0.707, p<0.01), SISF (r = 0.694, p<0.01), BMI (r = 0.838, p<0.01), BAI (r = 0.583, p<0.01), WHtR (r = 0.920, p<0.01), WHR (r = 0.700, p<0.01), CI (r = 0.649, p<0.01), TUA (r = 0.700, p<0.01), UMA (r = 0.666, p<0.01), UFA (r = 0.684, p<0.01), AFI (r = 0.538, p<0.01), PBF (r = 0.756,p<0.01), FM (r = 0.825, p<0.01), FFM (r = 0.713, p<0.01), FMI (r = 0.812, p<0.01) and FFMI (r = 0.718,p<0.01). Except with SH all the correlations were strong.

The HC was positively and significantly correlated with SH (r = 0.386, p<0.01), TSF (r = 0.595, p<0.01), BSF (r = 0.610, p<0.01), SSF (r = 0.627, p<0.01), SISF (r = 0.616, p<0.01), BMI (r = 0.769, p<0.01), BAI (r = 0.654, p<0.01), WHtR (r = 0.616, p<0.01), CI (r = 0.216, p<0.01), TUA (r = 0.677, p<0.01), UMA (r = 0.646, p<0.01), UFA (r = 0.647, p<0.01), AFI (r = 0.502, p<0.01), PBF (r = 0.681, p<0.01), FM (r = 0.768, p<0.01), FM (r = 0.786, p<0.01), FMI (r = 0.732, p<0.01), and FFMI (r = 0.668, p<0.01). The correlations observed were strong with HC except for SH, CI, FFM, and FFMI.

The SH was positively and significantly correlated with BSF (r = 0.130, p<0.01), SSF (r = 0.150, p<0.01), SISF (r = 0.135, p<0.01), CRI (r= 0.276, p<0.01), TUA (r = 0.169, p<0.01), UMA (r = 0.171, p<0.01), UFA (r = 0.099, p<0.05), PBF (r = 0.150, p<0.01), FM (r = 0.244, p<0.01), FFM (r = 0.528, p<0.01), and FMI (r = 0.135, p<0.01). The negatively and significantly correlated variables with SH were BAI (r = -0.272, p<0.01), WHtR (r = -0.116, p<0.01), WHR (r = -0.113, p<0.05). The correlations observed were low. Similarly ratio of leg trunk, correlations of CRI was low with other variables and indices except with RAL and LAL.

The TSF was positively and significantly correlated with BSF (r = 0.800, p<0.01), SSF (r = 0.721, p<0.01), SISF (r = 0.770, p<0.01), BMI (r = 0.661, p<0.01), BAI (r = 0.532, p<0.01), WHtR (r = 0.610, p<0.01), WHR (r = 0.317, p<0.01), CI (r = 0.247, p<0.01), TUA (r = 0.569, p<0.01), UMA (r = 0.476, p<0.01), UFA (r = 0.985, p<0.01), AFI (r = 0.976, p<0.01), PBF (r = 0.875, p<0.01), FM (r = 0.849, p<0.01), FFM (r = 0.346, p<0.01), FMI (r = 0.859, p<0.01), and FFMI (r = 0.388, p<0.01). The observed correlations were strong except with CI, UMA, FFM and FFMI.

The BSF was positively and significantly correlated with SSF (r = 0.781,p<0.01), SISF (r = 0.765, p<0.01), BMI (r = 0.723, p<0.01), BAI (r = 0.500, p<0.01), WHtR (r = 0.632, p<0.01), WHR (r = 0.366, p<0.01), CI (r = 0.231, p<0.01), TUA (r = 0.609, p<0.01), UMA (r = 0.545, p<0.01), UFA (r = 0.822, p<0.01), AFI (r = 0.740, p<0.01), PBF (r = 0.860, p<0.01), FM (r = 0.875, p<0.01) FFM (r = 0.453, p<0.01), FMI (r = 0.879, p<0.01) and FFMI (r = 0.473, p<0.01) among the male Limboo individuals. The observed correlations were strong except with WHR, CI, FFM, and FFMI.

The SSF was positively and significantly correlated with SISF (r = 0.778, p<0.01), BMI (r = 0.747, p<0.01), BAI (r = 0.539, p<0.01), WHtR (r = 0.673, p<0.01), WHR (r = 0.395, p<0.01), CI (r = 0.257, p<0.01), CRI (r= 0.154, p<0.01), TUA (r = 0.635, p<0.01), UMA (r = 0.584, p<0.01), UFA (r = 0.753, p<0.01), AFI (r = 0.649, p<0.01), PBF (r = 0.905,p<0.01), FM (r = 0.903, p<0.01), FFM (r = 0.445,p<0.01), FMI (r = 0.910, p<0.01) and FFMI (r = 0.488, p<0.01) among the male Limboo individuals. The correlations observed were strong except with WHR and CI.

The SISF was positively and significantly correlated with BMI (r = 0.713, p<0.01), BAI (r = 0.522, p<0.01), WHtR (r = 0.657, p<0.01), WHR (r = 0.389, p<0.01), CI (r = 0.278, p<0.01), SISF (r= 0.123, p<0.01),TUA (r = 0.628, p<0.01), UMA (r = 0.570, p<0.01), UFA (r = 0.795, p<0.01), AFI (r = 0.704, p<0.01), PBF (r = 0.909, p<0.01), FM (r = 0.895, p<0.01), FFM (r = 0.411, p<0.01), FMI (r = 0.899, p<0.01), and FM (r = 0.441, p<0.01) among the male Limboo individuals. The correlations observed were strong except with WHR, CI, FFM, and FFMI.

The BMI was positively and significantly correlated with BAI (r = 0.764, p<0.01), WHtR (r = 0.847, p<0.01), WHR (r = 0.444, p<0.01), CI (r = 0.185, p<0.01), CRI (r = 0.240, p<0.01), TUA (r = 0.788, p<0.01), UMA (r = 0.756, p<0.01), UFA (r = 0.725, p<0.01), AFI (r = 0.551, p<0.01), PBF (r = 0.791, p<0.01), FM (r = 0.861, p<0.01), FFM (r = 0.745, p<0.01), FMI (r = 0.884, p<0.01) and FFMI (r = 0.925, p<0.01) among the male Limboo individuals. The correlations of BMI were strong with anthropometric measurements and indices except with WHR, CI, and CRI.

The BAI was positively and significantly correlated with WHtR (r = 0.767, p<0.01), WHR (r = 0.173, p<0.01), CI (r = 0.199, p<0.01), CRI (r= 0.361, p<0.01), TUA (r = 0.538, p<0.01), UMA (r = 0.506, p<0.01), UFA (r = 0.563, p<0.01), AFI (r = 0.551, p<0.01), PBF (r = 0.581, p<0.01), FM (r = 0.574, p<0.01), FFM (r = 0.300, p<0.01), FMI (r = 0.654, p<0.01) and FFMI (r = 0.723, p<0.01) among the male Limboo individuals. The observed correlations were strong except for WHR, CI, CRI, and FFM.

The WHtR was positively and significantly correlated with WHR (r = 0.738, p<0.01), CI (r = 0.639, p<0.01), TUA (r = 0.642, p<0.01), UMA (r = 0.607, p<0.01), UFA (r = 0.653, p<0.01), AFI (r = 0.529, p<0.01), PBF (r = 0.717, p<0.01), FM (r =

0.740, p<0.01), FFM (r = 0.487,p<0.01), FMI (r = 0.784,p<0.01) and FFMI (r = 0.755, p<0.01) among the male Limboo individuals. The observed correlations were strong. Similarly another ratio of central obesity is WHR. The WHR was positively and significantly correlated with CI (r = 0.765, p<0.01), TUA (r = 0.332, p<0.01), UMA (r = 0.314, p<0.01), UFA (r = 0.340, p<0.01), AFI (r = 0.277, p<0.01), PBF (r = 0.417, p<0.01), FM (r = 0.423, p<0.01), FFM (r = 0.236, p<0.01), FMI (r = 0.443, p<0.01) and FFMI (r = 0.370, p<0.01) among the male Limboo individuals. The only strong correlation of WHR was observed with CI. The index of central obesity CI can be observed with strong positive correlations with WC, WHtR, and WHR. Remaining correlations with CI were all low.

The TUA was positively and significantly correlated with UMA (r = 0.994, p<0.01), UFA (r = 0.689, p<0.01), AFI (r = 0.392, p<0.01), PBF (r = 0.681, p<0.01), FM (r = 0.742, p<0.01), FFM (r = 0.664, p<0.01), FMI (r = 0.737, p<0.01), and FFMI (r = 0.696, p<0.01) among the male Limboo individuals. The observed correlations were strong except AFI. Further, UMA was positively and significantly correlated with UFA (r = 0.606, p<0.01), AFI (r = 0.292, p<0.01), PBF (r = 0.614, p<0.01), FM (r = 0.681, p<0.01), FFM (r = 0.665, p<0.01), FMI (r = 0.676, p<0.01) and FFMI (r = 0.694, p<0.01) among the male Limboo individuals. The correlations with UMA were observed strong except with AFI. Similarly, the UFA was positively correlated with AFI (r = 0.924, p<0.01), PBF (r = 0.889, p<0.01), FM (r = 0.885, p<0.01), FFM (r = 0.426, p<0.01), FMI (r = 0.892, p<0.01), and FFMI (r = 0.467, p<0.01) among the male Limboo individuals. These correlations of UFA were strong and significant except for FFM and FFMI. Furthermore, AFI was positively and significantly correlated with PBF (r = 0.821, p<0.01), FM (r = 0.769, p<0.01), FFM (r = 0.228, p<0.01), FMI (r = 0.782, p<0.01) and FFMI (r = 0.269, p<0.01) among the male

Limboo individuals. The correlations observed were strong except with FFM, and FFMI.

The PBF was positively correlated with FM (r = 0.971, p<0.01), FFM (r = 0.467, p<0.01), FMI (r = 0.978, p<0.01) and FFMI (r = 0.505, p<0.01) among the male Limboo individuals. The correlations were strong and significant. Further, the FM was positively correlated with FFM (r = 0.630, p<0.01), FMI (r = 0.987, p<0.01), and FFMI (r = 0.612, p<0.01) among the male Limboo individuals. The FFM was positively and significantly with FMI (r = 0.561, p<0.01) and FFMI (r = 0.769, p<0.01). The correlation of FMI (r = 0.639, p<0.01) was strong and positive with FFMI.

3.2.6 CORRELATIONS OF ANTHROPOMETRIC VARIABLE AMONG THE FEMALE LIMBOO INDIVIDUALS

The age was weakly correlated with weight (r = 0.145, p<0.01), MUAC (r = 0.131, p<0.01), NC (r= 0.225, p<0.01), WC (r= 0.206, p<0.01), HC (r = 0.134,p<0.01), BMI (r = 0.205, p<0.01), BAI (r = 0.196, p<0.01), WHtR (r = 0.239, p<0.01), WHR (r = 0.158, p<0.01), CI (r = 0.159,p<0.01), CRI (r = -0.106, p<0.01), TUA (r = 0.136,p<0.01), UMA (r = 0.169, p<0.01), FFM (r = 0.240, p<0.01) and FFMI (r = 0.338, p<0.01) among the Limboo female individuals which were positive and significant. On the contrary the age is negatively and significantly correlated with height (r = -0.111, p<0.01), SH (r = -0.183, p<0.01), TSF (r = -0.144, p<0.01), SISF (r = -0.107, p<0.05), AFI (r = -0.235, p<0.01) and PBF (r = -0.136, p<0.01) among the female Limboo individuals and the all the correlations were low.

The height is positively and significantly correlated with weight (r = 0.397, p<0.01), arm span (r = 0.821, p<0.01), RAL (r = 0.764, p<0.01), LAL (r = 0.753, p<0.01), MUAC (r = 0.128, p<0.01), NC (r = 0.235, p<0.01), WC (r = 0.179, p<0.01), HC (r = 0.280, p<0.01), SH (r = 0.676, p<0.01), SISF (r = 0.101, p<0.05), TUA (r = 0.136, p<0.01), UMA (r = 0.135, p<0.01), UFA(r = 0.101, p<0.05), FM (r = 0.259, p<0.01) and FFM (r = 0.473, p<0.01) among the female Limboo individuals. However, correlations between height and body composition parameters were observed to be low. On the contrary height is negatively and significantly correlated with BAI (r = -0.296, p<0.01), WHtR (r = -0.097, p<0.05), and CRI (r = -0.290, p<0.01). The strong correlation of height was observed with arm span, RAL, LAL, SH and all the inversed correlation with height was observed to be low.

The positive significant correlation of weight with MUAC (r = 0.827, p<0.01), NC (r = 0.806, p<0.01), WC (r = 0.823, p<0.01), HC (r = 0.864, p<0.01), SH (r = 0.407, p<0.01), TSF (r = 0.567, p<0.01), BSF (r = 0.653, p<0.01), SSF (r = 0.731, p<0.01), SISF (r = 0.610, p<0.01), BMI (r = 0.923, p<0.01), BAI (r = 0.622, p<0.01), WHtR (r = 0.718, p<0.01), TUA (r = 0.834, p<0.01), UMA (r = 0.817, p<0.01), UFA (r = 0.678, p<0.01), PBF (r = 0.729, p<0.01), FM (r = 0.933, p<0.01), FM (r = 0.951,p<0.01), FMI (r = 0.880, p<0.01) and FFMI (r = 0.851, p<0.01) among the female Limboo individuals were strong. However, correlation with arm span (r = 0.316, p<0.01), RAL (r = 0.295, p<0.01), LAL (r = 0.288, p<0.01), WHR (r = 0.250, p<0.01), CI (r = 0.280, p<0.01), and AFI (r = 0.369, p<0.01) were observed to be low.

The armspan was positively and significantly correlated with RAL (r = 0.867,p<0.01), LAL (r = 0.870, p<0.01), MUAC (r = 0.090, p<0.05), NC (r = 0.172, p<0.01), WC (r = 0.150, p<0.01), HC (r = 0.197, p<0.01), SH (r = 0.470, p<0.01), TUA (r = 0.099, p<0.05), UMA (r = 0.105, p<0.05), FM (r = 0.155, p<0.01) and FFM (r = 0.420, p<0.01) among the female Limboo individuals. On the contrary arm span was negatively and significantly correlated with BAI ($r = -0.276$, $p<0.01$) and CRI ($r = -0.350$, $p<0.01$). The correlations observed were low except with LAL.

The RAL was positively and significantly correlated with LAL ($r = 0.959$, $p<0.01$), MUAC ($r = 0.089$, $p<0.05$), NC ($r = 0.140$, $p<0.01$), HC ($r = 0.197$, $p<0.01$), WC ($r = 0.154$, $p<0.01$), SH ($r = 0.404$, $p<0.01$), TUA ($r = 0.099$, $p<0.05$), UMA ($r = 0.104$, $p<0.05$), FM ($r = 0.155$, $p<0.01$), and FFM ($r = 0.383$, $p<0.01$) among the female Limboo individuals. The only negatively and significantly correlated variables with RAL were BAI ($r = -0.246$, $p<0.01$), and CRI ($r = -0.367$, $p<0.01$) among females of the present study. The only strong correlation observed was with LAL.

LAL like RAL was positively and significantly correlated with MUAC ($r = 0.090$, $p<0.05$), NC ($r = 0.146$, $p<0.01$), HC ($r = 0.197$, $p<0.01$), WC ($r = 0.169$, $p<0.01$), SH ($r = 0.384$, $p<0.01$), CI ($r = 0.110$, $p<0.01$), TUA ($r = 0.102$, $p<0.05$), UMA ($r = 0.103$, $p<0.05$), FM ($r = 0.159$, $p<0.01$) and FFM ($r = 0.369$, $p<0.01$) among the female Limboo individuals. The only negatively and significantly correlated variables with LAL were BAI ($r = -0.254$, $p<0.01$), and CRI ($r = -0.380$, $p<0.01$) among the females of the present study. The correlations observed were low.

The MUAC was positively and significantly correlated with NC ($r = 0.698$, $p<0.01$), WC ($r= 0.694$, $p<0.01$), HC ($r= 0.747$, $p<0.01$), SH ($r= 0.216$, $p<0.01$), TSF ($r = 0.614$, $p<0.01$), BSF ($r= 0.622$, $p<0.01$), SSF ($r = 0.679$, $p<0.01$), SISF ($r = 0.519$, $p<0.01$), BMI ($r = 0.847$, $p<0.01$), BAI ($r= 0.662$, $p<0.01$), WHtR ($r = 0.665$, $p<0.01$), WHR ($r= 0.189$, $p<0.01$), CI ($r = 0.204$, $p<0.01$), CRI ($r= 0.131$, $p<0.01$), TUA ($r = 0.997$, $p<0.01$), UMA($r = 0.988$, $p<0.01$), UFA ($r = 0.751$, $p<0.01$), AFI ($r = 0.373$, $p <0.01$), PBF ($r = 0.713$, $p<0.01$), FM ($r = 0.821$, $p<0.01$), FFM ($r = 0.744$, p<0.01), FMI (r = 0.822, p<0.01) and FFMI (r = 0.768, p<0.01). All the correlation were strong except with SH, WHR, CI, CRI, and AFI.

The NC was positively and significantly correlated with WC (r = 0.696, p<0.01), HC (r= 0.675, p<0.01), SH (r = 0.271, p<0.01), TSF (r = 0.356, p<0.01), BSF (r = 0.516, p<0.01), SSF (r =0.607, p<0.01), SISF (r = 0.493, p<0.01), BMI (r = 0.781, p<0.01), BAI (r = 0.532, p<0.01), WHtR (r = 0.638, p<0.01), WHR (r = 0.275, p<0.01), CI (r = 0.263, p<0.01), TUA (r = 0.696, p<0.01), UMA (r = 0.702, p<0.01), UFA (r = 0.466, p<0.01), AFI (r = 0.170, p<0.01), PBF (r = 0.565, p<0.01), FM (r = 0.731, p<0.01), FFM (r = 0.784, p<0.01), FMI (r = 0.708, p<0.01) and FFMI (r = 0.755, p<0.01) among female Limboo individuals. Among them SH, WHR, CI, and AFI were weakly associated with NC.

The WC was positively and significantly correlated with HC (r = 0.743, p<0.01), SH (r = 0.191, p<0.01), TSF (r = 0.489, p<0.01), BSF (r = 0.625, p<0.01), SSF (r =0.671, p<0.01), SISF (r = 0.563, p<0.01), BMI (r= 0.822, p<0.01), BAI (r = 0.630, p<0.01), WHtR (r = 0.961, p<0.01), WHR (r = 0.621, p<0.01), CI (r = 0.760, p<0.01), TUA (r = 0.701, p<0.01), UMA (r = 0.684, p<0.01), UFA (r = 0.583, p<0.01), AFI (r = 0.320, p<0.01), PBF (r= 0.654, p<0.01), FM (r = 0.801, p<0.01), FFM (r = 0.753, p<0.01), FMI (r = 0.791, p<0.01), and FM (r = 0.751, p<0.01) among female Limboo individuals. The observed correlations were strong except with SH, TSF, AFI.

The HC was positively and significantly correlated with SH (r = 0.322, p<0.01), TSF (r = 0.570, p<0.01), BSF (r = 0.600, p<0.01), SSF (r =0.691, p<0.01), SISF (r = 0.591,p<0.01), BMI (r= 0.828, p<0.01), BAI (r = 0.832, p<0.01), WHtR (r = 0.672, p<0.01), CI (r = 0.275, p<0.01), TUA (r = 0.749, p<0.01), UMA (r = 0.725, p<0.01), UFA (r = 0.654, p<0.01), AFI (r = 0.407, p<0.01), PBF (r = 0.710, p<0.01), FM (r = 0.844, p<0.01), FFM (r = 0.789, p<0.01), FMI (r = 0.818, p<0.01) and FFMI (r = 0.736, p<0.01) among female Limboo individuals. The correlation observed were strong except with SH, CI, and AFI.

The SH was positively and significantly correlated with, TSF (r= 0.152, p<0.01), BSF (r = 0.215, p<0.01), SSF (r = 0.183, p<0.01), SISF (r = 0.223, p<0.01), BMI (r = 0.165, p<0.01), CRI (r = 0.509, p<0.01), TUA (r = 0.217, p<0.01), UMA (r = 0.213, p<0.01), UFA (r = 0.177,p<0.01), AFI (r = 0.107, p<0.05), PBF (r= 0.235, p<0.01), FM (r = 0.337, p<0.01), FFM (r = 0.423, p<0.01), FMI (r = 0.214, p<0.01) and FM (r = 0.099, p<0.05) among female Limboo individuals. The only strong correlation was observed with CRI.

The TSF was positively and significantly correlated with BSF (r = 0.598, p<0.01), SSF (r = 0.615, p<0.01), SISF (r = 0.520, p<0.01), BMI (r = 0.587, p<0.01), BAI (r = 0.519, p<0.01), WHtR (r = 0.475, p<0.01), WHR (r = 0.090, p<0.01), CI (r= 0.158, p<0.01), TUA (r = 0.612, p<0.01), UMA (r = 0.504, p<0.01), UFA (r= 0.975, p<0.01), AFI (r = 0.955, p<0.01), PBF (r = 0.800, p<0.01), FM (r = 0.735, p<0.01), FFM (r = 0.362, p<0.01), FMI (r = 0. 745, p<0.01) and FFMI (r = 0.365, p<0.01). The correlations observed were strong except with WHR and CI.

The BSF was positively and significantly correlated with SSF (r = 0.686, p<0.01), SISF (r = 0.625, p<0.01), BMI (r = 0.678,p<0.01), BAI (r = 0.543, p<0.01), WHtR (r = 0.609, p<0.01), WHR (r = 0.243,p<0.01), CI (r = 0.291, p<0.01), TUA (r = 0.629, p<0.01), UMA (r = 0.589, p<0.01), UFA (r = 0.650, p<0.01), AFI (r = 0.480, p<0.01), PBF (r = 0.790, p<0.01), FM (r = 0.786, p<0.01), FFM (r = 0.468, p<0.01), FMI (r = 0. 798, p<0.01), and FFMI (r = 0.482, p<0.01). Excluding WHR and CI, all correlations with BSF were strong.

The SSF was positively and significantly correlated with SISF (r = 0.690, p<0.01), BMI (r = 0.773, p<0.01), BAI (r = 0.649, p<0.01), WHtR (r = 0.661, p<0.01), WHR (r = 0.214, p<0.01), CI (r = 0.266, p<0.01), CRI (r = 0.168, p<0.01), TUA (r = 0.681, p<0.01), UMA (r = 0.644, p<0.01), UFA (r = 0.672, p<0.01), AFI (r = 0.484, p<0.01), PBF (r = 0.871, p<0.01), FM (r = 0.867, p<0.01), FFM (r = 0.536, p<0.01), FMI (r = 0. 885, p<0.01) and FFMI (r = 0.572, p<0.01). The correlations observed were strong except with WHR, CI, and CRI.

The SISF was positively and significantly correlated with BMI (r = 0.626, p<0.01), BAI (r = 0.529, p<0.01), WHtR (r = 0.542, p<0.01), WHR (r = 0.169, p<0.01), CI (r = 0.241, p<0.01), CRI (r = 0.172, p<0.01), TUA (r = 0.520, p<0.01), UMA (r = 0.484, p<0.01), UFA (r = 0.549, p<0.01), AFI (r = 0.436, p<0.01), PBF (r = 0.838, p<0.01), FM (r = 0.782, p<0.01), FFM (r = 0.397, p<0.01), FMI (r = 0. 792, p<0.01) and FFMI (r = 0.393, p<0.01). The correlations of SISF observed were strong except with WHR, CI, CRI, UMA, and AFI.

The BMI was positively and significantly correlated with BAI (r = 0.804, p<0.01), WHtR (r = 0.824, p<0.01), WHR (r = 0.291, p<0.01), CI (r = 0.283, p<0.01), CRI (r = 0.192, p<0.01), TUA (r = 0.850, p<0.01), UMA (r= 0.832, p<0.01), UFA (r = 0.696, p<0.01), AFI (r = 0.387, p<0.01), PBF (r =0.762, p<0.01), FM (r = 0.907, p<0.01), FFM (r = 0.838, p<0.01), FMI (r = 0.934, p<0.01) and FFMI (r = 0.941, p<0.01) among the female Limboo individuals. The correlation of BMI with WHR, CI, and AFI were observed to be low.

The BAI was positively and significantly correlated with CI (r = 0.242, p<0.01), CRI (r = 0.257, p<0.01), TUA (r = 0.659, p<0.01), UMA (r = 0.635, p<0.01), UFA (r = 0.586, p<0.01), AFI (r = 0.381, p<0.01), PBF (r = 0.655, p<0.01), FM (r = 0.683, p<0.01), FFM (r = 0.503, p<0.01), FMI (r = 0.769, p<0.01) and FFMI (r = 0.739, p<0.01) among the female Limboo individuals. The observed association of CI, CRI, and AFI with BAI were low.

The WHtR was positively and significantly correlated with WHR (r = 0.644, p<0.01), CI (r = 0.757, p<0.01), CRI (r = 0.121, p<0.01), TUA (r = 0.670, p<0.01), UMA (r = 0.653, p<0.01), UFA (r = 0.562, p<0.01), AFI (r = 0.314, p<0.01), PBF (r = 0.642, p<0.01), FM (r = 0.735, p<0.01), FFM (r = 0.626, p<0.01), FMI (r = 0.781, p<0.01) and FFMI (r = 0.765, p<0.01) among the female Limboo individuals. The observed correlations were strong except with CRI and AFI. Similarly, WHR was positively and significantly correlated with CI (r= 0.774, p<0.01), TUA (r = 0.197, p<0.01), UMA (r =0.198, p<0.01), UFA (r = 0.134, p<0.01), PBF (r = 0.175, p<0.01), FM (r = 0. 238, p<0.01), FFM (r = 0.233, p<0.01), FMI (r = 0.253, p<0.01) and FFMI (r = 0.290, p<0.01) among the female Limboo individuals. The only strong correlation was observed with CI another central obesity marker. The remaining correlation of CI with TUA (r = 0.212, p<0.01), UMA (r = 0.204, p<0.01), UFA (r = 0.191, p<0.01), AFI (r = 0.099, p<0.05), PBF (r = 0.247, p<0.01), FM (r = 0.294, p<0.01), FFM (r = 0.239, p<0.01), FMI (r = 0.293, p<0.01) and FFMI (r = 0.239, p<0.01) was observed low among the female Limboo individuals. As observed in preceding paragraphs WHR and CI were weakly correlated with skinfolds measurements like BSF, TSF, SSF, and SISF.

The TUA was positively and significantly correlated with UMA (r = 0.991, p<0.01), UFA (r = 0.754, p<0.01), AFI (r = 0.367, p<0.01), PBF (r = 0.706, p<0.01), FM (r = 0.826, p<0.01), FFM (r = 0.751, p<0.01), FMI (r = 0.825, p<0.01) and FFMI (r = 0.770, p<0.01). The negatively and significantly correlated variables with TUA were body density (r = -0.705, p<0.01), FFM (r = -0.640, p<0.01) and FFMI (r = -0.635, p<0.01). Further, UMA was positively and significantly correlated with UFA (r = 0.662, p<0.01), AFI (r = 0.367, p<0.01), PBF (r = 0.643, p<0.01), FM (r = 0.782, p<0.01), FFM (r = 0.759, p<0.01), FMI (r = 0.779, p<0.01) and FFM (r = 0.780, p<0.01). The correlations with TUA and UMA were strong except with AFI. The UFA was positively and significantly correlated with AFI (r = 0.867, p<0.01), PBF (r= 0.819,p<0.01), FM (r = 0.810,p<0.01), FFM (r = 0.491, p<0.01), FMI (r = 0.817, p<0.01) and FFMI (r = 0.497, p<0.01) among the female Limboo individuals. The correlations observed were strong with UFA. Furthermore, AFI was positively and significantly correlated with PBF (r = 0.707, p<0.01), FM (r = 0.573, p<0.01), FFM (r = 0.154, p<0.01), FMI (r = 0.587, p<0.01) and FFMI (r = 0.150, p<0.01), among the female Limboo individuals. The correlations were strong except with FFM and FFMI.

The PBF was positively and significantly correlated with FM (r = 0.916, p<0.01), FFM (r = 0.490, p<0.01), FMI (r = 0.934, p<0.01) and FFMI (r = 0.507, p<0.01). The correlations of FM with FFM (r = 0.775, p<0.01), FMI (r =0.979, p<0.01) and FFMI (r = 0.729, p<0.01) were positive and significant. The observed correlation of FFM with FMI (r = 0.701, p<0.01) and FFMI (r = 0.865, p<0.01) was positive and significant. The correlated of FMI with FFMI (r = 0.757, p<0.01) was positive and significant. The observed correlations were strong.

Table 3.6: Pearson correlation (r) between different anthropometric variables of male Limboo individuals

	Age	Height	Weight	Armspan	RAL	LAL	MUAC	NC	WC	HC	SH	TSF	BSF	SSF	SISF	BMI	BAI	WHtR	WHR	CI	CRI	TUA	UMA	UFA	AFI	PBF	FM	FFM	FMI	FFMI
Age	1																													
Height	-.130**	1																												
Weight	.156**	.411**	1																											
Armspan	-0.009	.788**	.392**	1																										
RAL	0.037	.794**	.341**	.900**	1																									
LAL	0.038	.787**	.343**	.910**	.977**	1																								
MUAC	.112*	.100*	.770**	.100*	0.083	.094*	1																							
NC	.144**	.197**	.740**	.181**	.149**	.165**	.636**	1																						
WC	.327**	.145**	.838**	.181**	.159**	.166**	.699**	.658**	1																					
HC	.164**	.330**	.860**	.319**	.280**	.277**	.681**	.651**	.765**	1																				
SH	-.114*	.783**	.453**	.540**	.516**	.499**	.170**	.258**	.198**	.386**	1																			
TSF	-0.049	0.019	.612**	0.014	-0.017	-0.013	.567**	.460**	.631**	.595**	0.074	1																		
BSF	0.041	0.075	.693**	0.063	0.033	0.034	.602**	.530**	.678**	.610**	.130**	.800**	1																	
SSF	.090*	0.044	.700**	0.01	-0.01	-0.007	.632**	.638**	.707**	.627**	.150**	.721**	.781**	1																
SISF	0.069	0.049	.675**	0.008	0	0.001	.627**	.574**	.694**	.616**	.135**	.770**	.765**	.778**	1															
BMI	.234**	-0.074	.876**	0.018	-0.044	-0.037	.789**	.706**	.838**	.769**	0.084	.661**	.723**	.747**	.713**	1														
BAI	.250**	-.495**	.456**	-.333**	-.375**	-.372**	.540**	.435**	.583**	.654**	-.272**	.532**	.500**	.539**	.522**	.764**	1													
WHtR	.370**	-.253**	.653**	-.134**	-.158**	-.148**	.640**	.563**	.920**	.616**	-.116**	.610**	.632**	.673**	.657**	.847**	.767**	1												
WHR	.319**	-.134**	.346**	-0.067	-0.058	-0.043	.328**	.301**	.700**	0.077	-.113*	.317**	.366**	.395**	.389**	.444**	.173**	.738**	1											
CI	.339**	-0.002	.172**	0.012	0.063	0.071	.151**	.161**	.649**	.216**	-0.048	.247**	.231**	.257**	.278**	.185**	.199**	.639**	.765**	1										
CRI	0.032	-.381**	0.037	-.408**	-.454**	-.469**	.095*	0.079	0.071	0.063	.276**	0.079	0.076	.154**	.123**	.240**	.361**	.220**	0.041	-0.066	1									
TUA	.117**	.098*	.769**	.097*	0.083	.093*	.998**	.626**	.700**	.677**	.169**	.569**	.609**	.635**	.628**	.788**	.538**	.642**	.332**	.156**	.098*	1								
UMA	.131**	.102*	.742**	.102*	.090*	.100*	.992**	.609**	.666**	.646**	.171**	.476**	.545**	.584**	.570**	.756**	.506**	.607**	.314**	.135**	.094*	.994**	1							
UFA	-0.016	0.037	.680**	0.034	0.005	0.01	.684**	.523**	.684**	.647**	.099*	.985**	.822**	.753**	.795**	.725**	.563**	.653**	.340**	.248**	0.087	.689**	.606**	1						
AFI	-0.087	-0.006	.499**	-0.012	-0.044	-0.043	.392**	.355**	.538**	.502**	0.041	.976**	.740**	.649**	.704**	.551**	.468**	.529**	.277**	.238**	0.068	.392**	.292**	.924**	1					
PBF	0.04	0.053	.746**	0.022	-0.004	0	.683**	.618**	.756**	.681**	.150**	.875**	.860**	.905**	.909**	.791**	.581**	.717**	.417**	.283**	.139**	.681**	.614**	.889**	.821**	1				
FM	.088*	.160**	.864**	.131**	.099*	.103*	.739**	.693**	.825**	.768**	.244**	.849**	.875**	.903**	.895**	.861**	.574**	.740**	.423**	.272**	.114*	.742**	.681**	.885**	.769**	.971**	1			
FFM	.178**	.523**	.935**	.513**	.457**	.458**	.667**	.654**	.713**	.786**	.528**	.346**	.453**	.445**	.411**	.745**	.300**	.487**	.236**	0.074	-0.024	.664**	.665**	.426**	.228**	.467**	.630**	1		
FMI	.102*	0.02	.814**	0.02	-0.015	-0.01	.735**	.671**	.812**	.732**	.135**	.859**	.879**	.910**	.899**	.884**	.654**	.784**	.443**	.271**	.167**	.737**	.676**	.892**	.782**	.978**	.987**	.561**	1	
FFMI	.303**	-.139**	.777**	0.014	-0.059	-0.053	.699**	.615**	.718**	.668**	0.029	.388**	.473**	.488**	.441**	.925**	.723**	.755**	.370**	0.083	.259**	.696**	.694**	.467**	.269**	.505**	.612**	.769**	.639**	1

** $p<0.01$; * $p<0.05$

Table 3.7: Pearson correlation (r) of different anthropometric variables of female Limboo individuals

	Age	Height	Weight	Armspan	RAL	LAL	MUAC	NC	WC	HC	SH	TSF	BSF	SSF	SISF	BMI	BAI	WHtR	WHR	CI	CRI	TUA	UMA	UFA	AFI	PBF	FM	FFM	FMI	FFMI
Age	1																													
Height	-.111*	1																												
Weight	.145**	.397**	1																											
Armspan	-0.021	.821**	.316**	1																										
RAL	0.032	.764**	.295**	.867**	1																									
LAL	0.02	.753**	.288**	.870**	.959**	1																								
MUAC	.131**	.128**	.827**	.090*	.089*	.090*	1																							
NC	.225**	.235**	.806**	.172**	.140**	.146**	.698**	1																						
WC	.206**	.179**	.823**	.150**	.154**	.169**	.694**	.696**	1																					
HC	.134**	.280**	.864**	.197**	.197**	.183**	.747**	.675**	.743**	1																				
SH	-.183**	.676**	.407**	.470**	.404**	.384**	.216**	.271**	.191**	.322**	1																			
TSF	-.144**	0.076	.567**	0.015	0.02	0.04	.614**	.356**	.489**	.570**	.152**	1																		
BSF	-0.036	0.083	.653**	-0.011	0.006	0.01	.622**	.516**	.625**	.600**	.215**	.598**	1																	
SSF	-0.014	0.06	.731**	-0.022	0.006	0.012	.679**	.607**	.671**	.691**	.183**	.615**	.686**	1																
SISF	-.107*	.101*	.610**	-0.015	-0.008	-0.002	.519**	.493**	.563**	.591**	.223**	.520**	.625**	.690**	1															
BMI	.205**	0.019	.923**	0.006	0.005	0	.847**	.781**	.822**	.828**	.165**	.587**	.678**	.773**	.626**	1														
BAI	.196**	-.296**	.622**	-.276**	-.246**	-.254**	.662**	.532**	.630**	.832**	-0.068	.519**	.543**	.649**	.529**	.804**	1													
WHtR	.239**	-.097*	.718**	-0.076	-0.057	-0.04	.665**	.638**	.961**	.672**	0.006	.475**	.609**	.661**	.542**	.824**	.719**	1												
WHR	.158**	-0.053	.250**	0	0.009	0.046	.189**	.275**	.621**	-0.049	-0.076	.090*	.243**	.214**	.169**	.291**	-0.031	.644**	1											
CI	.159**	0.052	.280**	0.058	0.079	.110*	.204**	.263**	.760**	.275**	-0.016	.158**	.291**	.266**	.241**	.283**	.242**	.757**	.774**	1										
CRI	-.106*	-.290**	0.064	-.350**	-.367**	-.380**	.131**	0.077	0.04	.090*	.509**	.108*	.183**	.168**	.172**	.192**	.257**	.121**	-0.036	-0.082	1									
TUA	.136**	.136**	.834**	.099*	.099*	.102*	.997**	.696**	.701**	.749**	.217**	.612**	.629**	.681**	.520**	.850**	.659**	.670**	.197**	.212**	.123**	1								
UMA	.169**	.135**	.817**	.105*	.104*	.103*	.988**	.702**	.684**	.725**	.213**	.504**	.589**	.644**	.484**	.832**	.635**	.653**	.198**	.204**	.118**	.991**	1							
UFA	-0.072	.101*	.678**	0.042	0.048	0.065	.751**	.466**	.583**	.654**	.177**	.975**	.650**	.672**	.549**	.696**	.586**	.562**	.134**	.191**	.111*	.754**	.662**	1						
AFI	-.235**	0.038	.369**	-0.021	-0.016	0.006	.373**	.170**	.320**	.407**	.107*	.955**	.480**	.484**	.436**	.387**	.381**	.314**	0.023	.099*	.094*	.367**	.247**	.867**	1					
PBF	-.136**	0.085	.729**	-0.031	-0.014	-0.008	.713**	.565**	.657**	.710**	.235**	.800**	.790**	.871**	.838**	.762**	.655**	.642**	.175**	.247**	.207**	.706**	.643**	.819**	.707**	1				
FM	0.016	.259**	.933**	.155**	.155**	.159**	.821**	.731**	.801**	.844**	.337**	.735**	.786**	.867**	.782**	.907**	.683**	.735**	.238**	.292**	.135**	.826**	.782**	.810**	.573**	.916**	1			
FFM	.240**	.473**	.951**	.420**	.383**	.369**	.744**	.784**	.753**	.789**	.423**	.362**	.468**	.536**	.397**	.838**	.503**	.626**	.233**	.239**	-0.004	.751**	.759**	.491**	.154**	.490**	.775**	1		
FMI	0.038	0.067	.880**	-0.003	0.007	0.011	.822**	.708**	.791**	.818**	.214**	.745**	.798**	.885**	.792**	.934**	.769**	.781**	.253**	.293**	.201**	.825**	.779**	.817**	.587**	.934**	.979**	.701**	1	
FFMI	.338**	-0.028	.851**	0.013	0.002	-0.01	.768**	.755**	.751**	.736**	.099*	.365**	.482**	.572**	.393**	.941**	.739**	.765**	.290**	.239**	.160**	.770**	.780**	.497**	.150**	.507**	.729**	.865**	.757**	1

** $p<0.01$; * $p<0.05$

3.2.7 LINEAR REGRESSION OF SEX ON ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES AMONG THE LIMBOO INDIVIDUALS

The linear regression was conducted to assess the impact of various anthropometric and body composition variables and indices on sex. The linear regression was conducted on the entire sample (n=992) and finding is presented in Table 3.8. The sex coded as 1 for "female" and 2 for "male" were taken as dependent variables and anthropometric variables/indices as independent variables. The anthropometric variables/indices such as height, weight, arm span, RAL, LAL, NC, SH, CRI, TUA, UMA, FFM, FFMI has significant positive effect on sex of the studied population. The remaining variables/indices like WC, HC, TSF, BSF, SSF, SISF, BMI, BAI, WHtR, WHR, CI, UFA, AFI, BFMA, PBF, FM and FMI have significant negative effect on the sex of the studied individuals. This indicates clear sexual dimorphism in the anthropometric variables/indices in the present study. The PBF (R^2 = 0.572) explains more variation of sex followed by SH (R^2 = 0.505), height (R^2 = 0.481), FFM (R^2 = 0.490), arm span (R^2 = 0.464), among Limboo individuals. Similar corresponding trend was noticed with SEE.

3.2.8 LINEAR REGRESSION OF AGE ON ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES AMONG THE LIMBOO INDIVIDUALS

To see the impact of various anthropometric variables/indices on age, linear regression was carried out with age as dependent variable and anthropometric variables/indices as independent variables among male and female Limboo individuals separately. The results are presented in Table 3.9 and 3.10. The variables with significant negative impact on the age of the male Limboo individuals were height and SH. Other variables like weight, arm span, MUAC, NC, WC, HC, BMI, BAI, WHtR, WHR, CI, TUA,UMA, BFMA and FMI has significant positive impact on age of the male Limboo individuals. The variable which explain more variation on age were WHtR (R^2 = 0.135), CI (R^2 = 0.113), WC (R^2 = 0.105) and WHR (R^2 = 0.100) based on adjusted R^2 however, proportion explain was very small. The same trend was found with SEE.

Table 3.8: Linear Regression of sex on anthropometric and body composition variables among the Limboo individuals

Variable	Intercept	B	p-value	R^2	SEE
Height	-5.490	0.045	< 0.01	0.481	0.360
Weight	0.648	0.016	< 0.01	0.098	0.478
Arm span	-4.482	0.038	< 0.01	0.464	0.366
RAL	-3.757	0.080	< 0.01	0.376	0.395
LAL	-3.785	0.081	< 0.01	0.383	0.393
MUAC	0.228	0.050	< 0.01	0.073	0.482
NC	-2.049	0.106	< 0.01	0.386	0.392
WC	2.261	-0.009	< 0.01	0.029	0.493
HC	2.403	-0.010	< 0.01	0.019	0.495
SH	-5.279	0.081	< 0.01	0.505	0.352
TSF	2.049	-0.062	< 0.01	0.257	0.431
BSF	1.904	-0.083	< 0.01	0.151	0.461
SSF	1.724	-0.020	< 0.01	0.031	0.493
SISF	1.836	-0.037	< 0.01	0.101	0.474
BMI	1.832	-0.015	< 0.01	0.010	0.498
BAI	3.303	-0.063	< 0.01	0.367	0.398
WHtR	3.228	-3.256	< 0.01	0.185	0.452
WHR	2.185	-0.746	< 0.01	0.011	0.498
CI	4.503	-2.374	< 0.01	0.171	0.455
CRI	-0.455	3.595	< 0.01	0.010	0.498
TUA	0.892	0.012	< 0.01	0.067	0.483
UMA	0.667	0.017	< 0.01	0.125	0.468
UFA	1.883	-0.107	< 0.01	0.155	0.460
AFI	2.228	-0.107	< 0.01	0.375	0.396
BFMA	1.103	-0.010	< 0.01	0.037	0.491
PBF	2.425	-0.050	< 0.01	0.572	0.327
FM	2.018	-0.051	< 0.01	0.260	0.430
FFM	-0.490	0.045	< 0.01	0.490	0.357
FMI	2.092	-0.135	< 0.01	0.373	0.396
FFMI	-0.348	0.100	< 0.01	0.200	0.440

The variables with significant positive impact on age of the female Limboo individuals were weight, RAL, MUAC, NC, WC, HC, BMI, BAI, WHtR, WHR, CI, TUA, UMA, BFMA, FFM and FFMI. The variables with significant negative impact on the age were height, armspan, SH, TSF, SISF, AFI and PBF among the female Limboo individuals. The associated R^2 values of these variables were below 0.056, impact were subtle. The observed trend was similar with SEE.

Table 3.9: Linear Regression of age on anthropometric and body composition variables among the Limboo male individuals

Variable	Intercept	B	p-value	R^2	SEE
Height	80.618	-0.281	< 0.01	0.015	12.672
Weight	22.955	0.064	< 0.01	0.022	12.625
Arm span	38.621	-0.017	ns	-0.002	12.780
RAL	25.127	0.157	ns	-0.001	12.772
LAL	24.958	0.160	ns	-0.001	12.772
MUAC	20.485	0.584	< 0.01	0.011	12.700
NC	8.114	0.787	< 0.01	0.019	12.646
WC	-9.162	0.562	< 0.01	0.105	12.078
HC	3.197	0.370	< 0.01	0.025	12.607
SH	76.454	-0.468	< 0.01	0.011	12.698
TSF	37.214	-0.211	ns	0.000	12.765
BSF	34.447	0.369	ns	0.000	12.770
SSF	33.036	0.259	ns	0.006	12.750
SISF	33.882	0.244	ns	0.003	12.750
BMI	14.519	0.945	< 0.01	0.053	12.424
BAI	9.056	1.037	< 0.01	0.061	12.374
WHtR	-13.918	98.913	< 0.01	0.135	11.874
WHR	-30.127	72.452	< 0.01	0.100	12.113
CI	-53.618	72.747	< 0.01	0.113	12.025
CRI	18.879	30.978	ns	-0.001	12.774
TUA	27.911	0.143	< 0.01	0.012	12.693
UMA	26.638	0.175	< 0.01	0.015	12.671
UFA	36.178	-0.141	ns	-0.002	12.779
AFI	38.774	-0.593	ns	0.006	12.732
BFMA	28.389	0.175	< 0.01	0.015	12.671
BD	81.936	-43.150	ns	0.000	12.771
PBF	34.479	0.101	ns	0.000	12.770
FM	33.643	0.279	ns	0.006	12.730
FFM	16.155	0.396	<0.001	0.000	12.769
FMI	33.287	0.830	< 0.05	0.008	12.714
FFMI	-3.288	2.005	< 0.001	0.090	12.182

ns = non-significant

Table 3.10: Linear Regression of age on anthropometric and body composition variables among the Limboo female individuals

Variable	Intercept	B	p-value	R^2	SEE
Height	72.954	-0.263	< 0.01	0.010	12.025
Weight	24.154	0.187	< 0.01	0.019	11.972
Armspan	39.594	-0.039	0.640	-0.002	12.097
RAL	25.812	0.126	0.483	-0.001	12.094
LAL	28.667	0.081	ns	-0.002	12.097
MUAC	19.685	0.570	< 0.01	0.015	11.996
NC	-4.650	1.218	< 0.01	0.049	11.789
WC	14.046	0.237	< 0.01	0.041	11.839
HC	15.703	0.201	< 0.01	0.016	11.992
SH	91.368	-0.714	< 0.01	0.031	11.897
TSF	38.453	-0.427	< 0.01	0.019	11.974
BSF	34.707	-0.164	ns	-0.001	12.092
SSF	34.217	-0.038	ns	-0.002	12.099
SISF	36.756	-0.285	< 0.01	0.010	12.030
BMI	18.730	0.648	< 0.01	0.040	11.843
BAI	17.025	0.529	< 0.01	0.036	11.866
WHtR	10.563	41.458	< 0.01	0.055	11.748
WHR	13.130	22.287	< 0.01	0.023	11.947
CI	7.596	20.102	< 0.01	0.023	11.947
CRI	76.966	-79.685	< 0.05	0.009	12.032
TUA	26.531	0.147	< 0.01	0.016	11.988
UMA	24.386	0.209	< 0.01	0.027	11.926
UFA	35.684	-0.446	ns	0.003	12.069
AFI	43.097	-1.089	< 0.01	0.053	11.761
BFMA	25.744	0.209	< 0.01	0.027	11.926
PBF	42.055	-0.343	< 0.01	0.017	11.987
FM	33.218	0.042	ns	-0.002	12.098
FFM	12.781	0.542	< 0.001	0.056	11.746
FMI	32.418	0.232	ns	-0.001	12.091
FFMI	-0.219	1.947	< 0.01	0.112	11.388

ns = non-significant

3.2.9 LINEAR REGRESSION OF BMI ON ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES AMONG THE LIMBOO INDIVIDUALS

The linear regression was also conducted to observe the impact of other anthropometric variables/indices on BMI, for which BMI was taken as dependent variables and other anthropometric variables/indices as independent variables (Table

3.11 and 3.12). The variables with significant positive impact on BMI among the Limboo male individuals were weight, MUAC, NC, WC, HC, SH, TSF, BSF, SSF, SISF, BAI, WHtR, WHR, CI, TUA, UMA, UFA, AFI, BFMA, PBF, FM, FFM, FMI and FFMI. According to the relative R^2 values variables best explaining variation on BMI were FFMI (R^2 = 0.855), FMI (R^2 = 0.781), weight (R^2 = 0.766), FM (R^2 = 0.741), WHtR (R^2 = 0.717),WC (R^2 = 0.702), PBF (R^2 = 0.625), BD (R^2 = 0.624), MUAC (R^2 = 0.621), TUA(R^2 = 0.621), HC (R^2 = 0.590), BAI (R^2 = 0.582), UMA (R^2 = 0.571), BFMA (R^2 = 0.571), SSF (R^2 = 0.557), UFA (R^2 = 0.525), BSF (R^2 = 0.521), SISF (R^2 = 0.508), NC (R^2 = 0.498) and TSF (R^2 = 0.436) in descending order. The trend was similar for SEE. The values are presented in Table 3.11.

Among the female Limboo individuals the variables which has significant positive impact on BMI were weight, MUAC, NC, WC, HC, SH, TSF, BSF, SSF, SISF, BAI, WHtR, WHR, CI, TUA, UMA, UFA, AFI, BFMA, PBF, FM, FFM, FMI and FFMI. The values are presented in Table 3.12. Based on the relative R^2 values variables best explaining variation on BMI were FFMI (R^2 = 0.885), FMI (R^2 = 0.871), weight (R^2 = 0.852), FM (R^2 = 0.823), TUA (R^2 = 0.722), MUAC (R^2 = 0.717), BFMA (R^2 = 0.691), UMA (R^2 = 0.691), HC (R^2 = 0.684), WHtR (R^2 = 0.679), WC (R^2 = 0.675), NC (R^2 = 0.609), SSF (R^2 = 0.596), PBF (R^2 = 0.580), UFA (R^2 = 0.483), BAI (R^2 = 0.464) and BSF (R^2 = 0.459) in descending order. The trend also corresponds with the SEE.

Table 3.11: Linear Regression of BMI on anthropometric and body composition variables among the Limboo male individuals

Variable	Intercept	B	p-value	R^2	SEE
Height	28.855	-0.040	ns	0.004	3.082
Weight	4.583	0.313	< 0.01	0.766	1.53
Arm span	21.043	0.009	ns	0.002	3.169
RAL	25.660	-0.046	ns	0.000	3.166
LAL	25.138	-0.039	ns	0.001	3.167
MUAC	-4.152	1.017	< 0.01	0.621	1.948
NC	-11.060	0.954	< 0.01	0.498	2.244
WC	-6.083	0.357	< 0.01	0.702	1.728
HC	-15.321	0.430	< 0.01	0.590	2.027
SH	14.973	0.086	< 0.01	0.005	3.158
TSF	17.642	0.711	< 0.01	0.436	2.378
BSF	16.648	1.470	< 0.01	0.521	2.191
SSF	16.828	0.535	< 0.01	0.557	2.106
SISF	17.663	0.621	< 0.01	0.508	2.221
BAI	2.260	0.785	< 0.01	0.582	2.046
WHtR	-5.747	56.193	< 0.01	0.717	1.683
WHR	-0.283	25.030	< 0.01	0.196	2.840
CI	10.386	9.845	< 0.01	0.032	3.115
CRI	-9.167	58.033	< 0.01	0.056	3.077
TUA	9.357	0.239	< 0.01	0.621	0.195
UMA	9.384	0.251	< 0.01	0.571	2.073
UFA	17.880	1.610	< 0.01	0.525	2.182
AFI	17.780	0.930	< 0.01	0.302	2.645
BFMA	11.895	0.251	< 0.01	0.571	2.073
PBF	16.199	0.492	< 0.01	0.625	1.938
FM	17.337	0.674	< 0.01	0.741	1.612
FFM	2.096	0.411	< 0.001	0.554	2.114
FMI	17.131	1.786	< 0.01	0.781	1.483
FFMI	-7.132	1.520	< 0.001	0.855	1.206

ns = non-significant

Table 3.12: Linear Regression of BMI on anthropometric and body composition variables among the Limboo female individuals

Variable	Intercept	B	p-value	R^2	SEE
Height	21.057	0.014	ns	-0.002	3.831
Weight	3.817	0.377	< 0.01	0.852	1.472
Arm span	22.718	0.003	ns	-0.002	3.832
RAL	22.845	0.006	ns	-0.002	3.832
LAL	23.200	0.000	ns	-0.002	3.832
MUAC	-5.711	1.171	< 0.01	0.717	2.037
NC	-18.981	1.338	< 0.01	0.609	2.392
WC	-1.655	0.299	< 0.01	0.675	2.180
HC	-12.233	0.394	< 0.01	0.684	2.150
SH	6.672	0.205	< 0.01	0.025	3.779
TSF	17.132	0.553	< 0.01	0.343	3.102
BSF	17.514	0.305	< 0.01	0.459	2.816
SSF	15.196	0.658	< 0.01	0.596	2.432
SISF	17.664	0.526	< 0.01	0.391	2.987
BAI	1.442	0.689	< 0.01	0.646	2.277
WHtR	-2.094	45.226	< 0.01	0.679	2.169
WHR	11.231	12.940	< 0.01	0.083	3.666
CI	8.467	11.327	< 0.01	0.078	3.675
CRI	-1.519	45.598	< 0.01	0.035	3.761
TUA	8.858	0.292	< 0.01	0.722	2.019
UMA	8.593	0.326	< 0.01	0.691	2.128
UFA	17.270	1.373	< 0.01	0.483	2.751
AFI	18.334	0.568	< 0.01	0.148	3.533
BFMA	10.711	0.326	< 0.01	0.691	2.128
PBF	8.492	0.608	< 0.01	0.580	2.480
FM	13.565	0.754	< 0.01	0.823	1.612
FFM	0.019	0.599	< 0.001	0.701	2.002
FMI	12.848	1.800	< 0.01	0.871	1.372
FFMI	-6.746	1.716	< 0.001	0.885	1.206

3.2.10 LINEAR REGRESSION OF HEIGHT ON THE VARIOUS ANTHROPOMETRIC VARIABLES OF LIMBOO INDIVIDUALS

The linear regression was conducted to estimate the height from various anthropometric variables and to find the best predictor of the height. The result of the linear regression is presented in Table 3.13 and 3.14. The height of individuals was taken as dependent variables and other anthropometric variables as independent variables. The variables taken were significantly and positively associated with height except for TSF, BSF, SSF, SISF measurement among the male Limboo individuals (Table 3.13). Among these variables the best predictor of height were right arm length (R^2 = 0.62), left arm length (R^2 = 0.61), arm span (R^2 = 0.62) and SH (R^2 = 0.61). The trend also corresponds with the SEE.

Among the female Limboo individuals' variables taken as independent variables were significantly and positively associated with the height except for TSF, BSF and SSF (Table 3.14). The best predictors of height based on R^2 among these variables were arm span (R^2 = 0.67), right arm length (R^2 = 0.58), left arm length (R^2 = 0.56) and sitting height (R^2 = 0.45), which is also supported by SEE.

Further, linear regression was carried out for sex combined (male + female) Limboo individuals with height as dependent variables and other anthropometric variables as independent variables. The result is presented in Table 3.15. Linear anthropometric variables like arm span (R^2 = 0.80), RAL (R^2 = 0.75), LAL (R^2 = 0.75), SH (R^2 = 0.75) were the best predictors of height which is supported by both R^2 and SEE among Limboo individuals of present study.

Table 3.13: Linear regression equation for height (cm) estimation from the various anthropometric variables of male Limboo individuals

Variable	Intercept	B	p-value	R^2	SEE
Weight	143.787	0.274	< 0.01	0.168	5.373
Arm span	43.446	4.077	< 0.01	0.621	3.627
RAL	54.054	1.556	< 0.01	0.629	3.587
LAL	54.706	1.551	< 0.01	0.619	3.633
MUAC	153.136	0.240	< 0.05	0.008	5.865
NC	142.045	0.494	< 0.01	0.037	5.780
WC	150.242	0.115	< 0.01	0.019	5.833
HC	129.265	0.343	< 0.01	0.107	5.565
SH	29.949	1.490	< 0.01	0.613	3.664
TSF	159.179	0.037	ns	-0.002	5.894
BSF	158.310	0.283	ns	0.004	5.879
SSF	158.814	0.059	ns	0.000	5.889
SISF	158.813	0.080	ns	0.000	5.888

ns = non-significant

Table 3.14: Linear regression equation for height (cm) estimation from the various anthropometric variables of female Limboo individuals

Variable	Intercept	B	p-value	R^2	SEE
Weight	137.681	0.216	< 0.01	0.156	4.696
Arm span	52.477	0.639	< 0.01	0.674	2.912
RAL	67.452	1.291	< 0.01	0.583	3.299
LAL	68.605	1.277	< 0.01	0.566	3.368
MUAC	142.995	0.235	< 0.01	0.014	5.074
NC	131.870	0.537	< 0.01	0.053	4.973
WC	141.601	0.087	< 0.01	0.030	5.034
HC	132.781	0.178	< 0.01	0.077	4.911
SH	58.625	1.118	< 0.01	0.455	3.771
TSF	147.758	0.096	ns	0.004	5.101
BSF	147.882	0.160	ns	0.005	5.098
SSF	147.975	0.069	ns	0.002	5.107
SISF	147.616	0.113	< 0.05	0.008	5.090

ns = non-significant

Table 3.15: Linear regression equation for height (cm) estimation from the various anthropometric variables of sex (female + male) combined Limboo individuals

Variable	Intercept	B	p-value	R^2	SEE
Weight	133.045	0.388	< 0.01	0.234	6.701
Arm span	33.926	0.766	< 0.01	0.801	3.412
RAL	40.278	1.741	< 0.01	0.753	3.804
LAL	41.261	1.732	< 0.01	0.747	3.847
MUAC	135.006	0.751	< 0.01	0.070	7.381
NC	105.900	1.446	< 0.01	0.304	6.385
WC	156.602	-0.006	ns	-0.001	7.659
HC	143.422	0.120	< 0.01	0.011	7.612
SH	28.111	1.504	< 0.01	0.746	3.857
TSF	159.455	-0.599	< 0.01	0.103	7.250
BSF	157.621	-0.716	< 0.01	0.048	7.471
SSF	155.796	-0.147	ns	0.007	7.630
SISF	156.866	0.300	< 0.05	0.028	7.547

ns = non-significant

3.2.11 STEP-WISE MULTIPLE LINEAR REGRESSION OF HEIGHT ON VARIOUS ANTHROPOMETRIC VARIABLES AMONG LIMBOO INDIVIDUALS

The step-wise multiple linear regression equations for height estimation were constructed on the weight, arm span, RAL, LAL, MUAC, NC, WC, HC, and SH. Since the variables like TSF, BSF, SSF, SISF were not significant predictor of height on simple linear regression as a result not considered for step-wise multiple linear. Results are presented in Table 3.16 and 3.17. Among the male Limboo individuals step-wise multiple linear regression yield six best fit models for estimation of height from RAL, SH, arm span, WC, weight, LAL, and MUAC. The prediction strength based on R^2 value increases with the addition of variables in the model such as 1st (R^2 = 0.82), 2nd (R^2 = 0.82), 3rd (R^2 = 0.83), 4th (R^2 = 0.83), 5th (R^2 = 0.83) and 6th (R^2 = 0.83). The stated strength of models for height estimation were also supported the SEE.

Similarly among the female Limboo individuals there were five best fit models (Table 3.17). The models are constructed based on arm span, RAL, weight, MUAC and WC. Prediction strength of the models increases with the addition of variables in the model i.e. 1st (R^2 = 0.78), 2nd (R^2 = 0.79), 3rd (R^2 = 0.79), 4th (R^2 = 0.80) and 5th (R^2 = 0.80) which is also supported by SEE.

Table 3.16: Step-wise multiple linear regression equation for height estimation from various anthropometric variables of male Limboo individuals

Model No.	Variable	Intercept	B	p-value	R^2	SEE
1	RAL	4.697	1.041	< 0.01	0.820	2.500
	SH		0.969	< 0.01		
2	RAL	1.308	0.721	< 0.01	0.826	2.455
	SH		0.931	< 0.01		
	Arm span		0.174	< 0.01		
3	RAL	2.470	0.717	< 0.01	0.828	2.442
	SH		0.944	< 0.01		
	Arm span		0.180	< 0.01		
	WC		-0.038	< 0.01		
4	RAL	10.422	0.735	< 0.01	0.830	2.425
	SH		0.892	< 0.01		
	Arm span		0.159	< 0.01		
	WC		-0.109	< 0.01		
	Weight		0.079	< 0.01		
5	RAL	10.499	0.349	< 0.05	0.832	2.411
	SH		0.902	< 0.01		
	Arm span		0.122	< 0.01		
	WC		-0.112	< 0.01		
	Weight		0.080	< 0.01		
	LAL		0.465	< 0.01		
6	RAL	16.088	0.327	ns	0.834	2.401
	SH		0.882	< 0.01		
	Arm span		0.106	< 0.01		
	WC		-0.112	< 0.01		
	Weight		0.123	< 0.01		
	LAL		0.498	< 0.01		
	MUAC		-0.172	< 0.01		

ns = non-significant

Table 3.17: Step-wise multiple linear regression equation for height (cm) estimation from various anthropometric variables of female Limboo individuals

Model No.	Variable	Intercept	B	p-value	R^2	SEE
1	Arm span	23.302	0.503	< 0.01	0.782	2.919
	SH		0.616	< 0.01		
2	Arm span	22.209	0.357	< 0.01	0.793	2.389
	SH		0.617	< 0.01		
	RAL		0.364	< 0.01		
3	Arm span	23.814	0.354	< 0.01	0.794	2.320
	SH		0.592	< 0.01		
	RAL		0.357	< 0.01		
	Weight		0.025	< 0.05		
4	Arm span	32.181	0.337	< 0.01	0.802	2.276
	SH		0.570	< 0.01		
	RAL		0.347	< 0.01		
	Weight		0.108	< 0.01		
	MUAC		-0.312	< 0.01		
5	Arm span	36.797	0.330	< 0.01	0.804	2.260
	SH		0.545	< 0.01		
	LAL		0.350	< 0.01		
	Weight		0.162	< 0.01		
	MUAC		-0.322	< 0.01		
	WC		-0.0.50	< 0.01		

3.2.12 ASSESSMENT OF NUTRITIONAL STATUS USING BMI AMONG THE LIMBOO INDIVIDUALS

In the present study assessment of nutritional status was carried using BMI classification recommended by WHO (1995) and WHO (2000). The former is known as traditional classification and later was specifically recommended for population of Asia-Pacific region. The results obtained using both classifications are presented below in details.

3.2.12.1 Nutritional status of Limboo adults based on BMI classification of WHO (1995)

The prevalence of CED, overweight and obesity based on WHO (1995) classification is presented in Table 3.18. The combined (CED I, CED II and CED III) prevalence of underweight (BMI < 18.5 kg/m2) among the male and female Limboo individuals was 34 (6.85%) and 41 (8.27%), respectively. The overall underweight prevalence was 75 (7.56 %). Specifically, the prevalence of CED I, CED II and CED III was 61 (6.15%), 11 (1.11%) and 3 (0.30%), respectively among the Limboo individuals of the present study. The overall distribution of CED grades, overweight and obesity is presented in Figure 3.23. Among them more than half were identified as normal based on WHO (1995) criteria i.e. 665 (67.04%) individuals. Table 3.18 also depicts the sex wise distribution of different grades of CED, overweight and obesity of the present study. The CED I was found among the 29 (5.85%) male and 32 (6.45%) female Limboo individuals. The prevalence of CED II was 3 (0.60%) and 8 (1.61%) among the male and female individuals respectively. Further, the prevalence of CED III was 2 (0.40%) among males and 1 (0.20%) among females in the present study. The combined (CED I, CED II and CED III) prevalence of underweight (BMI < 18.5 kg/m^2) among Limboo individuals was independent of sex (χ^2 –value 0.707; d.f. 1; p > 0.05).The sex difference in the prevalence of CED I (χ^2 – value 0.157; d.f.1; p> 0.05), CED II (χ^2 – value 2.29; d.f.1; p> 0.05) and CED III (χ^2 – value 2.68; d.f.1; p> 0.05) were statistically non-significant.

Table 3.18: Prevalence of underweight, overweight and obesity using WHO (1995) classification among the Limboo individuals

BMI	Male (n = 496)	Female (n = 496)	Total (n = 992)
Normal	360 (72.58)	305 (61.49)	667 (67.24)
CED I	29 (5.85)	32 (6.45)	61 (6.15)
CED II	3 (0.60)	8 (1.61)	11 (1.11)
CED III	2(0.40)	1 (0.20)	3 (0.30)
CED Combined	34 (6.85)	41 (8.27)	75 (7.56)
Overweight	91 (18.35)	121 (24.40)	212 (21.37)
Obese	11 (2.23)	29 (5.85)	40 (4.03)

Figures in the parentheses are percentage

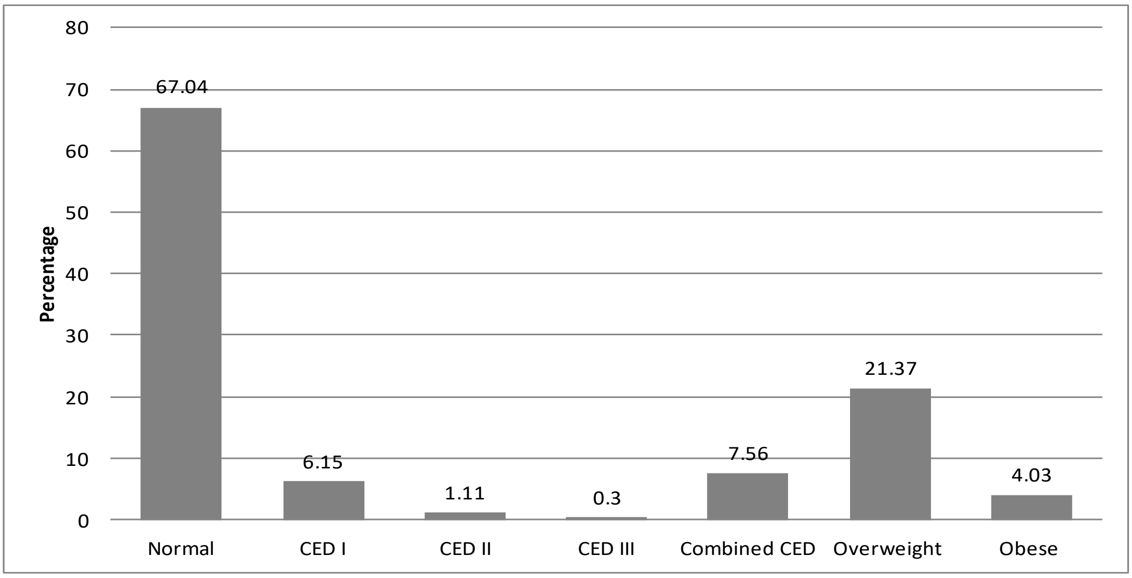

Figure 3.23: The overall prevalence of underweight, overweight, and obesity using WHO (1995) classification among the Limboo individuals.

The overall 212 (21.37%) and 40 (4.03%) individuals, was observed overweight and obese, respectively in the present study (Table 3.18). The observed sex specific prevalence of overweight was 91 (18.35%) male and 121 (24.40%) female Limboo individuals in the present study. The sex differences on the prevalence of overweight among the Limboo individuals were significant (χ^2 – value 5.79; d.f.1; $p< 0.05$). The prevalence of obesity among male individuals was 2.23% and among females was 5.85% in the present study. The prevalence of obesity between sexes of the present study was statistically significant (χ^2 – value 10.95; d.f.1; $p< 0.05$). The sex wise distribution of different grades of CED, overweight and obesity is also presented in the Figure 3.24.

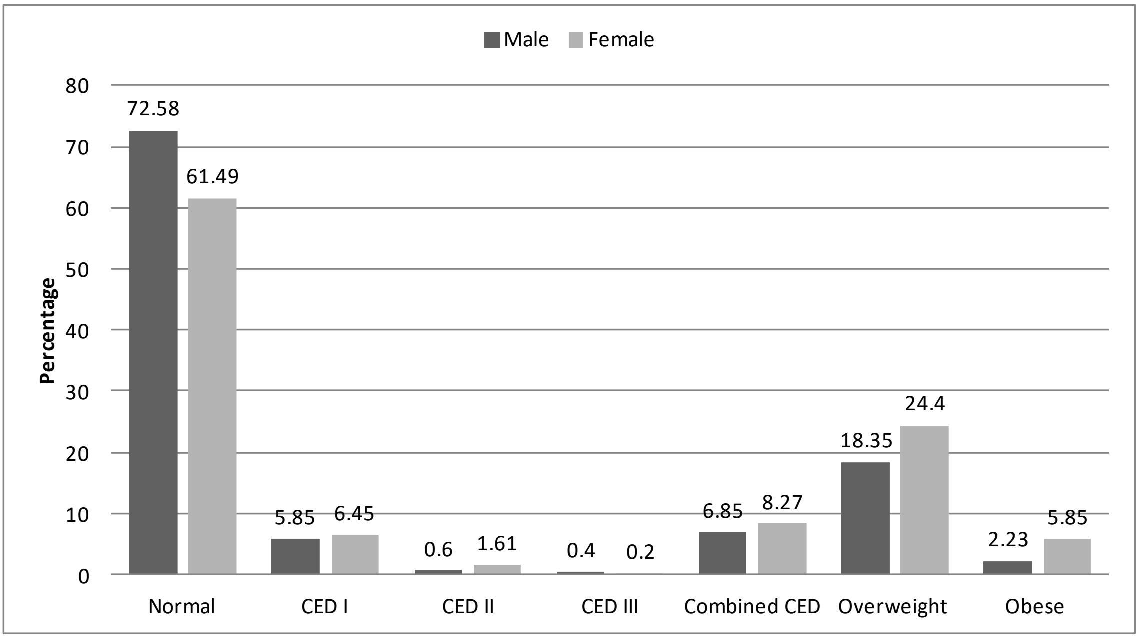

Figure 3.24: Sex specific prevalence of CED, overweight and obesity using WHO (1995) classification among the Limboo individuals.

Table 3.19: Age group wise prevalence of CED, overweight, and obesity using WHO (1995) classification among Limboo individuals

BMI Class	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
Normal	151 (79.89)	151 (69.91)	140 (64.85)	112 (54.63)	69 (75.82)	42 (56.00)
CED I	16 (8.47)	22 (10.19)	10 (4.63)	4 (1.95)	3 (3.30)	6 (8.00)
CED II	1(0.53)	6 (2.78)	2 (0.93)	1 (0.49)	0 (0.00)	1 (1.33)
CED III	0 (0.00)	0 (0.00)	1 (0.46)	0 (0.00)	1 (1.10)	1 (1.33)
CED (all)	17 (8.99)	28 (12.96)	13 (6.02)	5 (2.44)	4 (4.40)	8 (10.67)
Overweig ht	20 (10.58)	31 (14.35)	56 (25.93)	72 (35.12)	15 (16.48)	18 (24.00)
Obese	1 (0.53)	6 (2.78)	7 (3.24)	16 (7.80)	3 (3.30)	7 (9.33)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

The age group for the present study was 18-29 years, 30-49 years and 50-64 years. The overall age specific prevalence of underweight was high among female Limboo individuals of 18-29 years (12.96%) and 50-64 years (10.67%). In the age group 30-49 years, males (6.02%) were more undernourished than females (2.44%). The sex differences within each of the age group were found to be non-significant for underweight. However, the prevalence of prevalence of underweight was significant between the three age group (χ^2 –value 13.832; d.f. 2; $p < 0.01$). Details are presented in Table 3.19.

Further, prevalence of CED I was higher in the age group 18-29 years with 16 (8.47%) male and 22 (10.19%) female Limboo individuals. The prevalence of CED II was 1 (0.53%) among males and 6 (2.78%) among females. However, CED III was absent (0.0%) in both the sexes. In the middle age group i.e. 30-49 years, the prevalence of CED I was 10 (4.63%) among males and 4 (1.95%) among females. The prevalence of CED II was 2 (0.93%) and 1 (0.49%) among the Limboo male and female individuals respectively. Similarly, CED III was found among 1 (0.46%) male and absent (0.0%) among females of this age group. Among the 50-64 years individuals, 3 (3.30%) and 6 (8.00%), male and female individuals was observed with CED I, respectively. In the same age group lower prevalence of CED II was noted among males (0.00%) and females (1.33%). Similarly the prevalence of CED III was low in this age group (males: 1.10% and females: 1.33%).

The age group 18-29 years consists of 20 (10.58%) male and 31 (14.35%) female overweight individuals. The prevalence of overweight was high among the 30-49 years middle age Limboo individuals comprised of 56 (25.93%) males and 72 (35.12%) females. Similarly, prevalence of overweight among the old adults was 15 (16.48%) males and 18 (24.00%) females. On the other hand prevalence of obesity was relatively lower with 1 (0.53%) males and 6 (2.78%) females affected in the age group 18-29 years followed by 7 (3.24%) males and 16 (7.80%) females among the

30-49 years age group adults. Finally age group 50-64 years consists of 3 (3.30%) males and 7 (9.33%) females individuals with obesity.

The details are presented in Table 3.19 and supplemented with bar diagram (Figure 3.25). The sex difference in the prevalence of CED I, CED II, CED III, overweight and obesity across all age group were not significant except for overweight (χ^2-value 0.040;d.f.1;p>0.05) and obese (χ^2-value 0.010;d.f.1;p>0.05) 30-49 years individuals. Remaining χ^2-values are not presented here.

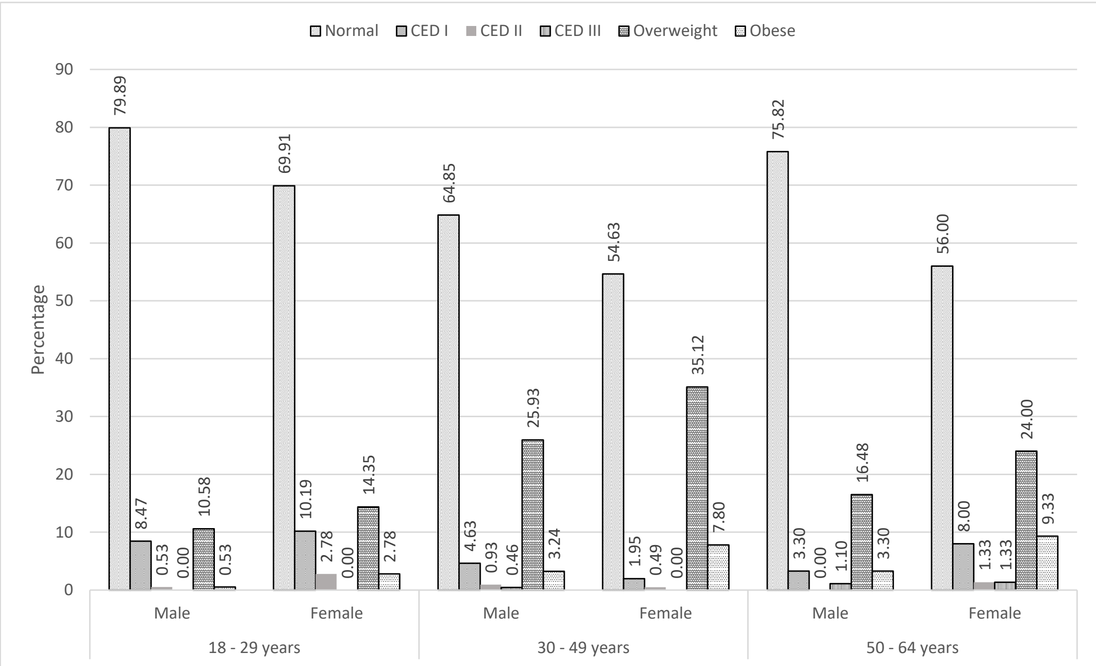

Figure 3.25: Distribution of age group wise prevalence of underweight, overweight, and obese using WHO (1995) classification among the Limboo individuals.

3.2.12.2 Nutritional status of Limboo individuals based on BMI criteria of WHO (2000).

The prevalence of overweight according this criterion was 17.14% each for male and female Limboo individuals of the present study (Table 3.20). The prevalence of overweight irrespective of sex was also same. The obesity category was further divided into obese I and obese II, which was observed among 214 (21.57%) and 39 (3.93%) individuals, respectively irrespective of sex. The sex specific prevalence of obesity I was 18.75% and 24.40%, among male and female individuals, respectively in the present study. Similarly the prevalence of obese II was 10 (2.02%) among male and 29 (5.85%) among female Limboo individuals of the present study.

The chance of falling under the normal range of WHO (2000) classification was associated with sex of the individuals in the present study (χ^2 –value 11.758; d.f. 1; $p < 0.01$). The normal range is also regarded as increasing but acceptable risk in this classification by Yajnik and Yudkin (2004) and association of average risk co-morbidities by WHO (2000).The occurrence of overweight was independent of sex (χ^2 –value 0.000; d.f. 1; $p > 0.05$). Further, significant association of sex with prevalence of obese I (χ2 –value 4.671; d.f. 1; $p < 0.05$) and obese II (χ^2 –value 9.635; d.f. 1; $p < 0.05$) was observed in the present study.

Table 3.20: Prevalence of undernutrition, overweight and obesity using WHO (2000) classification among the Limboo individuals of Sikkim

BMI class	Male	Female	Total
Normal	274(55.24)	220 (44.35)	494 (49.80)
Overweight	85 (17.14)	85 (17.14)	170 (17.14)
Obese I	93(18.75)	121 (24.40)	214 (21.57)
Obese II	10 (2.02)	29 (5.85)	39 (3.93)
Total	496	496	992

Figures in the parentheses are percentage

More males were under the normal category in each of these age groups 18-29 years (68.78% vs. 52.31%), 30-49 years (43.52% vs. 37.07%), and 50-64 years (54.95% vs. 41.33%) as presented in Table 3.21. The sex difference in the individuals falling under the normal category was only significant for age group 50-64 years (χ^2 –value 11.391; d.f.1; $p<0.01$). The females (17.59%) of age group 18-29 years were overweight than their male (10.58%) counterparts in the present study which was not significant. However, the prevalence of overweight was high among males of age group 30-49 years (21.30 %) and 50-64 years (17.56 %) compared to their female counterparts (20.88 % and 14.67 %). In the prevalence of overweight, the significant sex difference was only observed in age group 50-64 years (χ^2 –value 4.038; d.f. 1; p < 0.05). The rate of obese I was high among females Limboo individuals of different age group compared to males counterparts. The highest prevalence (35.12%) was found among females of age group 30-49 years. The prevalence of obese I across the age group was independent of sex. Similarly, more females were observed to be obese II compared to males in each of the age groups such as 18-29 years (males: 0.53% vs. females: 2.78%), 30-49 years (males: 2.78% vs. females: 7.80%), and 50-64 years (males: 3.30% vs. females: 9.33%) among the Limboo individuals of the present study. The sex difference in the prevalence of obese II was only observed in 30-49 years (χ^2 –value 5.367; d.f. 1; $p < 0.05$).

Table 3.21: Age group specific prevalence of overweight, obese I and obese II using WHO (2000) classification among Limboo individuals

BMI class	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
Normal	130 (68.78)	113 (52.31)	94 (43.52)	76 (37.07)	50 (54.95)	31 (41.33)
Overweight	20 (10.58)	38 (17.59)	46 (21.30)	36 (17.56)	19 (20.88)	11 (14.67)
Obese I	21 (11.11)	31 (14.35)	57 (26.39)	72 (35.12)	15 (16.48)	18 (24.00)
Obese II	1 (0.53)	6 (2.78)	6 (2.78)	16 (7.80)	3 (3.30)	7 (9.33)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

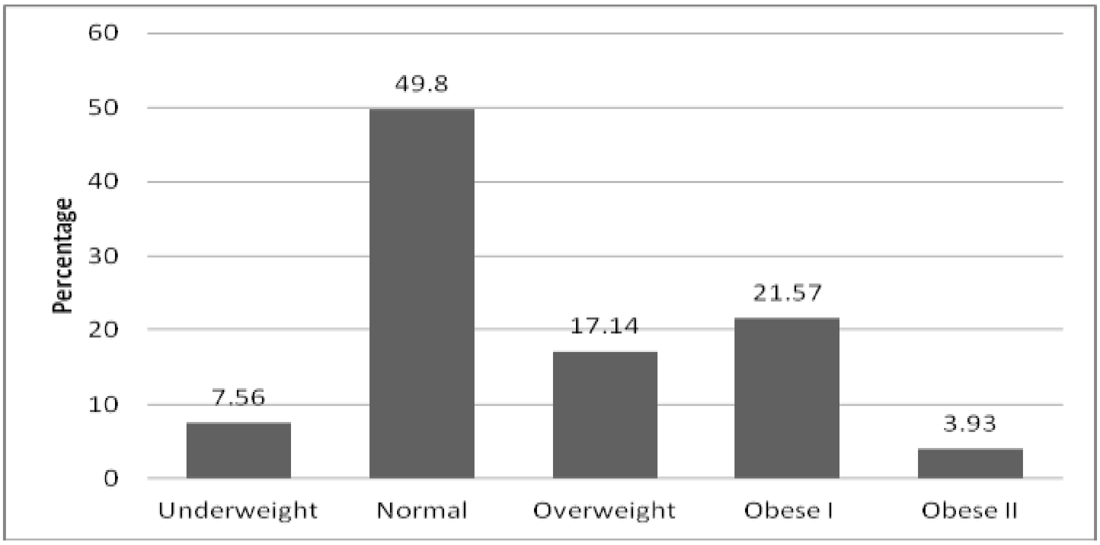

Figure 3.26: Overall prevalence of underweight, overweight, obese I, and obese II based using WHO (2000) classification among the Limboo individuals.

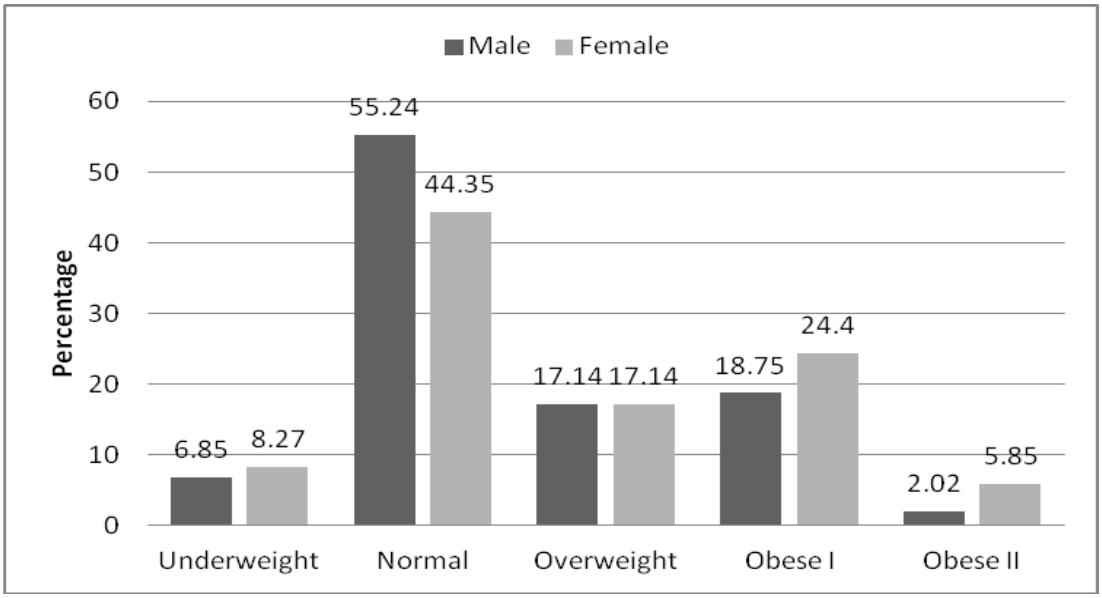

Figure 3.27: Sex specific prevalence of underweight, overweight, obese I, and obese II using WHO (2000) classification among the Limboo individuals.

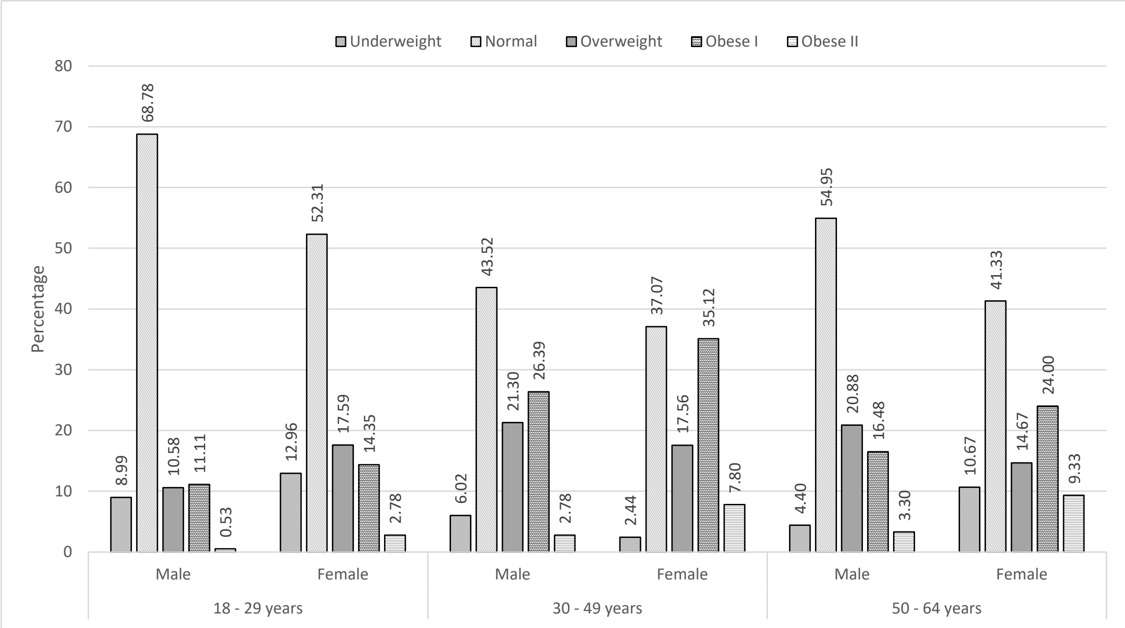

Figure 3.28: Age specific prevalence of undernutrition overweight and obesity using WHO (2000) classification among Limboo individuals.

The present study utilised χ^2 test to assess association of age with the prevalence of normal, overweight, obese I, and obese II among the male and female Limboo individuals. The age difference was noted significant in normal category Asia-Pacific BMI criteria (χ^2 –value 31.865; d.f.2; $p<0.01$). There was no association of age with the prevalence of overweight. However, significant age difference was observed in the prevalence of obese I (χ^2 –value 39.003; d.f.2; $p<0.01$) and obese II (χ^2 –value 8.996; d.f.2; $p<0.01$) among Limboo individual of the present study.

3.2.13 ASSESSMENT OF UNDERNUTRITION USING MUAC AMONG LIMBOO INDIVIDUALS

Table 3.22 shows the prevalence of undernutrition base on MUAC cut-offs given by James et al. (1994). The prevalence of undernutrition was high among females (13.91%) compared to males (6.45%) of the present study. The sex difference on the prevalence of MUAC based undernutrition was statistically significant (χ^2 –value 15.091; d.f.1; $p<0.05$). The overall prevalence of MUAC based undernutrition was 101 (10.18%) among the population of present study. This is also depicted in Figure 3.29.

Table 3.22: Prevalence of undernutrition using MUAC among the Limboo individuals

Sex	N	Undernutrition	Normal
Male	496	32 (6.45)	464 (93.55)
Female	496	69 (13.91)	427 (86.09)
Total	992	101 (10.18)	891 (89.82)

Figures in the parentheses are percentage

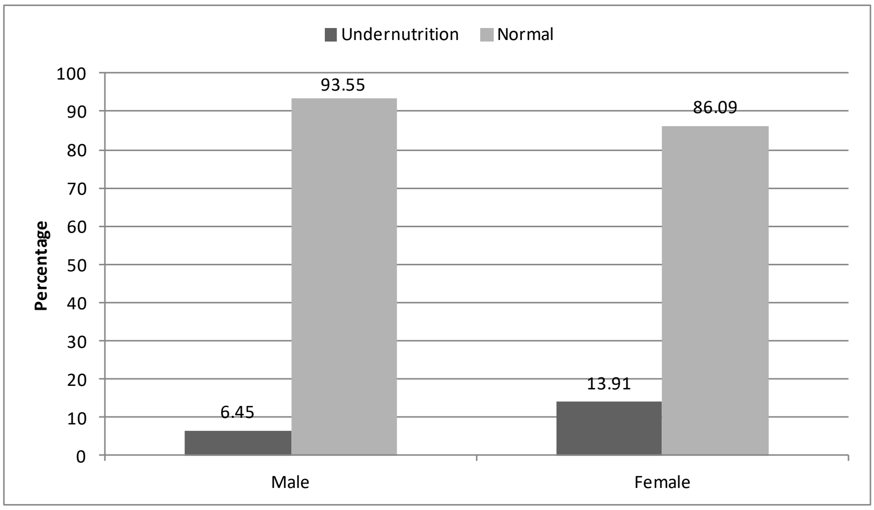

Figure 3.29: Sex specific distribution of undernutrition using MUAC among the Limboo individuals.

Table 3.23: Age specific prevalence of underweight using MUAC among the Limboo individuals

MUAC class	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
Underweight	13 (7.39)	39 (22.03)	10 (4.85)	12 (6.22)	9 (10.98)	18 (31.58)
Normal	176 (93.12)	177 (81.94)	206 (95.37)	193 (94.15)	82 (90.11)	57 (76.00)
N	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

The age specific undernutrition identified using MUAC showed high prevalence among females of 50-64 years (31.58%) followed by females of 18-29 years (22.03%) and then 30-49 years females (6.22%). Similarly, among men 50-64 years (10.98%) was more undernourished followed by females of 18-29 years (7.39%) and then 30-49 years females (4.85%). Sex specific χ^2 test within age group revealed significant difference in age group 18-29 years (χ^2 – value 11.253; d.f.1; $p < 0.001$) and age group 50-64 years (χ^2 – value 6.010; d.f.1; $p < 0.05$). These values are presented in Table 3.23.

Table 3.24: Prevalence of undernutrition using combination of BMI and MUAC among the Limboo individuals

Sex	MUAC	Norma-l	CED I	CED II	CED III	Over-weight	Obese	Total
Male	< 23 cm	15 (3.02)	14 (2.82)	2 (0.40)	1 (0.20)	0 (0.00)	0 (0.00)	32 (6.45)
	> 23 cm	345 (69.56)	15 (3.02)	1 (0.20)	1 (0.20)	91 (18.35)	9 (1.81)	464 (93.55)
	Total	360 (72.58)	29 (5.85)	3 (0.60)	2 (0.40)	91 (18.35)	9 (1.81)	496 (100)
Female	< 22 cm	34 (6.85)	26 (5.24)	8 (1.61)	1 (0.20)	0 (0.00)	0 (0.00)	69 (13.91)
	> 22 cm	271 (54.64)	6 (1.21)	0 (0.00)	0 (0.00)	121 (24.40)	29 (5.85)	427 (86.09)
	Total	305 (61.49)	32 (6.45)	8 (1.61)	1 (0.20)	121 (24.40)	29 (5.85)	496 (100)

Figures in the parentheses are percentage

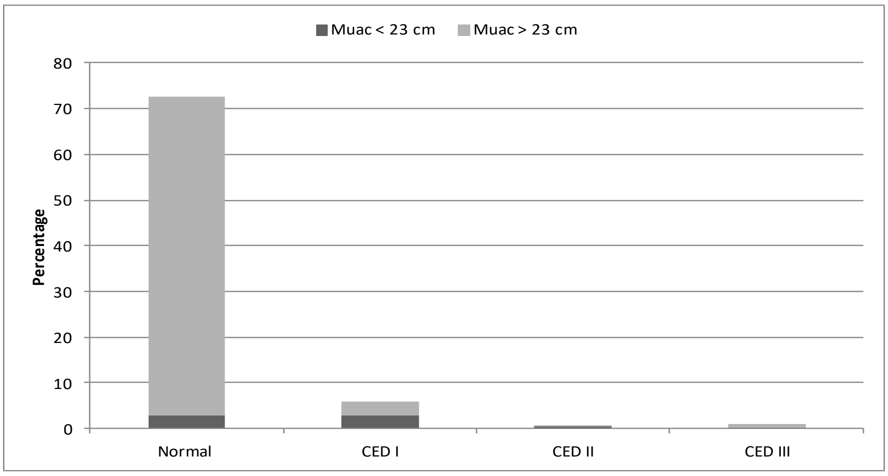

Figure 3.30a: Prevalence of undernutrition using combination of BMI and MUAC among the male Limboo individuals.

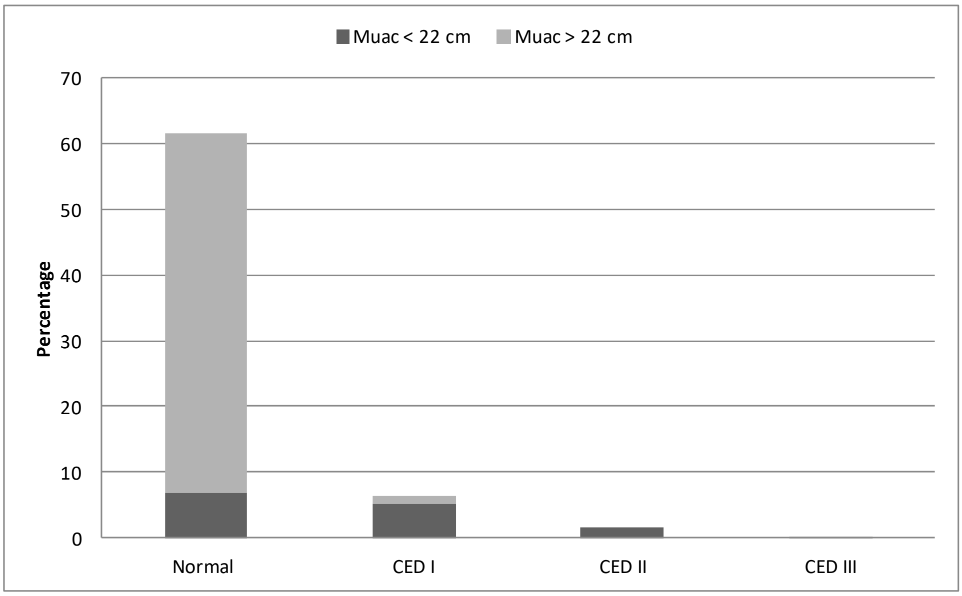

Figure 3.30b: Prevalence of undernutrition using combination of BMI and MUAC among the female Limboo individuals.

The combined prevalence of undernutrition given by MUAC with different grades of BMI is presented in Table 3.24. As observed there was 32 (6.45%) undernourished Limboo males identify by MUAC of which 15 (3.02%) was normal based on BMI category. Remaining 14 (2.82%), 2 (0.40%) and 1 (0.20%) male individuals was under the category of CED I, CED II and CED III, respectively. Similarly 69 (13.91%) Limboo female individuals was undernourished of which 34 (6.09%) was categorised as normal by BMI. The remaining 26 (5.24%), 8 (1.61%), 1 (0.20%) female individuals was categorised as CED I, CED II and CED III, respectively. These are represented in Figure 3.30a and 3.30b. Hence, the undernourished individual identified by MUAC as well as CED was 17 (3.42%) males and 35 (7.05%) females in the present study.

3.2.14 ASSESSMENT OF CENTRAL ADIPOSITY AND OVERALL ADIPOSITY AMONG LIMBOO INDIVIDUALS

The cut-offs for WC, WHtR (WHO 2000), WHR (WHO 2008) and CI (Valdez et al. 1993) along with BMI criteria for overweight (WHO 1995; 2000) has been utilised to identify the individuals at risk of adiposity related morbidity. This comparative prevalence is presented in Table 3.25. Based on BMI ($\geq$ 25kg/m^2) overweight/obesity was observed among 102 (20.56%) and 150 (30.24%), male and female Limboo individuals, respectively. The overall prevalence of overweight/obesity among the Limboos of the present study was 25.40%. The sex difference in the prevalence of overweight/obesity (BMI $\geq$ 25kg/m^2) between Limboo male and female was statistically significant (χ^2 – value 13.369; d.f.1; $p<0.001$). Individuals with BMI $\leq$ 25kg/m^2 were clubbed as “rest” in the table. The result of similar analysis using BMI of WHO (2000) showed 188 (37.90%) males and 235 (47.38%) females as overweight/obese (BMI $\geq$ 23kg/m^2). Irrespective of sex there were 423 (42.64%) individuals with BMI above 23 kg/m^2. The sex difference in the prevalence of high BMI (BMI $\geq$ 23kg/m^2) was observed to be significant (χ^2 – value 9.104; d.f.1; $p<0.05$) as presented in Table 3.25.

The WC is another index of adiposity has identified 54 (10.89%) males and 293 (59.07%) females Limboo individuals under the risk. Overall, 347 (34.98%) Limboo individuals were at risk of ill health associated with adiposity. The sex difference in the prevalence of ill health was statistically significant (χ^2 – value 253.174; d.f.1; $p< 0.05$). Similarly, utilizing WHtR 242 (48.79%) Limboo males and 408 (82.26%) Limboo females were identified at risk of adiposity related ill health. Overall 650 (65.52%) individuals were at risk of adiposity related diseases. The sex difference in the prevalence of risk was statistically significant (χ^2 – value 122.967; d.f.1; $p < 0.05$). The percentage prevalence is presented in Table 3.25 and Figure 3.31.

The other measure of central obesity such as WHR has identified 491 (98.99%) males and 473 (95.36%) females at the risk of adiposity related ill health. The overall prevalence of risk was 964 (97.18%) among the Limboo individuals of the present study. The sex difference in the incidence of risk was statistically significant (χ^2 – value 11.908; d.f.1; $p < 0.05$). The prevalence of risk due to adiposity identified by CI was 216 (43.55%) and 456 (91.94%) among the male and female Limboo individuals of West Sikkim. The overall prevalence of adiposity related risk was 672 (67.74%) among the studied population. The sex difference in the prevalence of adiposity related risk was statistically significant (χ^2 – value 265.714; d.f.1; $p < 0.001$).

Among the various indices used to assess adiposity the highest number of individuals at risk of adiposity related morbidity was identified by WHR (98.99%) followed by WHtR (48.79%), CI (43.55%), BMI/WHO 2000 (37.90), BMI/ WHO, 1995 (20.20%), and WC (10.89%) among the male Limboo individuals. Similarly, among female Limboo individuals, high adiposity was given by WHR (95.36%) followed by CI (91.94%), WHtR (82.26%), WC (59.07%), BMI/WHO 2000 (47.38), and BMI (30.20%). The overall adiposity risk assessed was highest for WHR (97.18%) followed by CI (67.74%), WHtR (65.52%), BMI/WHO 2000 (42.64), WC (34.98%), and BMI (25.20%). The trend observed for overall adiposity risk was similar to female Limboo individuals. Compare to male individuals females were more predisposed to adiposity related risk except for WHR. The findings are presented in Table 3.25 and Figure 3.31 in details.

Table 3.25: Prevalence of adiposity using different adiposity index among the Limboo individuals

Indices		Male (n=496)	Female (n=496)	Total (n=992)	χ2 -value
BMI (WHO 1995)	Rest	396 (79.80)	346 (69.80)	743 (74.80)	13.369**
	≥25kg/m^2	102 (20.56)	150 (30.24)	252 (25.40)	
BMI (WHO 2000)	Rest	308 (62.10)	261 (52.62)	569 (57.36)	9.104*
	≥23kg/m^2	188 (37.90)	235 (47.38)	423 (42.64)	
WC	Normal	442 (89.11)	203 (40.93)	645 (65.02)	253.174**
	At Risk	54 (10.89)	293 (59.07)	347 (34.98)	
WHtR	Normal	245 (49.40)	88 (17.74)	333 (33.57)	122.967**
	At Risk	242 (48.79)	408 (82.26)	650 (65.52)	
WHR	Normal	5 (1.01)	23 (4.64)	28 (2.82)	11.908**
	At Risk	491 (98.99)	473 (95.36)	964 (97.18)	
CI	Normal	280 (56.45)	40 (8.06)	320 (32.26)	265.714**
	At Risk	216 (43.55)	456 (91.94)	672 (67.74)	

*p<0.05; **p<0.01; d.f. = 1; Figures in the parentheses are percentage

3.2.14.1 Age specific prevalence of central adiposity among Limboo individuals.

The age and sex specific prevalence of high central obesity classified using WC (Table 3.26), WHtR (Table 3.27), WHR (Table 3.28), and CI (Table 3.29) among the Limboo individuals of Sikkim is detailed below. Utilizing WC the prevalence of central adiposity was observed high among the females (46.76 % vs. 71.71% vs. 60.00%) compared to males (5.82% vs. 12.96% vs. 16.48%) across the age groups in the present study. Further, 147 (71.71%) females of middle age group (30-49 years) and 15 (16.48%) males of 50-64 years were observed to be at high risk of central adiposity related morbidities utilizing WC as criterion. This is also depicted in Figure 3.32.

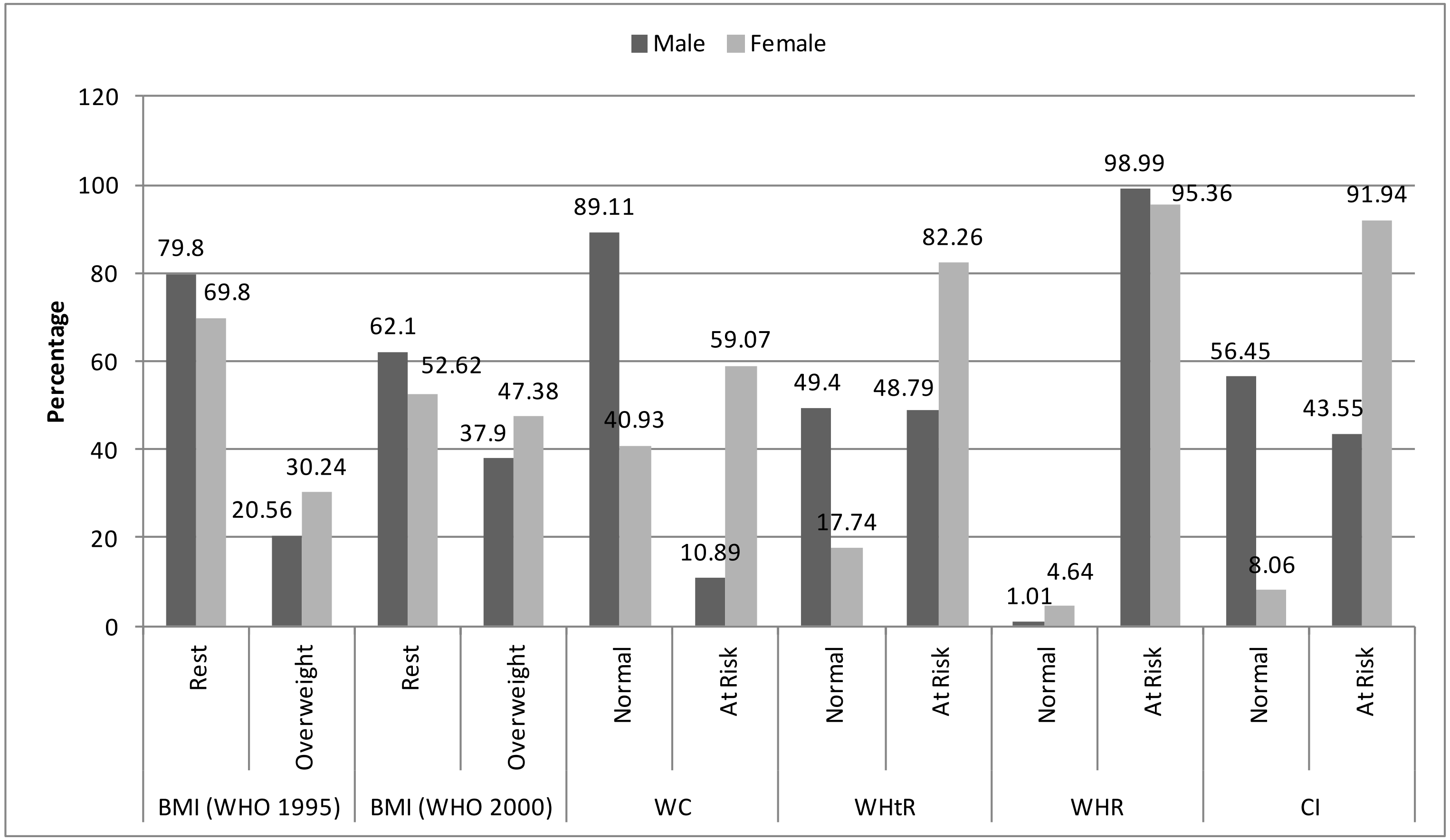

Figure 3.31: Comparison of adiposity given by general and central obesity indices of the Limboo individuals.

Table 3.26: Age and sex specific prevalence of central obesity using WC among the Limboo individuals

WC	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
High	11 (5.82)	101 (46.76)	28 (12.96)	147 (71.71)	15 (16.48)	45 (60.00)
Normal	178 (94.18)	115 (53.24)	188 (87.04)	58 (28.29)	76 (83.52)	30 (40.00)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

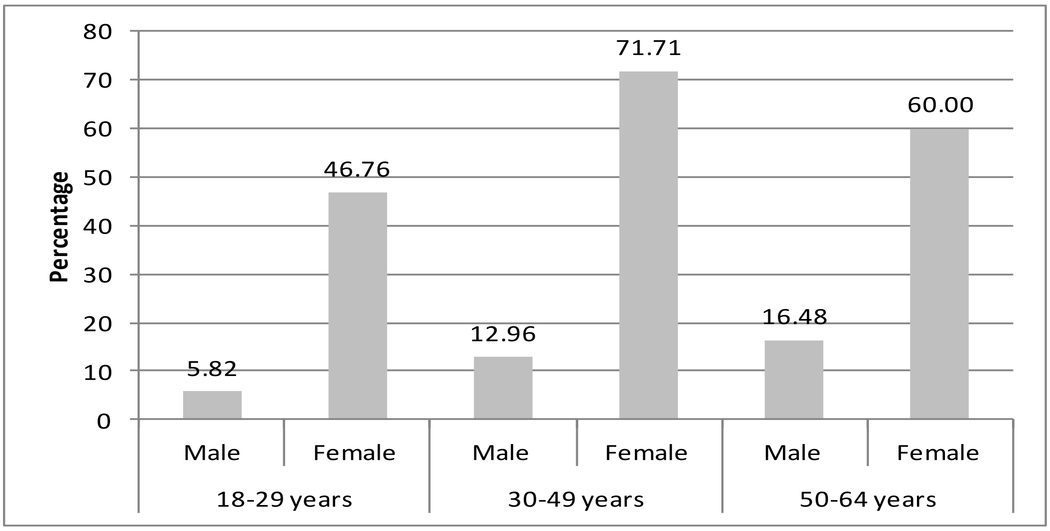

Figure 3.32: Age and sex specific distribution of WC related risk among the Limboo individuals.

A similar pattern of high central adiposity distribution was observed utilizing the WHtR as the female Limboo individuals being more centrally obese than the males (27.51% vs. 74.07%; 61.11 % vs. 90.24 %; 63.74% vs. 84.00%). The distribution is presented in Table 3.27. Further, among females of age group 30-49 years (90.24%) and among males the age group 50-64 years (63.74%) were at higher risk of central adiposity related morbidities using WHtR (Figure 3.33).

Table 3.27: Age and sex specific prevalence of central obesity using WHtR among the Limboo individuals

WHtR	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
High	52 (27.51)	160 (74.07)	132 (61.11)	185 (90.24)	58 (63.74)	63 (84.00)
Normal	137 (72.49)	56 (25.93)	84 (38.89)	20 (9.76)	33 (36.26)	12 (16.00)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

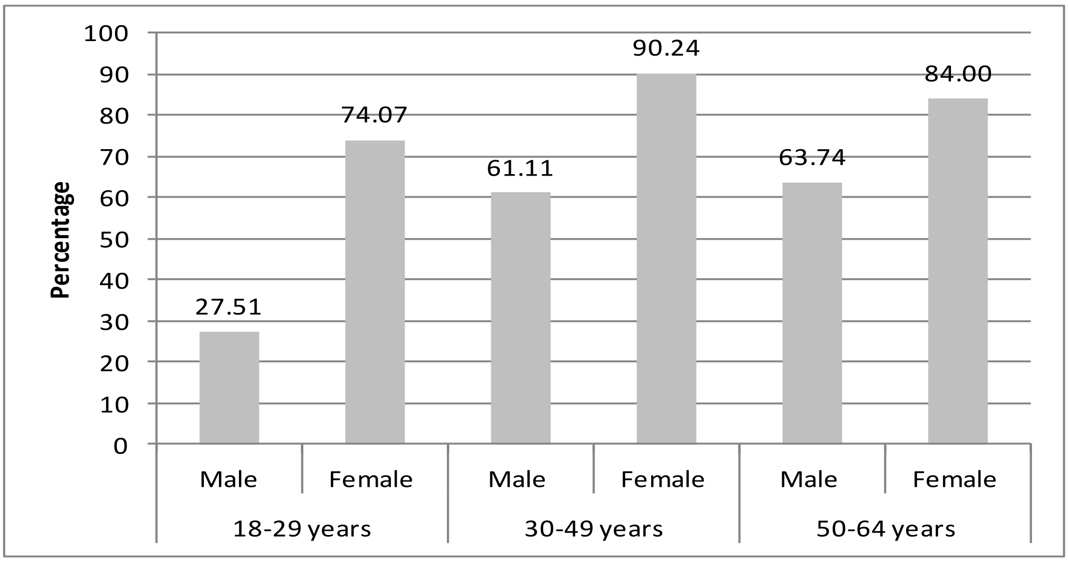

Figure 3.33: Age and sex specific distribution of WHtR related risk among the Limboo individuals.

The age and sex specific distribution of Limboo individuals based on WHR is presented in Table 3.28. The male individuals were observed at the high risk of central adiposity related risks compared to female individuals with narrow sex difference utilizing WHR as criteria across the age groups (98.94% vs. 94.44%, 99.07% vs. 97.07%, 98.90% vs. 93.33%). The high number of centrally obese individuals was observed among 30-49 years age group for both male and female Limboo individuals of the present study. The distribution is presented in Figure 3.34.

Table 3.28: Age and sex specific prevalence of central obesity using WHR among the Limboo individuals

WHR	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
High	187 (98.94)	204 (94.44)	214 (99.07)	199 (97.07)	90 (98.90)	70 (93.33)
Normal	2 (1.06)	12 (5.56)	2 (0.93)	6 (2.93)	1 (1.10)	5 (6.67)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

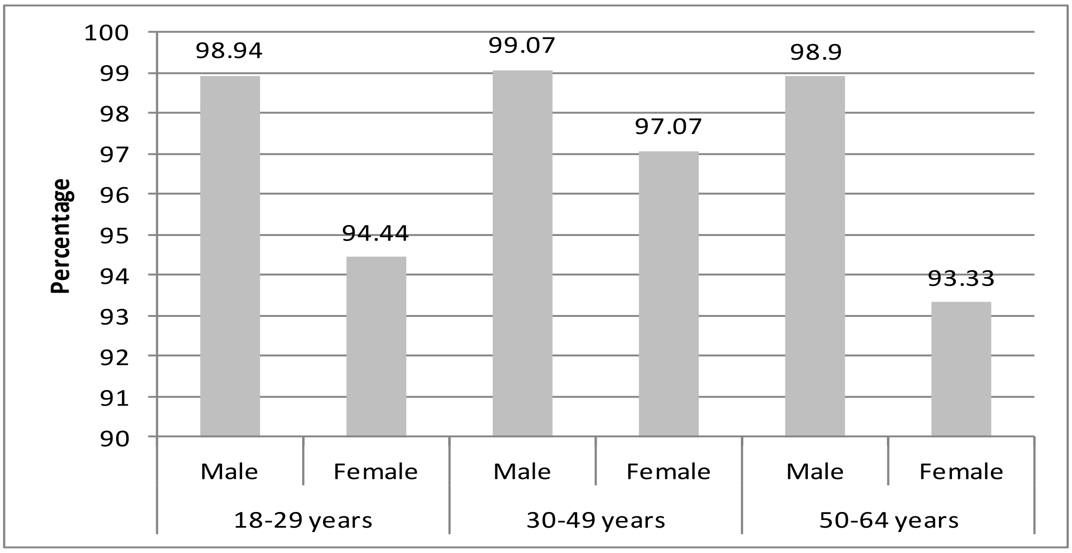

Figure 3.34: Age and sex specific distribution WHR related risk among the Limboo individuals.

Moreover, the prevalence pattern of central obesity utilizing CI was observed similar to that observed with WC and WHtR, where the prevalence was high among females across age groups (25.40% vs. 92.13%, 51.85% vs. 94.15%, 61.54% vs. 85.33%). Further, females of 30-49 years (94.15%) and males of 50-64 years (61.54%) were more at the risk of central adiposity related morbidities compared to Limboo individuals of other age groups. For details see Table 3.29 and Figure 3.35.

Table 3.29: Age and sex specific prevalence central obesity using CI among the Limboo individuals

CI	18-29 years		30-49 years		50-64 years	
	Male	Female	Male	Female	Male	Female
High	48 (25.40)	199 (92.13)	112 (51.85)	193 (94.15)	56 (61.54)	64 (85.33)
Normal	141 (74.60)	17 (7.87)	104 (48.15)	12 (5.85)	35 (38.46)	11 (14.67)
Total	189 (100)	216 (100)	216 (100)	205 (100)	91 (100)	75 (100)

Figures in the parentheses are percentage

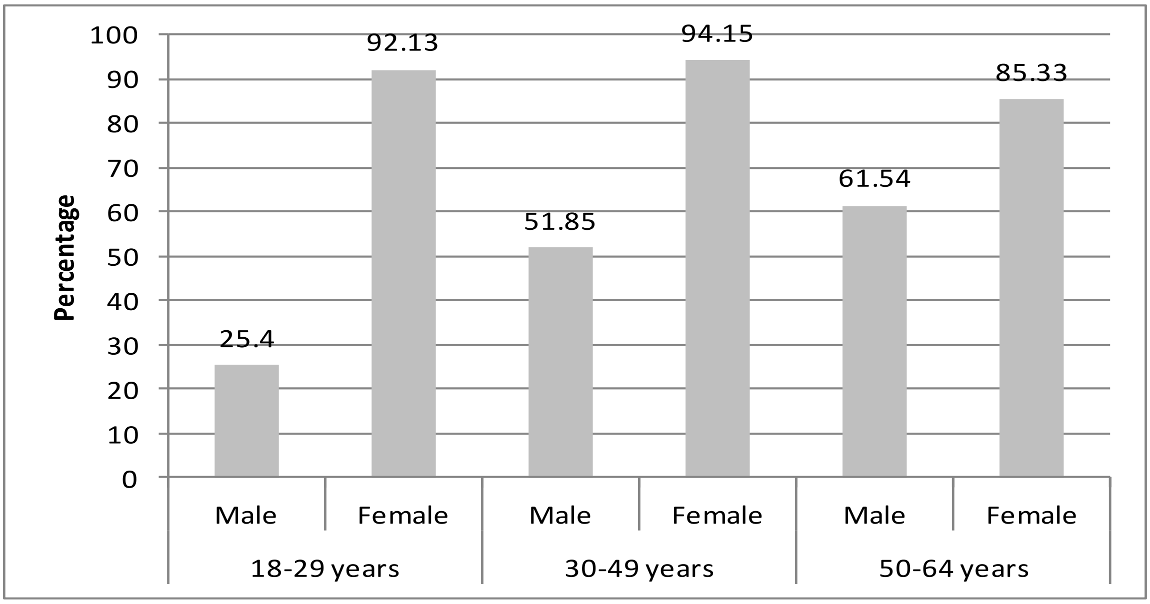

Figure 3.35: Age and sex specific distribution CI related risk among the Limboo individuals.

There was a significant difference between age groups in the prevalence of high central adiposity identified using WC (χ^2 – value 17.688; d.f.2; p<0.001) among the Limboo individuals of the present study. Similarly difference in the central adiposity prevalence identified using WHtR (χ^2 – value 52.924; d.f.2; p<0.001) and CI (χ^2 – value 14.290; d.f.2; p<0.001) among different age groups were observed significant except for central adiposity identified using WHR among the Limboo individuals of the present study.

3.2.15 EVALUTION OF ADIPOSITY USING BMI IN COMBINATION WITH WC, WHtR, WHR, AND CI

The high risk of illness due to excess adiposity was given by the cross combination of BMI with different indices of central adiposity such as WC, WHtR, WHR, and CI of male and female Limboo individuals is presented in Table 3.30 and 3.31 respectively. The individuals identified as normal by BMI and obese by WC was absent among Limboo males. Such normal weight centrally obese individuals as defined by BMI and WHR was highest 270 (54.44%) followed by 100 (20.16%) individuals defined by BMI and CI and finally 68 (13.71%) individuals defined by BMI and WHtR among the male Limboo individuals of the present study. Similarly, among female Limboo individuals normal weight centrally obese individuals as defined by BMI and WHR was highest 207 (41.73%) followed by 199 (40.12%) individuals defined by BMI and CI and then 165 (33.27%) individuals defined by BMI and WHtR and finally 76 (15.32%) individuals defined by BMI and WC.

Table 3.30: Prevalence of adiposity using BMI in combination with WC, WHtR, WHR, and CI among the male Limboo individuals

BMI	WC		WHtR		WHR		CI	
	Normal	High	Normal	High	Normal	High	Normal	High
< 18.5 kg/m^2	34 (6.85)	0 (0.00)	33 (6.65)	1 (0.20)	1 (0.20)	33 (6.65)	23 (4.64)	11 (2.22)
18.5-23 kg/m^2	274 (55.24)	0 (0.00)	206 (41.53)	68 (13.71)	4 (0.81)	270 (54.44)	174 (35.08)	100 (20.16)
> 23 kg/m^2	134 (27.02)	54 (10.89)	15 (3.02)	173 (34.88)	0 (0.00)	188 (37.90)	83 (16.73)	105 (21.17)
$\chi 2$ - value	99.276**		232.254**		3.748		18.851**	

d.f. 2; * p<0.05; ** p< 0.001; Figures in the parentheses are percentage

Table 3.31: Prevalence of adiposity using BMI in combination with WC, WHtR, WHR, and CI among the female Limboo individuals

BMI	WC		WHtR		WHR		CI	
	Normal	High	Normal	High	Normal	High	Normal	High
< 18.5 kg/m2	37 (7.46)	4 (0.81)	30 (6.05)	11 (2.22)	7 (1.41)	34 (6.85)	8 (1.81)	33 (6.65)
18.5-23 kg/m2	144 (29.03)	76 (15.32)	55 (11.09)	165 (33.27)	13 (2.62)	207 (41.73)	21 (4.23)	199 (40.12)
> 23 kg/m2	22 (4.44)	213 (42.94)	3 (0.60)	232 (46.77)	3 (0.60)	232 (46.77)	11 (2.22)	224 (45.16)
χ2 - value	192.836**		137.909**		21.146**		11.527*	

d.f. 2; * p<0.05; ** p< 0.001; Figures in the parentheses are percentage

Further, participants were identified as simultaneously obese by BMI and each central obesity index such as WC, WHtR, WHR and CI separately. The combination of BMI and WC give the least number of simultaneously obese (10.89%) individuals among the male Limboo individuals of the present study. The male Limboo individuals were found affected higher in number by combined assessment of BMI with WHR 188 (37.90%), compared to combination with WHtR 173 (34.88%), and CI 105 (21.17%) among the males of the present study. Similarly, among female Limboo individuals cross combination of BMI with WHtR and with WHR identified the equal number of individual i.e. 232 (46.77%) at high risk of adiposity followed by CI 224 (45.16%) and WC 54 (10.89%).

The combined risk prevalence identified by BMI and a index of central adiposity was significant in case of WC (χ^2 – value 99.276; d.f.2; p< 0.001), WHtR (χ^2 – value 232.254; d.f.2; p< 0.001), CI (χ^2 – value 18.851; d.f.2; p< 0.001) and only in case WHR (χ^2 – value 3.748; d.f.2; p> 0.05) the prevalence was non-significant among male Limboo individuals. In contrast among female Limboo individuals of present study the prevalence of combined risk was significant in all cases such as WC (χ^2 – value 192.836; d.f.2; p< 0.001), WHtR (χ^2 – value 137.909; d.f.2; p< 0.001), WHR (χ^2 – value 21.146; d.f.2; $p < 0.001$), and CI (χ^2 – value 11.527; d.f.2; $p < 0.05$). The combined risk prevalence of adiposity among male and female Limboo individuals is presented in Figure 3.36 and 3.37, respectively.

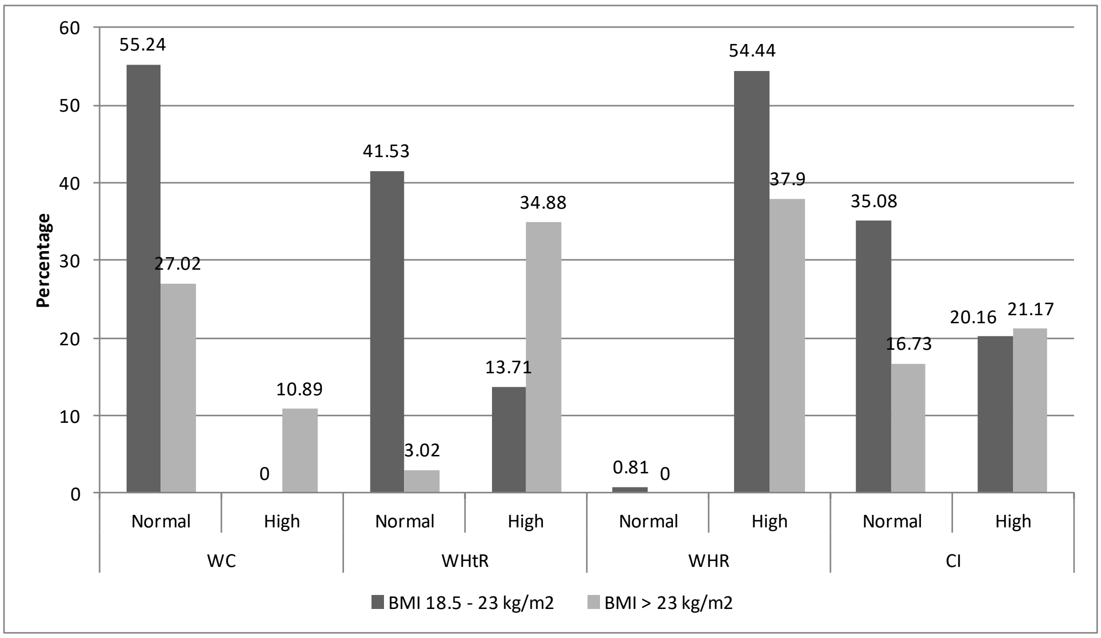

Figure 3.36: Prevalence of adiposity using BMI in combination with WC, WHtR, WHR, and CI among the male Limboo individuals.

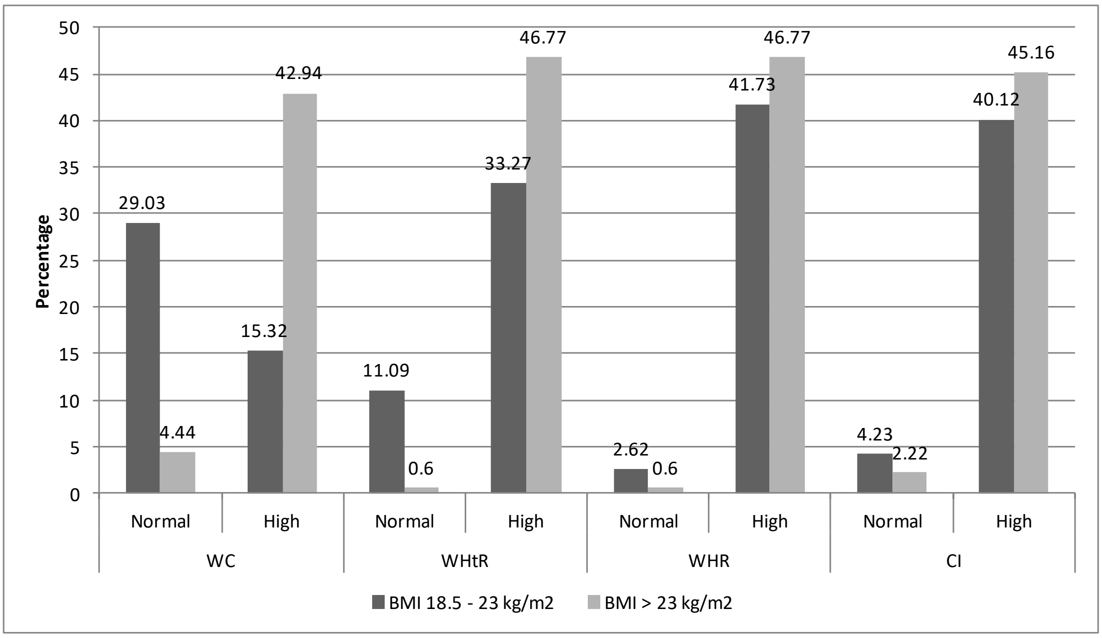

Figure 3.37: Prevalence of adiposity using BMI in combination with WC, WHtR, WHR, and CI among the female Limboo individuals.

3.3 BODY FAT AND FITNESS AMONG LIMBOO INDIVIDUALS.

3.3.1 PBF USING COMMONLY QUOTED 25/30 CRITERIA AMONG LIMBOO INDIVIDUALS.

Table 3.32 presents the distribution of PBF based on cut-offs of 25% for male and 30% for female cut-offs value. The overall prevalence of at risk Limboo individuals were 63 (6.35%) conversely a large number of individuals were below the level of risk related to adiposity. The sex wise prevalence of people at risk of adiposity related morbidity was 6 (1.21%) for male and 57 (11.49%) for female Limboo individuals of the present study. The $\chi 2$-test for the sex difference was found to be significant ($\chi 2$ = 44.085; d.f.1; p<0.01) in the prevalence of high PBF using 25% and 30% as cut-offs for male and female in the present study.

Table 3.32: Distribution of PBF based on 25% for male and 30% for female cut-offs among the Limboo individuals

Sex	N	Below	Above
Male	496	490 (98.79)	6 (1.21)
Female	496	439 (88.51)	57 (11.49)
Total	992	929 (93.65)	63 (6.35)

Figures in the parentheses are percentage

The age specific PBF classification is presented in Table 3.33. In the age group 18-29 years, 17 (7.87%) female Limboo individuals were at risk of higher adiposity compared to male 1 (0.53%) individuals. In the age group, 30-49 years, 4 (1.85%) male and 34 (16.59%) female Limboo individuals were at risk of higher adiposity. Similarly, in the age group, 50-64 years, 1 (1.10%) male and 6 (8.00%) female Limboo individuals were at the risk of higher adiposity. Across the age groups, the females were more at risk compared to males

The sex difference within age group such as 18-29 years ($\chi 2$ = 12.792; d.f.1; p< 0.01), 30-49 years ($\chi 2$ = 27.805; d.f.1; p< 0.01) and 50-64 years ($\chi 2$ = 4.848; d.f.1; p< 0.05) in the observed PBF were significant. Further prevalence across the age groups were found to be significant ($\chi 2$ = 8.812; d.f.1; p< 0.01). The distribution is also presented in Figure 3.38.

Table 3.33: Age and sex specific distribution of PBF using 25/30 cut-offs among the Limboo individuals

Age groups	Sex	N	Normal	High
18-29 years	Male	189	188 (99.47)	1 (0.53)
	Female	216	199 (92.13)	17 (7.87)
30-49 years	Male	216	212 (98.15)	4 (1.85)
	Female	205	171(83.41)	34 (16.59)
50-64 years	Male	91	90 (98.90)	1 (1.10)
	Female	75	69 (92.00)	6 (8.00)

Figures in the parentheses are percentage

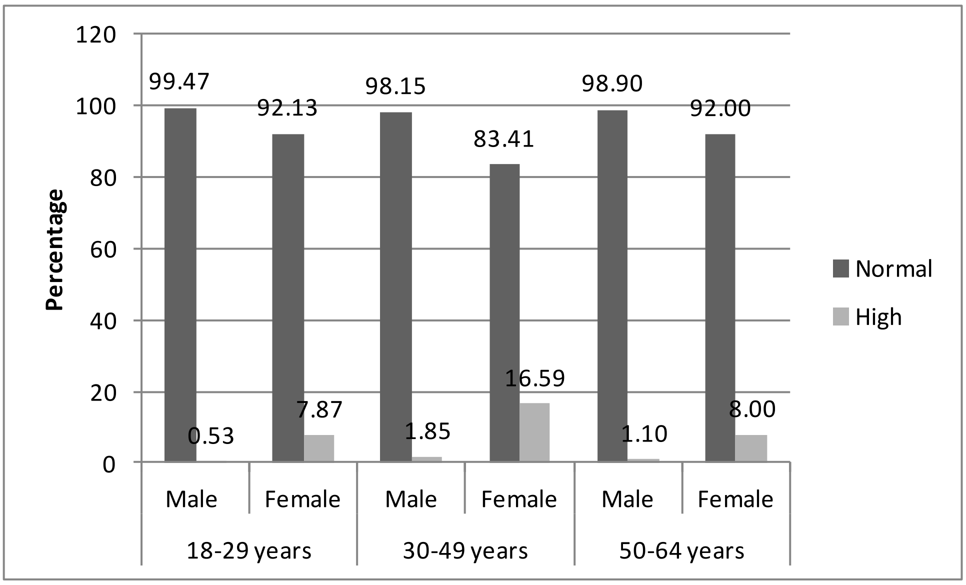

Figure 3.38: Age and sex specific distribution of PBF using 25/30 cut-offs among the Limboo individuals.

3.3.2 EVALUATION OF BODY FITNESS USING NIEMAN (1995) CLASSIFICATION.

The prevalence of adiposity related risk assessed using Nieman (1995) criteria for PBF among Limboo individuals is presented in Table 3.34. Overall 29.23% individuals were lean, followed by optimal fat (42.94%), fat (26.21%) and over fat (1.61%). Among male Limboo individuals prevalence of lean were 283 (57.06%) followed by optimal fat 203 (40.93%) and fat 10 (2.02%) individuals. Over fat, individuals were not found based on the criteria used in the present study. On the contrary, female Limboo individuals were more fat 250 (50.40%), followed by optimal fat 223 (44.96%), over fat 16 (3.23%) and lean 7 (1.41%). This is also presented in Figure 3.39. The sex difference in the occurrence of lean, fat and over fat individuals was significant except for optimal fat.

Table 3.34: Distribution of PBF using Nieman (1995) classification among the Limboo individuals

Sex	n	LEAN	OPTIMAL FAT	FAT	OVER FAT
Male	496	283 (57.06)	203 (40.93)	10 (2.02)	0 (0.00)
Female	496	7 (1.41)	223 (44.96)	250 (50.40)	16 (3.23)
Total	992	290 (29.23)	426 (42.94)	260 (26.21)	16 (1.61)

Figure in parentheses are percentage

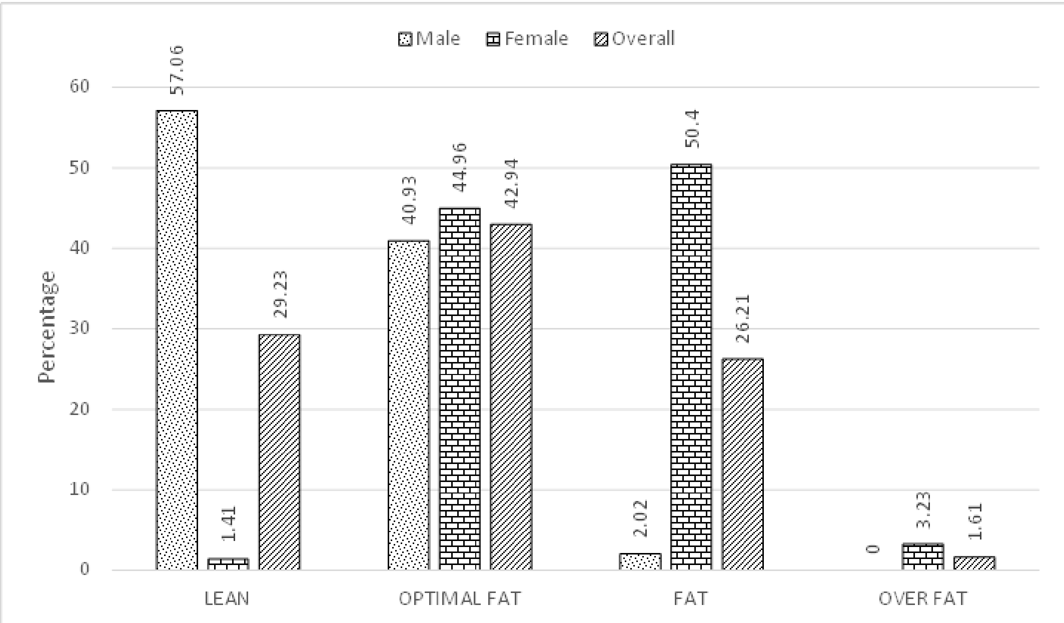

Figure 3.39: Distribution of body fitness using Nieman (1995) classification among the Limboo individuals.

Table 3.35: Age and sex specific distribution of PBF using Nieman (1995) classification among the Limboo individuals

Age group	Sex	n	Lean	Optimal fat	Fat	Over fat
18-29 years	Male	189	127 (67.20)	61 (32.28)	1 (0.53)	0 (0.00)
	Female	216	1 (0.46)	97 (44.91)	113 (52.31)	5 (2.31)
30-49 years	Male	216	98 (45.37)	111 (51.39)	7 (3.24)	0 (0.00)
	Female	205	3 (1.46)	78 (38.05)	116 (56.59)	8 (3.90)
50-64 years	Male	91	58 (63.74)	31 (34.07)	2 (2.20)	0 (0.00)
	Female	75	3 (4.00)	48 (64.00)	21 (28.00)	3 (4.00)

Figures in the parentheses are percentage

The age specific distribution of lean, optimal fat, fat, and over fat individuals according to Nieman (1995) is presented in Table 3.35. In the age group 18-29 years, lean male Limboo individuals were 127 (67.20%) and lean female Limboo individuals were 1 (0.46 %). The Limboo male individuals with optimal fat were 61 (32.280%) and Limboo female were 97 (44.91%). There were 1 (0.53%) fat male Limboo individuals and female Limboo individuals were 113 (52.31%). The over fat male Limboo individuals were 0 (0.00%) and female Limboo were 5 (2.31%). The sex difference in the occurrence of lean ($\chi 2$ = 207.66; d.f.1; p< 0.01), optimal fat ($\chi 2$ = 6.761; d.f.1; p< 0.01), fat ($\chi 2$ = 133.657; d.f.1; p< 0.01) and over fat ($\chi 2$ = 4.430; d.f.1; p< 0.05) were statistically significant within the age group.

In the age group 30-49 years, the lean male Limboo individuals were 98 (45.37%) and lean female Limboo individuals were 3 (1.46%). The male individuals with optimal fat were 111 (51.39%) and female individuals were 78 (38.05%). The fat male Limboo individuals were 7 (3.24%) and female individuals were 116 (56.59%). There were 0 (0.00%) over fat male individuals and 8 (3.90%) female individuals. The sex difference in the occurrence of lean ($\chi 2$ = 111.915; d.f.1; p< 0.01), optimal fat

($\chi 2$ = 7.556; d.f.1; p< 0.01), fat ($\chi 2$ = 144.727; d.f.1; p< 0.01) and over fat ($\chi 2$ = 8.593; d.f.1; p< 0.01) were statistically significant within the age group.

Further in the age group 50-64 years, lean male Limboo individuals were 58 (63.74%) and female Limboo individuals were 3 (4.00%). The Limboo optimal fat males were 31 (34.07%) and the females were 48 (64.00%). There were 2 (2.20%) and 21 (28.00%) male and female fat Limboo individuals respectively. Over fat male Limboo individuals were 0 (0.00%) and over fat females were 3 (4.00%) in this age group. The sex difference in the occurrence of lean ($\chi 2$ = 63.120; d.f.1; p< 0.01), optimal fat ($\chi 2$ = 14.771; d.f.1; p< 0.01), fat ($\chi 2$ = 22.933; d.f.1; p< 0.01) were statistically significant except for over fat ($\chi 2$ = 3.707; d.f.1; p> 0.05) within the age group.

The higher numbers of lean Limboo male individuals were observed compared to lean female Limboo individuals across the three study age group according to PBF criteria by Nieman (1995). The $\chi 2$ test for age group difference was significant ($\chi 2$ = 11.225; d.f.2; p< 0.01) among the observed lean individuals. In the optimal fat category, the female Limboo individuals were higher in number except for 30-49 years age group and the observed age group difference was not significant. Similarly more females were fat and over fat compared to males of the present study. However, the trend was statistically significant for only fat ($\chi 2$ = 15.855; d.f.2; p< 0.01) and not for over fat. The distribution is also presented in Figure 3.40.

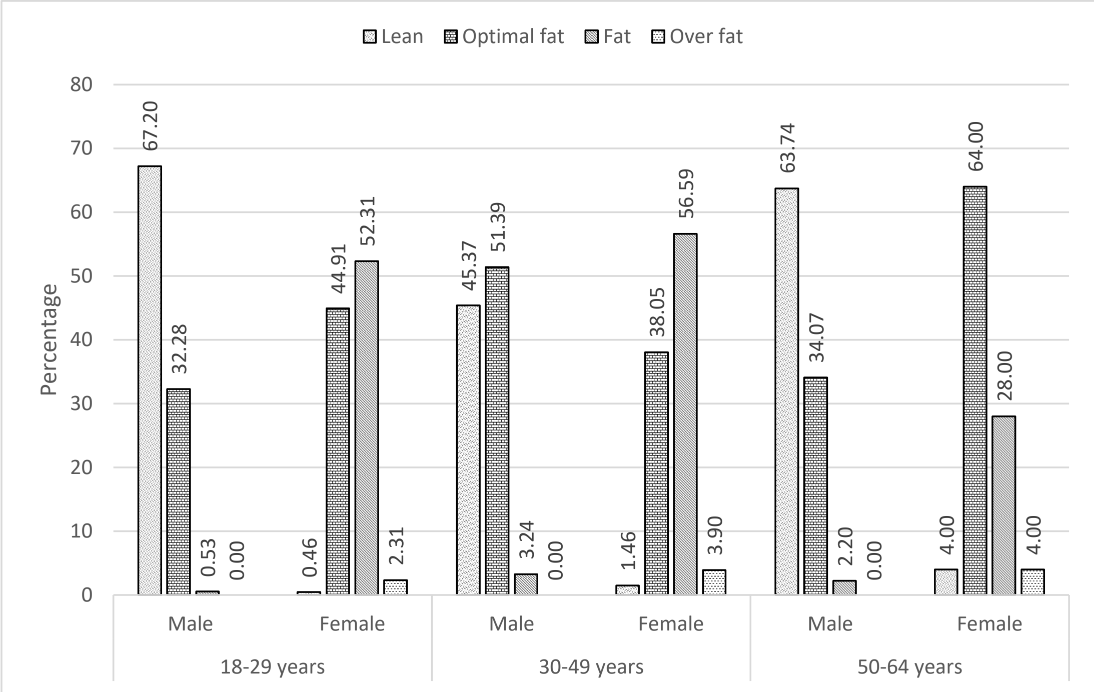

Figure 3.40: Age and sex specific distribution of PBF using Nieman (1995) classification among the Limboo individuals

3.3.3 EVALUATION OF BODY FITNESS USING MUTH (2009) CRITERIA.

Table 3.36 shows the distribution of PBF based on the criteria given by Muth (2009) among the Limboo male and female individuals. This system of classification has four categories as in the system given by Niemen (1995). In the present study more males were identified as underweight (6.45% vs. 1.61%) and more females were overweight (39.11% vs. 17.94%) and obese (4.84% vs. 1.21%) based on given PBF cut-offs (Muth, 2009). The difference between sexes among identified underweight individuals was statistically significant ($\chi 2$ = 15.34; d.f.1; $p < 0.01$). Similarly, difference between sex among the identified overweight ($\chi 2$ = 38.96; d.f.1; $p < 0.01$) and obese ($\chi 2$ = 10.80; d.f.1; $p < 0.01$) individuals were also statistically significant. The distribution according to Muth (2009) cut-offs is also presented in Figure 3.41.

Table 3.36: Distribution of PBF using Muth (2009) classification among the Limboo individuals

Sex	n	Normal	Underweight	Overweight/At risk	Obese/Morbid
Male	496	369 (74.40)	32 (6.45)	89 (17.94)	6 (1.21)
Female	496	270 (54.44)	8 (1.61)	194 (39.11)	24 (4.84)
Overall	992	639 (64.42)	40 (4.03)	283 (28.53)	30 (3.02)

Figures in the parentheses are percentage

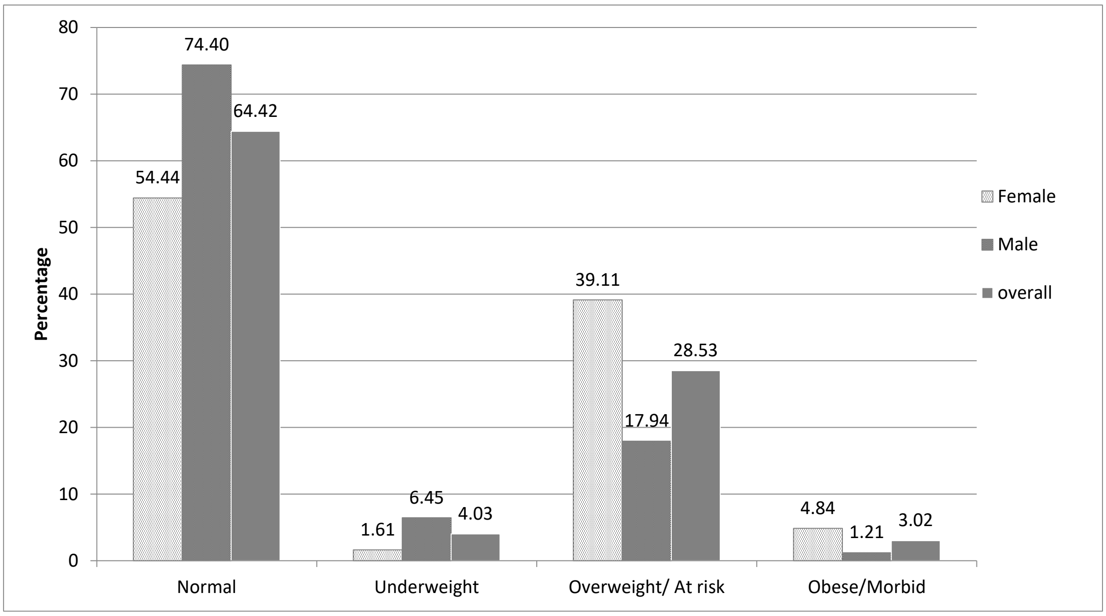

Figure 3.41: Distribution of PBF using Muth (2009) classification among Limboo individuals.

Table 3.37 presents the age group specific classification of Limboo male and female individuals according to the criteria of PBF by Muth (2009). In the age group, 18-29 years, more male Limboo individuals 10 (5.29%) were underweight compared to female Limboo individuals 1 (0.46%). On other hands, higher number of female Limboo individuals were identified as overweight (40.28%) and Obese (4.63%) compared to male Limboo individuals. The difference between sex among the identified underweight individuals were statistically significant ($\chi 2$ = 7.36; d.f.1; p< 0.01). The sex difference was also significant for overweight ($\chi 2$ = 37.24; d.f.1; p< 0.01) and obese ($\chi 2$ = 7.36; d.f.1; p< 0.01).

In the age group 30-49 years, the higher numbers of the Limboo male were lean compared to female Limboo individuals (6.48% vs. 1.46%). The overweight (45.37% vs. 25.46%) and obese (4.00% vs. 1.10%) female Limboo individuals were higher than the male Limboo individuals. The sex difference in the identification of underweight ($\chi2$ = 7.12; d.f.1; p< 0.01) and overweight ($\chi2$ = 9.76; d.f.1; p< 0.01) individuals were statistically significant. The sex difference in obese was not significant.

In the age group 50-64 years, underweight Limboo males were 8 (8.79%) and females were 4 (5.33%). As earlier the more females 14 (18.67%) were overweight than males 11 (12.09%) in the age group. The obese Limboo individuals were 3 (4.00%) females and 1 (1.10%) male. The sex difference in the identified underweight, overweight, and obese was not found significant in the age group 50-64 years. The prevalence of underweight given by Muth (2009) was observed higher among male individuals compared to females in both overall and age specific distributions. However, the overweight and obese individuals were observed higher among female Limboo individuals. The distribution is also presented in Figure 3.42.

Table 3.37: Age and sex specific distribution of PBF using Muth (2009) classification among the Limboo individuals

Age groups	Sex	n	Normal	Underweight	Overweight/ At risk	Obese/ Morbid
18-29 years	Male	189	155 (82.01)	10 (5.29)	23 (12.17)	1 (0.53)
	Female	216	118 (54.63)	1 (0.46)	87 (40.28)	10 (4.63)
30-49 years	Male	216	143 (66.20)	14 (6.48)	55 (25.46)	4 (1.85)
	Female	205	98 (47.80)	3 (1.46)	93 (45.37)	11 (5.37)
50-64 years	Male	91	71 (78.02)	8 (8.79)	11 (12.09)	1 (1.10)
	Female	75	54 (72.00)	4 (5.33)	14 (18.67)	3 (4.00)

Figures in the parentheses are percentage

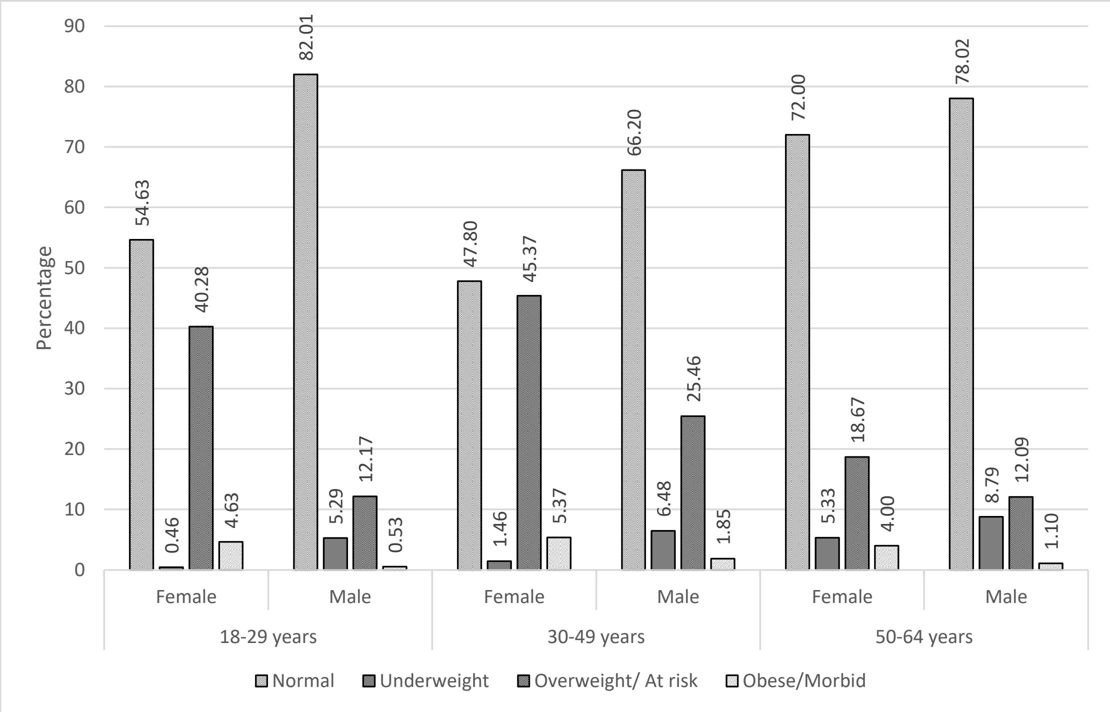

Figure 3.42: Age and sex specific distribution of PBF using Muth (2009) classification among the Limboo individuals.

3.3.4 EVALUATION OF COMPONENTS OF BODY COMPOSITION.

The distinguishing the components of body composition have the important implication on diseases and nutritional status assessment. The distribution of FMI and FFMI among the Limboo male and female individuals was conducted utilizing the cut-offs given by Khongsdier (2005) and Liu et al. (2013). According to Khongsdier (2005) cut-offs, 291 (58.67%) male individuals were identified with low FMI as the presented in Table 3.38. The high FFMI was observed among only 2 male individuals of the present study as presented in Table 3.38. The 2 individuals constituted 0.40% of male. Remaining individuals were identified as low FFMI and there were no individuals identified with normal FFMI.

Further, using sex specific cut-offs of FMI given by Liu et al. (2013), the Limboo female individuals (13.91%) were more at risk than Limboo male individuals (2.02%) in the present study (Table 3.39). The classification given using Liu et al.

(2013) is presented in Table 3.39. The sex difference using *χ2* was found significant (*χ2* = 47.87; d.f.1; p<0.001).

Table 3.38: Distributions of FMI and FFMI using Khongsdier (2005) classification among the male Limboo individuals

Index	n	Normal	Low	High
FMI	496	182 (36.69)	291 (58.67)	23 (4.64)
FFMI	496	0 (0.00)	494 (99.60)	2 (0.40)

Figures in the parentheses are percentage

Table 3.39: Distributions of FMI using Liu et al. (2013) classification among the Limboo individuals

Sex	n	Normal	At Risk
Male	496	486 (97.98)	10 (2.02)
Female	496	427 (86.09)	69 (13.91)
Overall	992	913 (92.04)	79 (7.96)

Figures in the parentheses are percentage

The age specific distribution of FMI observed using FMI cut-offs of Khongsdier (2005) is presented in Table 3.40. The FMI was observed high among the males of 30-49 years age group followed by 18-29 years age group and then 50-64 years age group. The prevalence of high FMI was 6.94% among 30-49 years age group male Limboo individuals. The high FMI was observed among 3.17% male Limboo individuals of 18-29 years and 2.20% male Limboo individuals of 50-64 years in the present study using cut-off given by Khongsdier (2005). In contrast, the prevalence of low FMI was observed more among males of 18-29 years (70.37%), followed by 50-64 years (64.84), and 30-49 years (45.83%) in the present study. As shown in Table 3.40 using cut-off given by Khongsdier (2005).

Similarly, age specific distribution of FMI using cut-offs given by Liu et al. (2013) is presented in Table 3.41. Using the cut-offs given by Liu et al. (2013) more male (3.24%) and female (20.98%) Limboo individuals of 30-49 years were observed at risk. The age 30-49 years were followed by 50-64 years (male: 2.20%; female: 10.67%) and then 18-29 years (male: 0.53%; female: 8.33%) according to high FMI or perceived risk (Table 3.41). However, the across age group females were more at risk than males. The obtained χ^2 results for age groups 18-29 years (χ^2 = 13.73; d.f.1; p< 0.001), 30-49 years (χ^2 = 31.61; d.f.1; p< 0.001), and 50-64 years (χ^2 = 5.21; d.f.1; p< 0.05) were statistically significant for the prevalence of high FMI using Liu et al. (2013) cut-offs.

Table 3.40: Age specific distribution of FMI using Khongsdier (2005) classification among male Limboo individuals

Age groups	Sex	N	Normal	Low	High
18-29 years	Male	189	50 (26.46)	133 (70.37)	6 (3.17)
30-49 years	Male	216	102(47.22)	99 (45.83)	15 (6.94)
50-64 years	Male	91	30 (32.97)	59 (64.84)	2 (2.20)

Figures in the parentheses are percentage

Table 3.41: Age and sex specific distributions of FMI using Liu et al. (2013) classification among the Limboo individuals

Age groups	Sex	N	Normal	At Risk
18-29 years	Male	189	188 (99.47)	1 (0.53)
	Female	216	198 (91.67)	18 (8.33)
30-49 years	Male	216	209 (96.76)	7 (3.24)
	Female	205	162 (79.02)	43 (20.98)
50-64 years	Male	91	89 (97.80)	2 (2.20)
	Female	75	67 (89.33)	8 (10.67)

Figures in the parentheses are percentage

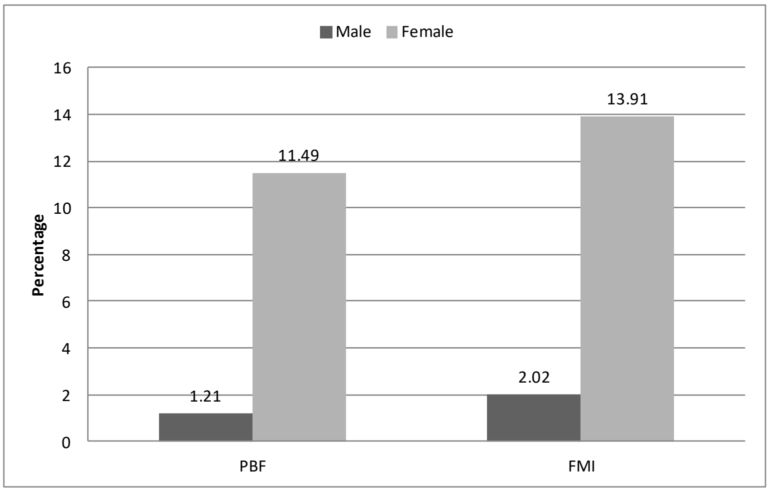

Figure 3.43: Comparison of the prevalence of the PBF and FMI related risk among the Limboo individuals

3.4 DETERMINANTS OF UNDERWEIGHT, OVERWEIGHT AND OBESITY AMONG LIMBOO INDIVIDUALS

The following analyses were an effort to show association of various demographic, socio-economic and life style determinants of underweight, overweight, and obesity among Limboo individuals of the present study. Further, analyses were made to identify possible factors among the different variables using logistic regression.

3.4.1 ASSOCIATION OF DEMOGRAPHIC, SOCIO-ECONOMIC, AND LIFE STYLE VARIABLES WITH OVERWEIGHT AND HIGH REGIONAL ADIPOSITY AMONG LIMBOO INDIVIDUALS.

The χ^2 test was conducted to understand the association of various demographic, socio-economic, and life style variables with the general adiposity defined using BMI above 25 kg/m^2 and regional adiposity defined using WC, WHtR, and WHR separately among male and female individuals of the present study. The results are discussed below in details.

3.4.1.1 Association of demographic, socio-economic, and life style variables with high BMI (≥ 25 kg/m^2) among male and female Limboo individuals.

Among the male Limboo individuals of the present study the prevalence of high BMI (≥ 25kg/m^2) was observe among the age group 30 – 49 years (12.30%), followed by 18 - 29 years (4.23%) and then 50 – 64 years (3.43%). Further, 86 (17.34%) married men and 55 (11.09%) men involved in the manual occupation were found to be associated with high BMI (≥ 25 kg/m^2). The educational attainments of male individuals were not found associated with high BMI (≥ 25 kg/m^2), however, monthly income, SES, and house type were found associated significantly. The monthly income of ≥ ₹10000/= consists of 13.10% male Limboo individuals followed by the monthly income of ₹5000/= - ₹9999/= (4.84%) and ₹4999/= (2.02%). The male individuals falling under the lower middle SES group of Kuppuswamy scale were 6.05% followed by upper middle (8.27%) and upper lower (5.65%). The dwelling like semi-pakka house showed 10.69% individuals with high BMI (≥ 25 kg/m^2) followed by kacha (3.43%) and pakka (3.43%) house type. The remaining variables like family size, land holding, house type, portable water, and toilet were not found associated with high BMI (≥ 25 kg/m^2). The χ^2 value is presented in Table 3.42a.

Association of high BMI (≥ 25 kg/m^2) with different demographic, socio-economic, and life style variables was same as that of male with one exception i.e. the educational attainments of female individuals were found associated significantly and monthly income was found associated non-significantly. The female Limboo individuals with high BMI (≥ 25 kg/m^2) were observed high among the individuals of age group 30 - 49 years (17.74%) followed by 18 – 29 years (7.46%) and 50 – 64 years (5.04%). The 132 (26.61%) married female individuals were more affected by high BMI (≥ 25 kg/m^2) than 18 (3.63%) unmarried individuals. As in the case of male Limboo individuals the female Limboo individuals involved in manual occupations (23.79%) were found highly associated with increased BMI (≥ 25 kg/m^2) followed by non-manual (5.24%) and others (1.21%). Trend noted in SES showed more individuals falling under the upper lower (14.11%) category followed by lower middle (8.25%) and upper middle (7.86%). The remaining variables like family size, land holding, house type, portable water, and hygienic toilet were not found associated with high BMI (≥ 25 kg/m^2) among Limboo females of present study. The respective χ^2 value is presented in Table 3.42b.

3.4.1.2 Association of demographic, socio-economic, and life style variables with high BMI (≥ 23 kg/m^2) among male and female Limboo individuals.

The variables like age, marital status, occupation, SES, family size, and house type were found significantly associated with high BMI (≥ 23 kg/m^2) among the male Limboo individuals of the present study. The distribution of high BMI (≥ 23 kg/m^2) was comparatively high among the individuals 30-49 years (21.98%) followed by 18-29 years (8.47%) and 50-64 years (7.46%). Again the married (31.85%) individuals were more exposed to adiposity inducing environment compared to unmarried (6.05%) male individuals. Among male individuals occupation involving manual labour seems more prone to high BMI 23 kg/m^2 as criteria. Male individuals falling under the upper lower (14.52%) category of kuppuswamy scale were more susceptible to high BMI (≥ 23 kg/m^2) followed by lower middle (12.90%) and then upper middle (10.48%). People living in large family (27.42%) were more prone to high BMI (≥ 23 kg/m^2). The male individuals dwelling Semi-Pakka house type were observed with high BMI (23 kg/m^2) followed by Pakka house type (8.87%) and Kacha house type (8.67%). The values are presented in Table 3.43a.

Among female Limboo individuals the variables like age marital status, occupation, and SES were found significant as in the case of male Limboo individuals. However, drinking water was observed associated significantly with high BMI ($\geq$ 23 kg/m^2) instead of variables like family size and house type. The distribution and trend noted for age group of individuals with high BMI ($\geq$ 23 kg/m^2) were similar to that of male Limboo individuals (30-49 years > 18-29 years > 50-64 years). The married individuals with high BMI were 199 (40.12%). The 184 (37.10%) female individuals involved in manual labour were observed with high BMI ($\geq$ 23 kg/m^2) followed by 33 (6.65%) non-manual and 18 (3.63%) other occupations. Individuals falling under the upper lower (23.19%) SES were more prone to high BMI ($\geq$ 23 kg/m^2) followed by lower middle (14.31%), and upper middle (9.88%). Lastly the individuals of house hold with drinking water piped from spring (28.43%) were more affected by high BMI then with government supply (18.97%) drinking water. For details refer Table 3.43b.

3.4.1.3 Association of demographic, socio-economic, and life style variables with high WC (female: > 80 cm; male: > 90 cm) related risk among male and female Limboo individuals.

The index of central adiposity, WC was observed significantly ($p<0.001$ and $p<0.05$) associated with age groups distribution, marital status, occupation, monthly income, SES, and house type (Table 3.44a). The male individuals with high WC were observed high in the age group 30 – 49 year (5.65%), followed by 50 – 64 years (3.02%) and 18 – 29 years (2.22%). The 51 (10.28%) married individuals, 29 (5.85%) individual with manual occupations, and 39 (7.86%) individuals of monthly income above ₹10000/= were observed to be associated with high central adiposity given by WC. Other variables like SES and house type were also found to be associated with

WC related adiposity. Such as semi-pakka house type (6.45%) and upper middle (4.44%) SES groups were observed with high percentage of individuals with WC related adiposity. The respective χ^2 value is given in Table 3.56a. The remaining variable like years of schooling, family size, land holding, drinking water facility, and toilet facility were not found associated with high WC (> 90 cm) among the male Limboo individuals of the present study.

Further, WC was observed significantly associated with age groups, marital status, occupation type, and SES among the female Limboo individuals of the present study. Unlike that of males 30 – 49 years age group (29.64%) were at higher risk followed by 18 – 29 years age group (20.36%) and 50 – 64 years age group (9.07%). Other variables like being married and involved in manual occupation were found to associate with high WC (≥ 80 cm) among female Limboos with 243 (48.99%) and 225 (45.36%) individuals respectively. A large percentage of females were found with high WC in the upper lower (30.44%) category of SES followed by lower middle (16.53%), and upper middle (12.10%). The association of remaining variables were not found significant and the χ^2 results are presented in Table 3.44b.

3.4.1.4 Association of demographic, socio-economic, and life style variables with high WHtR (> 0.05) related risk among male and female Limboo individuals.

The variables associated with high WHtR (> 0.05) among male Limboo individuals of the present study were age groups, marital status, occupation type, SES, house type, and toilet type. These variables were associated significantly with high WHtR (> 0.05). According to age groups distribution high numbers of individuals with high WHtR (> 0.05) were found among males of 30 – 49 years (26.61%) age group followed by 50 – 64 years (11.69%) and 18 – 29 years (10.48%). Once again

204 (41.13%) married male individuals were observed with high WHtR, 154 (31.05%) individuals involved in manual occupation were observed with high WHtR in the present study. The distributions of male Limboo individuals were observed high in the upper lower (20.77%) category of SES followed by lower middle (16.33%) and upper middle (31.05%). Similarly, male individual residing in semi-pakka (26.41%) house were at higher risk of high WHtR (≥ 0.05) followed by kacha (11.96%), and pakka (10.69%). The male Limboo individuals of house hold with commode toilets (44.35%) were found to be associated with high WHtR (≥ 0.05). The χ2 test results and other non-significantly associated variables for males are presented in Table 3.45a. In contrast to male Limboo individuals only age groups distribution and marital status were found associated with high WHtR (> 0.05) among females. The females of age group 30 – 49 years (37.30%) were observed with high incidence of high WHtR (> 0.05) followed by 18 – 29 years (32.26%) and 50 – 64 years (12.70%). The results of χ^2 test and distribution of other remaining variables are shown in Table 3.45b.

3.4.1.5 Association of demographic, socio-economic, and life style variables with high WHR (males: > 0.9; females: > 0.8) related risk among male and female Limboo individuals.

Among the male Limboo individuals of the present study high distribution of WHR related central adiposity was observed in age group 30 – 49 years (28.43%) followed by 18 – 29 years (14.92%) and 50 – 64 years (13.10%). Like in the previous indices the married (45.77%) individual were once again found associated with high adiposity related to WHR. The distribution of individuals with high WHR was observed with manual occupations (37.30%) followed by non-manual (15.12%) and others (4.03%) types of occupations. The remaining variables were not found associated significantly with high WHR among the male Limboo individuals of the presents study. The results of χ^2 test are presented in Table 3.46a. However among the female Limboo individuals of the present study none of the demographic, socio-economic, and life style variables were found associated significantly. The results are presented in Table 3.46b.

Table 3.42a: Association of demographic, socio-economic and life style variables with overweight among the male Limboo individuals

Variables	Categories	BMI < 25 kg/m^2	BMI > 25 kg/m^2	χ^2 – value
Age group	18-29 years	168 (33.87)	21 (4.23)	18.63; d.f.2; p<0.001
	30-49 years	155 (31.25)	61 (12.30)	
	50-64 years	74 (14.92)	17 (3.43)	
Marital status	Unmarried	122 (24.60)	13 (2.62)	12.39; d.f.1; p<0.001
	Married	275 (55.44)	86 (17.34)	
Education	Illiterate	59 (11.90)	11 (2.22)	3.43; d.f. 2; P>0.05
	Upto 8th grade	189 (38.10)	41 (8.27)	
	≥ 9th grade	149 (30.04)	47 (9.48)	
Occupation	Manual	276 (55.65)	55 (11.09)	40.10; d.f. 2 p<0.001
	Non-manual	62 (12.50)	42 (8.47)	
	Others	59 (96.72)	2 (0.40)	
Income	≤ ₹4999	48 (9.68)	10 (2.02)	9.23; d.f.2; p<0.01
	₹5000 – ₹9999	157 (31.65)	24 (4.84)	
	≥ ₹10000	192 (38.71)	65 (13.10)	
Kuppuswamy SES	Upper Middle (UM)	59 (11.90)	30 (6.05)	24.59; d.f.2; p<0.001
	Lower Middle (LM)	121 (24.40)	41 (8.27)	
	Upper Lower (UL)	217 (88.57)	28 (5.65)	
Family size	Small	137 (27.62)	30 (6.05)	0.62; d.f.1; p>0.05
	Large	260 (52.42)	69 (13.91)	
Land holding	0 – 0.99 acre	118 (23.79)	21 (4.23)	2.85; d.f. 1; p>0.05
	≥ 1 acre	279 (56.25)	78 (15.73)	
House type	Kacha	121 (24.40)	17 (3.43)	15.76;d.f. 2; p<0.001
	Semi-pakka	220 (44.35)	53 (10.69)	
	Pakka	56 (11.29)	17 (3.43)	
Drinking water	Supply	241 (48.59)	64 (12.90)	0.52; d.f.1; p>0.05
	Piped from spring	156 (31.45)	35 (7.06)	
Toilet	Pit	55 (11.09)	9 (1.81)	1.60;d.f.1; p>0.05
	Commode	342 (68.95)	90 (18.15)	

Figures in the parentheses are percentage

Table 3.42b: Association of demographic, socio-economic and life style variables with overweight among the female Limboo individuals

Variables	Categories	BMI < 25 kg/m^2	BMI > 25 kg/m^2	χ^2 – value
Age group	18-29 years	179 (36.09)	37 (7.46)	33.58; d.f.2; p<0.001
	30-49 years	117 (23.59)	88 (17.74)	
	50-64 years	50 (10.08)	25 (5.04)	
Marital status	Unmarried	94 (18.95)	18 (3.63)	13.77; d.f.1; p<0.001
	Married	252 (50.81)	132 (26.61)	
Education	Illiterate	114 (22.98)	61 (12.30)	6.03; d.f. 2; P<0.05
	Upto 8th grade	106 (21.37)	51 (10.28)	
	≥ 9th grade	126 (25.40)	38 (7.66)	
Occupation	Manual	263 (53.02)	118 (23.79)	21.42; d.f. 2 p<0.001
	Non-manual	27 (50.94)	26 (5.24)	
	Others	56 (11.29)	6 (1.21)	
Income	≤ ₹4999	43 (8.67)	13 (2.62)	14.12; d.f.2; p>0.001
	₹5000 – ₹9999	152 (30.65)	44 (8.87)	
	≥ ₹10000	151 (30.44)	93 (18.75)	
Kuppuswamy SES	Upper Middle (UM)	43 (8.67)	39 (7.86)	14.58; d.f.1; p<0.001
	Lower Middle (LM)	99 (19.96)	41 (8.25)	
	Upper Lower (UL)	204 (41.13)	70 (14.11)	
Family size	Small	112 (22.58)	54 (10.89)	0.62; d.f.1; p>0.05
	Large	234 (47.18)	96 (19.35)	
Land holding	0 – 0.99 acre	130 (26.21)	57 (11.49)	0.01; d.f. 1; p>0.05
	≥ 1 acre	216 (43.55)	93 (18.75)	
House type	Kacha	96 (19.35)	28 (5.65)	4.60; d.f. 2; p>0.05
	Semi-pakka	184 (37.30)	90 (18.15)	
	Pakka	66 (13.31)	32 (6.45)	
Drinking water	Supply	185 (67.52)	89 (17.94)	1.45; d.f.1; p>0.05
	Piped from spring	161 (32.46)	61 (12.30)	
Toilet	Pit	55 (11.09)	15 (3.02)	3.0; d.f.1; p>0.05
	Commode	291 (58.67)	135 (27.22)	

Figures in the parentheses are percentage

Table 3.43a: Association of demographic, socio-economic and life style variables with overweight based on BMI >23 kg/m^2 among the male Limboo individuals

Variables	Categories	BMI < 23 kg/m^2	BMI > 23 kg/m^2	χ^2 – value
Age group	18-29 years	147 (29.64)	42 (8.47)	34.52; d.f.2; p<0.001
	30-49 years	107 (21.57)	109 (21.98)	
	50-64 years	54 (10.89)	37 (7.46)	
Marital status	Unmarried	105 (21.17)	30 (6.05)	19.38; d.f.1; p<0.001
	Married	203 (40.93)	158 (31.85)	
Education	Illiterate	113 (22.78)	83 (16.73)	2.90; d.f.2; P>0.05
	Upto 8th grade	151 (30.44)	79 (15.93)	
	≥ 9th grade	44 (8.87)	26 (5.24)	
Occupation	Manual	216 (43.55)	115 (23.19)	36.11; d.f. 2 p<0.001
	Non-manual	41 (8.27)	63 (12.70)	
	Others	51 (10.28)	10 (2.02)	
Income	≤ ₹4999	40 (8.06)	18 (3.63)	7.32; d.f.2; p>0.05
	₹5000 – ₹9999	123 (24.80)	58 (11.69)	
	≥ ₹10000	145 (29.23)	112 (22.58)	
Kuppuswamy SES	Upper Middle (UM)	37 (7.46)	52 (10.48)	23.65; d.f.2; p<0.001
	Lower Middle (LM)	98 (19.76)	64 (12.90)	
	Upper Lower (UL)	173 (34.88)	72 (14.52)	
Family size	Small	115 (23.19)	52 (10.48)	4.90; d.f.1; p<0.05
	Large	193 (38.91)	136 (27.42)	
Land holding	0 – 0.99 acre	94 (18.95)	45 (9.07)	2.51; d.f. 1; p>0.05
	≥ 1 acre	214 (43.15)	143 (28.83)	
House type	Kacha	95 (19.15)	43 (8.67)	9.70; d.f. 2; p<0.05
	Semi-pakka	172 (34.68)	101 (20.36)	
	Pakka	41 (8.27)	44 (8.87)	
Drinking water	Supply	185 (37.30)	120 (24.19)	2.98; d.f.1; p>0.05
	Piped from spring	123 (24.80)	68 (13.71)	
Toilet	Pit	46 (9.27)	18 (3.63)	3.0; d.f.1; p>0.05
	Commode	262 (52.82)	170 (34.27)	

Figures in the parentheses are percentage

Table 3.43b: Association of demographic, socio-economic and life style variables with overweight based on 23kg/m^2 among the female Limboo individuals

Variables	Categories	BMI < 23 kg/m^2	BMI > 23 kg/m^2	χ^2 – value
Age group	18-29 years	141 (28.43)	75 (15.12)	28.02; d.f.2; p<0.001
	30-49 years	81 (16.33)	124 (25.00)	
	50-64 years	39 (7.86)	36 (7.26)	
Marital status	Unmarried	76 (15.32)	36 (7.26)	13.47; d.f.1; p<0.001
	Married	185 (37.30)	199 (40.12)	
Education	Illiterate	94 (18.95)	70(14.11)	2.17; d.f. 2; P>0.05
	Upto 8th grade	79 (15.93)	78 (15.73)	
	≥ 9th grade	88 (17.74)	87 (17.54)	
Occupation	Manual	197 (39.72)	184 (37.10)	13.21; d.f. 2 p<0.001
	Non-manual	20 (4.03)	33 (6.65)	
	Others	44 (8.87)	18 (3.63)	
Income	≤ ₹4999	34 (6.85)	22 (4.44)	6.03; d.f.2; p>0.05
	₹5000 – ₹9999	112 (22.58)	84 (16.94)	
	≥ ₹10000	115 (23.19)	129 (26.01)	
Kuppuswamy SES	Upper Middle (UM)	33 (6.85)	49 (9.88)	8.88; d.f.2; p<0.05
	Lower Middle (LM)	69 (13.91)	71 (14.31)	
	Upper Lower (UL)	159 (32.06)	115 (23. 19)	
Family size	Small	85 (17.14)	81 (16.33)	0.20; d.f.1; p>0.05
	Large	176 (35.48)	154 (31.05)	
Land holding	0 – 0.99 acre	97 (19.56)	90 (18.15)	0.07; d.f. 1; p>0.05
	≥ 1 acre	164 (33.06)	145 (29.23)	
House type	Kacha	72 (14.52)	52 (10.48)	3.24; d.f. 2; p>0.05
	Semi-pakka	144 (29.03)	130 (26.21)	
	Pakka	45 (9.07)	53 (10.69	
Drinking water	Supply	128 (25.81)	94 (18.97)	4.10; d.f.1; p<0.05
	Piped from spring	133 (26.81)	141(28.43)	
Toilet	Pit	38 (7.66)	32 (6.45)	0.91; d.f.1; p>0.05
	Commode	223 (44.96)	203 (40.93)	

Figures in the parentheses are percentage

Table 3.44a: Association of demographic, socio-economic and life style variables with WC related risk among the male Limboo individuals

Variables	Categories	WC< 90 cm	WC >90 cm	χ^2 – value
Age group	18-29 years	178 (35.89)	11 (2.22)	8.90; d.f.2; p<0.05
	30-49 years	188 (37.90)	28 (5.65)	
	50-64 years	76 (15.32)	15 (3.02)	
Marital status	Unmarried	132 (26.61)	3 (0.60)	14.35; d.f.1; p<0.001
	Married	310 (62.50)	51 (10.28)	
Education	Illiterate	62 (12.50)	8 (1.61)	0.80; d.f.2; P>0.05
	Upto 8th grade	208 (41.94)	22 (4.44)	
	≥ 9th grade	172 (34.68)	24 (4.84)	
Occupation	Manual	302 (60.89)	29 (5.85)	27.54; d.f.2 p<0.001
	Non-manual	79 (15.93)	25 (5.04)	
	Others	61 (12.30)	0 (0.00)	
Income	≤ ₹4999	56 (11.29)	2 (0.40)	10.74; d.f.2; p<0.01
	₹5000 – ₹9999	168 (33.87)	13 (2.62)	
	≥ ₹10000	218 (43.95)	39 (7.86)	
Kuppuswamy SES	Upper Middle (UM)	67 (13.51)	22 (4.44)	23.31; d.f.1; p<0.001
	Lower Middle (LM)	145 (29.23)	17 (3.43)	
	Upper Lower (UL)	230 (46.37)	15 (3.02)	
Family size	Small	151 (30.44)	16 (3.23)	0.44; d.f.1; p>0.05
	Large	291 (58.67)	38 (7.66)	
Land holding	0 – 0.99 acre	128 (25.81)	11 (2.22)	1.76; d.f.1; p>0.05
	≥ 1 acre	314 (63.31)	43 (8.67)	
House type	Kacha	132 (26.61)	6 (1.21)	11.80; d.f.2; p<0.01
	Semi-pakka	241 (48.59)	32 (6.45)	
	Pakka	69 (13.91)	16 (3.23)	
Drinking water	Supply	270 (54.44)	35 (7.06)	0.28; d.f.1; p>0.05
	Piped from spring	172 (34.68)	19 (3.83)	
Toilet	Pit	59 (11.90)	5 (1.01)	0.71; d.f.1; p>0.05
	Commode	383 (77.22)	49 (9.88)	

Figures in the parentheses are percentage

Table 3.44b: Association of demographic, socio-economic and life style variables with WC related risk among the female Limboo individuals

Variables	Categories	WC< 80 cm	WC >80 cm	χ^2 – value
Age group	18-29 years	115 (23.19)	101 (20.36)	χ^2 – value - 27.11; d.f.2; p<0.001
	30-49 years	58 (11.69)	147 (29.64)	
	50-64 years	30 (6.05)	45 (9.07)	
Marital status	Unmarried	62 (12.50)	50 (10.8)	χ^2 – value - 12.45; d.f.1; p<0.001
	Married	141 (28.43)	243 (48.99)	
Education	Illiterate	68 (13.71)	107 (21.57)	χ^2 – value - 3.80; d.f.2; P>0.05
	Upto 8th grade	58 (11.69)	99 (19.96)	
	≥ 9th grade	77 (15.52)	87 (17.54)	
Occupation	Manual	156 (31.45)	225 (45.36)	6.42; d.f.2 p<0.05
	Non-manual	15 (3.02)	38 (7.66)	
	Others	32 (6.45)	30 (6.05)	
Income	≤ ₹4999	28 (5.65)	28 (5.65)	3.54; d.f.2; p>0.05
	₹5000 – ₹9999	84 (16.94)	112 (22.58)	
	≥ ₹10000	91 (18.35)	153 (30.85)	
Kuppuswamy SES	Upper Middle (UM)	22 (4.44)	60 (12.10)	8.53; d.f.2; p<0.05
	Lower Middle (LM)	58 (11.69)	82 (16.53)	
	Upper Lower (UL)	123 (24.80)	151 (30.44)	
Family size	Small	76 (15.32)	90 (18.15)	2.43; d.f.1; p>0.05
	Large	127 (25.60)	203 (40.93)	
Land holding	0 – 0.99 acre	80 (16.13)	107 (21.57)	0.43; d.f. 1; p>0.05
	≥ 1 acre	123 (24.80)	186 (37.50)	
House type	Kacha	60 (12.10)	64 (12.90)	4.22; d.f. 2; p>0.05
	Semi-pakka	108 (21.77)	166 (33.47)	
	Pakka	35 (7.06)	63 (12.70)	
Drinking water	Supply	115 (23.19)	159 (32.06)	0.27; d.f.1; p>0.05
	Piped from spring	88 (17.74)	134 (27.02)	
Toilet	Pit	32 (6.45)	38 (7.66)	0.77; d.f.1; p>0.05
	Commode	171 (34.48)	293 (59.07)	

Figures in the parentheses are percentage

Table 3.45a: Association of demographic, socio-economic and life style variables with WHtR related risk among the male Limboo individuals

Variables	Categories	WHtR< 0.5	WHtR > 0.5	χ^2 – value
Age group	18-29 years	137 (27.62)	52 (10.48)	55.50; d.f.2; p<0.001
	30-49 years	84 (16.94)	132 (26.61)	
	50-64 years	33 (6.65)	58 (11.69)	
Marital status	Unmarried	97 (19.56)	38 (7.66)	31.63; d.f.1; p<0.001
	Married	157 (31.65)	204 (41.13)	
Education	Illiterate	31 (6.25)	39 (7.86)	1.66; d.f.2; P>0.05
	Upto 8th grade	122 (24.60)	108 (21.77)	
	≥ 9th grade	101 (20.36)	95 (19.15)	
Occupation	Manual	177 (35.69)	154 (31.05)	34.04; d.f.2 p<0.001
	Non-manual	31 (6.25)	73 (14.72)	
	Others	46 (9.27)	15 (3.02)	
Income	≤ ₹4999	28 (5.65)	30 (6.05)	5.30; d.f.2; p>0.05
	₹5000 – ₹9999	105 (21.17)	76 (15.32)	
	≥ ₹10000	121 (24.40)	136 (27.42)	
Kuppuswamy SES	Upper Middle (UM)	31 (6.25)	58 (11.69)	14.12; d.f.2; p<0.001
	Lower Middle (LM)	81 (16.33)	81 (16.33)	
	Upper Lower (UL)	142 (28.63)	103 (20.77)	
Family size	Small	89 (17.94)	78 (15.73)	0.44; d.f.1; p>0.05
	Large	165 (33.27)	164 (33.06)	
Land holding	0 – 0.99 acre	73 (14.72)	66 (13.31)	0.13; d.f. 1; p>0.05
	≥ 1 acre	181 (36,49)	176 (35.48)	
House type	Kacha	80 (16.13)	58 (11.69)	8.85; d.f. 2; p<0.05
	Semi-pakka	142 (28.63)	131 (26.41)	
	Pakka	32 (6.45)	53 (10.69)	
Drinking water	Supply	154 (31.05)	151 (30.44)	0.16; d.f.1; p>0.05
	Piped from spring	100 (20.16)	91 (18.35)	
Toilet	Pit	42 (8.47)	22 (4.44)	6.11; d.f.1; p<0.05
	Commode	212 (42.74)	220 (44.35)	

Figures in the parentheses are percentage

Table 3.45b: Association of demographic, socio-economic and life style variables with WHtR related risk among the female Limboo individuals

Variables	Categories	WHtR< 0.5	WHtR > 0.5	χ^2 – value
Age group	18-29 years	56 (11.29)	160 (32.26)	19.02; d.f.2; p<0.001
	30-49 years	20 (4.03)	185 (37.30)	
	50-64 years	12 (2.42)	63 (12.70)	
Marital status	Unmarried	27 (5.44)	85 (17,14)	4.02; d.f.1; p<0.05
	Married	61 (12.30)	323 (65.12)	
Education	Illiterate	29 (5.85)	146 (29.44)	2.26; d.f. 2; P>0.05
	Upto 8th grade	24 (4.84)	133 (26.81)	
	≥ 9th grade	35 (7.06)	129 (26.01)	
Occupation	Manual	66 (13.31)	315 (63.51)	1.30; d.f. 2 p>0.05
	Non-manual	8 (1.61)	45 (9.07)	
	Others	14 (2.82)	48 (9.68)	
Income	≤ ₹4999	8 (1.61)	48 (9.68)	0.87; d.f.2; p>0.05
	₹5000 – ₹9999	38 (7.66)	158 (31.85)	
	≥ ₹10000	42 (8.47)	202 (40.73)	
Kuppuswamy SES	Upper Middle (UM)	12 (2.42)	70 (14.11)	1.45; d.f.2; p>0.05
	Lower Middle (LM)	29 (5.85)	111 (22.38)	
	Upper Lower (UL)	47 (9.48)	227 (45.77)	
Family size	Small	27 (5.44)	139 (28.02)	0.34; d.f.1; p>0.05
	Large	61 (12.30)	269 (52.23)	
Land holding	0 – 0.99 acre	35 (7.06)	152 (3.65)	0.20; d.f. 1; p>0.05
	≥ 1 acre	53 (10.69)	256 (51.61)	
House type	Kacha	24 (4.84)	100 (20.16)	0.62; d.f. 2; p>0.05
	Semi-pakka	49 (9.88)	225 (45.36)	
	Pakka	15 (3.02)	83 (16.73)	
Drinking water	Supply	50 (10.08)	224 (45.16)	0.10; d.f.1; p>0.05
	Piped from spring	38 (7.66)	184 (37.10)	
Toilet	Pit	15 (3.02)	55 (11.09)	0.76; d.f.1; p>0.05
	Commode	73 (14.72)	353 (71.17)	

Figures in the parentheses are percentage

Table 3.46a: Association of demographic, socio-economic and life style variables with WHR related risk among the male Limboo individuals

Variables	Categories	WHR< 0.9	WHR > 0.9	χ^2 – value
Age group	18-29 years	115 (23.19)	74 (14.92)	38.15; d.f.2; p<0.001
	30-49 years	75 (15.12)	141 (28.43)	
	50-64 years	26 (5.26)	65 (13.10)	
Marital status	Unmarried	82 (16.53)	53 (10.69)	22.30; d.f.1; p<0.001
	Married	134 (27.02)	227 (45.77)	
Education	Illiterate	29 (5.85)	41 (8.27)	0.48; d.f. 2; P>0.05
	Upto 8th grade	98 (19.76)	132 (26.61)	
	≥ 9th grade	89 (17.94)	107 (21.57)	
Occupation	Manual	146 (29.44)	185 (37.30)	24.31; d.f. 2 p<0.001
	Non-manual	29 (5.85)	75 (15.12)	
	Others	41 (8.27)	20 (4.03)	
Income	≤ ₹4999	21 (4.23)	37 (7.46)	1.89; d.f.2; p>0.05
	₹5000 – ₹9999	84 (16.94)	97 (19.56)	
	≥ ₹10000	111 (22.38)	146 (29.44)	
Kuppuswamy SES	Upper Middle (UM)	30 (6.05)	59 (11.90)	4.95; d.f.2; p>0.05
	Lower Middle (LM)	70 (14.11)	92 (18.55)	
	Upper Lower (UL)	116 (23.39)	129 (26.01)	
Family size	Small	68 (13.71)	99 (19.96)	0.82; d.f.1; p>0.05
	Large	148 (29.84)	181 (36.47)	
Land holding	0 – 0.99 acre	57 (11.49)	82 (16.53)	0.20; d.f.1; p>0.05
	≥ 1 acre	159 (32.06)	198 (39.92)	
House type	Kacha	58 (11.69)	80 (16.13)	0.57; d.f. 2; p>0.05
	Semi-pakka	123 (24.80)	150 (30.24)	
	Pakka	35 (47.06)	50 (10.08)	
Drinking water	Supply	141 (28.43)	164 (33.06)	0.10; d.f.1; p>0.05
	Piped from spring	75 (15.12)	116 (23.39)	
Toilet	Pit	29 (5.85)	35 (7.06)	0.76; d.f.1; p>0.05
	Commode	187 (37.70)	245 (49.40)	

Figures in the parentheses are percentage

Table 3.46b: Association of demographic, socio-economic and life style variables with WHR related risk among the female Limboo individuals

Variables	Categories	WHR< 0.8	WHR > 0.8	χ^2 – value
Age group	18-29 years	12 (2.42)	204 (41.13)	2.46; d.f.2; p>0.05
	30-49 years	6 (1.21)	199 (40.12)	
	50-64 years	5 (1.01)	70 (14.11)	
Marital status	Unmarried	8 (1.61)	104 (20.97)	2.05; d.f.1; p>0.05
	Married	15 (3.02)	369 (74.40)	
Education	Illiterate	10 (2.02)	165 (33.27)	0.48; d.f. 2; P>0.05
	Upto 8th grade	4 (0.81)	153 (30.85)	
	≥ 9th grade	9 (1.81)	155 (31.25)	
Occupation	Manual	16 (3.23)	365 (73.59)	1.18; d.f. 2 p>0.05
	Non-manual	4 (0.81)	49 (9.88)	
	Others	3 (0.60)	59 (11.90)	
Income	≤ ₹4999	2 (0.40)	54 (10.89)	0.24; d.f.2; p>0.05
	₹5000 – ₹9999	10 (2.02)	186 (38.50)	
	≥ ₹10000	11 (2.22)	233 (46.98)	
Kuppuswamy SES	Upper Middle (UM)	5 (1.01)	77 (15.52)	0.47; d.f.2; p>0.05
	Lower Middle (LM)	6 (1.21)	134(27.02)	
	Upper Lower (UL)	12 (2.42)	262 (52.82)	
Family size	Small	7 (1.41)	159 (32.06)	0.10; d.f.1; p>0.05
	Large	16 (3.23)	314 (63.31)	
Land holding	0 – 0.99 acre	7 (1.41)	180 (36.29)	0.54; d.f. 1; p>0.05
	≥ 1 acre	16 (3.23)	293 (59.07)	
House type	Kacha	9 (1.81)	115 (23.19)	3.11; d.f. 2; p>0.05
	Semi-pakka	9 (1.81)	265 (43.43)	
	Pakka	9 (1.81)	115 (23.19)	
Drinking water	Supply	16 (3.23)	258 (52.02)	2.00; d.f.1; p>0.05
	Piped from spring	7 (1.41)	215 (43.35)	
Toilet	Pit	3 (0.60)	67 (13.51.)	0.02; d.f.1; p>0.05
	Commode	20 (4.03)	406 (81.85)	

Figures in the parentheses are percentage

3.4.2 RESULT OF LOGISTIC REGRESSION TO ACERTAIN POSSIBLE DETERMINANTS OF UNDERWEIGT, OVERWEIGHT, OBESITY AND CENTRAL ADIPOSITY.

The multinomial logistic regressions were conducted to identify the possible determinants of undernutrition and overweight among the Limboo population of Sikkim in the present study. Multinomial logistic regressions were carried out to find out possible factors for underweight, overweight, and obesity given by BMI (WHO 1995). Similarly, multinomial logistic regressions were carried out to identify possible factors causing high central adiposity among the Limboo population based on WC, WHtR, and WHR. The respective results are delineated below.

3.4.2.1 Multinomial logistic regression for being underweight, overweight and obese using BMI WHO (1995) classification.

The multinomial logistic regression was performed to analyse the effect of various socio-economic and socio-demographic variables on the outcome variables like underweight, overweight and obese compare to normal weight individuals using BMI (1995) classification. The socio-economic and socio-demographic variables were sex (male; female), age (18-29 years; 30-49 years;50-64 years), marital status (unmarried; married), education (illiterate; upto 8^{th} grade; ≥ 9^{th} grade), occupation (manual; non-manual; others), monthly income (≤ ₹4999/=; ₹5000/= - ₹9999/=; ≥ ₹10000/=), socio-economic status based on Kuppuswamy scale (upper lower; lower middle; upper middle), family size (large; small), land holding (≥1 acre; 0-0.99 acre), house type (semi-pakka; pakka; kacha), drinking water (supply; piped from spring) and hygienic toilet (Commode; pit). The words in the brackets are categories of the each variable which were used as predictors.

Multinomial logistic regression analyses result for being underweight compare to normal weight individuals was only significant ($p<0.05$) for middle age group (30 - 49 years) with odd of 0.48 (95% CI 0.27 – 0.85) than the young adults. However, the odd ratio was less than 1 which suggests the event is significantly less likely to occur. The observed non-significant odds of 50 – 64 years age group was 0.73 (95% CI 0.37-1.42) indicate their less likelihood of being underweight compared to 18-29 years age group. All the other variables have non-significant (p>0.05) odds for being underweight. The education categories upto 8th grade and above 9th grade, land holding below 1 acre, kacha house dwelling, Pakka house dwelling, presence of unhygienic toilet facility have less likelihood of being underweight with non-significant (p>0.05) odds. Other variable like being female, married, occupation involving manual and non-manual work, income of ₹5000/= – ₹9999/=, income of ≥ ₹10000/=, upper middle (UM) SES, lower middle (LM) SES based on Kuppuswamy scale, small family size and drinking water piped from spring have non-significant (p>0.05) odd of above 1. The values are presented in Table 3.47.

The odd ratios obtained for being overweight compare to normal weight were significant (p<0.05) for sex, age groups, marital status, occupation, income, and socio-economic status based on Kuppuswamy scale. The odd of being overweight for females was 1.57 (95% CI 1.15 – 2.14) times than males. Age group 30 – 49 years have highly significant (p < 0.001) odd of 3.01 (95% CI 2.09 – 4.33) for being overweight and older age group 50-64 years have significant (p < 0.05) odd of 1.76 (95% CI 1.08 – 2.87) compare to age group 18-29 years. Married individuals have highly significant (p<0.001) odd of 3.27 (95% CI 2.07 – 5.17) for being effected by overweight. Similarly highly significant (p < 0.001) odds were observed for manual occupation (OR: 4.64, 95% CI 2.11 – 10.19) and non-manual occupation (OR: 11.12, 95% CI 4.82 – 25.67). The odd of income above ₹10000/= (OR: 1.77, 95% CI 1.05 – 2.97) was observed significant (p<0.01) against the income ≤ ₹4999/= and income of ₹5000/= – ₹9999/=. The upper middle (UM) and lower middle (LM) levels of SES against upper lower (UL) were observed with highly significant (p<0.001) odd of 2.92 (95% CI 1.94 – 4.38) and significant odd of 1.62 (95% CI 1.13 – 2.33) respectively. The remaining variables such as levels of education, family size, landholding source of drinking water and hygienic toilet have non-significant odds values less than 1 for being overweight. Only kacha house type was observed with odd above 1 which was observed non- significant ($p>0.05$).

The result of multinomial logistic regression analyses for being obese compare to normal BMI individuals were highly significant ($p<0.001$) for female, 30-49 years age group and LM level of SES. Similarly significant ($p<0.05$) odd were observed 50 – 64 years age, non-manual occupation and piped source of drinking water. The chance of being obese for female was 3.11 (95% CI 1.53 – 6.33) times than male. The middle age group (OR: 3.94, 95% CI 1.66 – 9.33) and old age group (OR: 3.89, 95% CI 1.44 – 10.46) individuals have higher likelihood of being obese compared to young adults. Individuals with non-manual occupation were more likely to get obese than manual occupation and the "other" occupation category with odd ratio of 14.76 (95% CI 1.87 – 116.70). The individual of high SES such as UM was 3.38 (95% CI 1.53 – 7.47) times likely to get obese compared to individual of UL SES level. The individuals with education upto 8^{th} grade and piped source of drinking water were significantly ($p<0.05$) less likely to get obese with odd ratios of 0.42 (95% CI 0.19 – 0.94) and 0.45 (95% CI 0.22 – 0.93) respectively. The remaining variables were non-significant such as marital status, higher education, income levels, LM level of SES, family size, land holding, house types, and hygienic toilet (Table 3.47).

3.4.2.3 Multinomial logistic regression for being at high WC (male: > 90 cm; female: > 80 cm).

The multinomial logistic regression was performed to analyse the effect of various demographic, socio-economic and life style variables for predisposing the individuals to various adiposity related morbidity based on waist circumference (WC) measurement (Table 3.48). The outcome variables are being at risk of higher WC and not at risk which is mark off by WHO cut off for waist circumference (90 cm for male and 80 cm for female). Lower WC or not at risk was set as reference. The demographic, socio-economic and life style variables used were same as that used in case of multinomial logistic regression of using BMI.

The logistic regression analyses for being at risk of high WC compared to normal WC measurement were highly significant ($p<0.05$) for sex, middle age groups, marital status, education, and UM SES. The significant odds were observed for 50 – 64 years, occupations, family monthly income ≥ ₹10000, and Kacha house type. The females were more at risk of high regional adiposity measured by WC compared to males (OR: 11.81, 95% CI 8.46 – 16.51). The age group 30 – 49 years and 50 – 69 years were 1.86 (95% CI 1.39 – 2.49) and 1.48 (95% CI 1.01 – 2.18) times likely to be at risk of high WC compared to young individuals of age group 18 – 29 years respectively. The married individuals were 2.39 (95% CI 1.70 – 3.34) times likely to be centrally obese against the unmarried individuals of the present study. Compared to the others occupation category non-manual occupation have significant odds of 2.08 (95% CI 1.23 – 3.50) even higher than 1.72 (95% CI 1.11 – 2.67) observed for manual occupation. The high income group with family monthly income of ≥ ₹10000/= were observed with odds of 1.74 (95% CI 1.11 – 2.74). Individuals falling under the UM SES level were more prone to high WC with highly significant odd of 1.96 (95% CI 1.38 – 2.79).

On the other hand individuals dwelling kacha house were observed with less likelihood of being at risk of high WC with significant ($p<0.05$) odds of 0.64 (95% CI 0.47 – 0.89). The odd ratios observed for remaining variables were non-significant ($p > 0.05$) which are presented in Table 3.48.

3.4.2.5 Multinomial logistic regression for being at risk of high WHtR(> 0.5).

The multinomial logistic regression was performed to analyse the effect of various demographic, socio-economic and life style variables for predisposing the individuals to various adiposity related morbidity based on WHtR (Table 3.49). The outcome variables were being at risk of higher WHtR and not at risk which is mark off by WHO (2008) cut off for WHtR (> 0.5 for both sexes). The demographic, socio-economic and life style variables are same as used in previous logistic regressions.

The results for being at risk of high WHtR compared to normal WHtR were highly significant ($p<0.05$) for sex, age group, marital status, education and occupations. The Limboo female individuals were at high risk with significant odds of 4.87 (95% CI 3.64 – 6.50) compared to male individuals. Further, compared to younger age group older age group 30-49 years and 50-64 years were more predisposed to risk of high WHtR with odds of 2.78 (95% CI 2.07 – 3.73) and 2.45 (95% CI 1.65 – 3.63) respectively. Comparatively middle age group individuals were more at risk. The married individuals were 2.44 (95% CI 1.81 – 3.27) times likely to be at the high WHtR against unmarried individuals. The individuals involved in non-manual occupation (OR: 2.88, 95% CI 1.74 – 4.78) and manual occupation (OR: 1.84, 95% CI 1.25 – 2.70) were more likely to be centrally obese against 'other' occupation, the odds observed were higher for non-manual occupation. Lastly individuals falling under the UM SES and Pakka house were significantly at risk of high central adiposity using WHtR the odds observed were 1.71 (95% CI 1.16 – 2.52) and 1.55 (95% CI 1.07 – 2.26) respectively.

The odds of people educated upto 8th grade and ≥ 9th grade were observed with 0.54 (95% CI 0.38 – 0.77) and 0.53 (95% CI 0.37 – 0.77) respectively. This suggests educated people are significantly less likely to get centrally obese using the WHtR as marker. The unhygienic toilets were found significantly less likely to influence the prevalence of high central obesity. The odds observed for absent of hygienic toilet were 0.67 (0.46 – 0.97). The remaining variables have no influence in the prevalence of central obesity. The figures are presented in Table 3.49.

3.4.2.6 Multinomial logistic regression for being at high WHR (male: > 0.90; female: > 0.80).

The multinomial logistic regression was performed to analyse the effect of various demographic, socio-economic and life style variables for predisposing the individuals to various adiposity related morbidity based on WHR (Table 3.50). The outcome variables are being at risk of higher WHR and not at risk which was mark off by WHO (2008) cut-off for WHR. The demographic, socio-economic and life style variables were same as in previous cases.

The logistic regression analyses result of being at risk of high WHR was significantly ($p<0.05$) less likely for female with odd 0.21 (95% CI 0.08 – 0.56). The education level upto 8^{th} grade make individuals more prone to high WHR for which observed odds was 1.98 (95% CI 1.09 – 8.18) in the present study. The remaining odds values obtain were non-significant which are presented in Table 3.50.

Table 3.47: Results of Multinomial Logistic Regression analysis of being at the risk of underweight, overweight and obese vs. normal BMI (1995) by socio-economic and demographic variables among the Limboo individuals

	Underweight (vs. Normal)			Overweight (vs. Normal)			Obese (vs. Normal)		
	Wald	Odds	95 % CI	Wald	Odds	95 % CI	Wald	Odds	95% CI
Sex									
Male®		1			1			1	
Female	2.08	1.42	0.88-2.30	8.03	1.57**	1.15 - 2.14	9.80	3.11***	1.53 - 6.33
Age group									
18-29 years®		1			1			1	
30-49 years	6.36	0.48**	0.27-0.85	34.95	3.01***	2.09-4.33	9.70	3.94***	1.66-9.33
50-64 years	0.87	0.73	0.37-1.42	5.14	1.76*	1.08 - 2.87	7.22	3.89**	1.44-10.46
Marital status									
Unmarried®		1			1			1	
Married	0.26	1.15	0.67-1.97	25.94	3.27***	2.07-5.17	2.55	1.97	0.86-4.53
Education									
Illiterate®		1			1			1	
Upto 8^{th} grade	0.66	0.78	0.42-1.43	0.79	0.84	0.57-1.24	4.44	0.42*	0.19-0.94
≥ 9^{th} grade	0.20	0.87	0.47-1.60	1.39	0.79	0.53-1.17	1.99	0.58	0.27-1.24
Occupation									
Manual	0.80	1.40	0.67-2.91	14.60	4.64***	2.11-10.19	3.17	6.18	0.83-45.95
Non-manual	0.35	1.34	0.51-3.54	31.84	11.12***	4.82-25.67	6.51	14.76**	1.87-116.70
Others ®		1			1			1	
Income									
≤ ₹4999®		1			1			1	
₹5000 – ₹9999	1.17	1.65	0.67-4.08	0.31	0.85	0.49-1.49	0.64	1.86	0.41-8.45
≥ ₹10000	1.41	1.72	0.70-4.21	4.60	1.77*	1.05-2.97	2.99	3.62	0.84-15.57

	Underweight (vs. Normal)			Overweight (vs. Normal)			Obese (vs. Normal)		
	Wald	Odds	95 % CI	Wald	Odds	95 % CI	Wald	Odds	95% CI
Kuppuswamy SES									
Upper Middle (UM)	0.17	1.16	0.57-2.35	26.69	2.92***	1.94-4.38	9.05	3.38***	1.53-7.47
Lower Middle (LM)	0.33	1.17	0.69-2.00	6.92	1.62**	1.13-2.33	1.82	1.69	0.79-3.62
Upper Lower (UL)®		1			1			1	
Family size									
Small	0.21	1.12	0.68-1.85	0.01	0.98	0.71-1.37	0.04	1.07	0.55-2.10
Larger ®		1			1			1	
Land holding									
0 – 0.99 acre	0.30	0.87	0.52-1.45	0.97	0.85	0.61-1.18	0.02	1.05	0.54-2.06
≥ 1 acre ®		1			1			1	
House type									
Kacha	2.98	0.60	0.34-1.07	8.03	0.56**	0.38-0.84	1.68	0.56	0.24-1.34
Pakka	3.18	0.49	0.23-1.07	1.30	1.26	0.85- 1.86	1.28	1.54	0.73-3.28
Semi-Pakka®		1			1			1	
Drinking water									
Supply®		1			1			1	
Piped from spring	0.00	1.00	0.62-1.62	0.18	0.93	0.68-1.28	4.64	0.45*	0.22-0.93
Toilet									
Commode®		1			1			1	
Pit	1.97	0.56	0.25-1.26	3.39	0.63	0.39-1.03	2.89	0.29	0.07-1.21

® Reference; *p < 0.05; **p<0.001

Table 3.48: Result of Multinomial Logistic Regression analysis of being at risk of higher waist circumference (vs. Normal Waist Circumference) based on socio-economic and demographic variables among the Limboo individuals

Variables	Categories	High WC (vs. Normal)		
		Wald	Odds	95% CI
Sex	Male®		1	
	Female	209.39	11.81 ***	8.46 - 16.51
Age group	18-29 years®		1	
	30-49 years	17.44	1.86***	1.39 - 2.49
	50-64 years	4.01	1.48*	1.01 - 2.18
Marital status	Unmarried®		1	
	Married	25.52	2.39***	1.70 - 3.34
Education	Illiterate®		1	
	Upto 8th grade	15.57	0.51***	0.37 - 0.72
	≥ 9 grade	15.97	0.50***	0.36 - 0.71
Occupation	Manual	5.85	1.72*	1.11 - 2.67
	Non-manual	7.57	2.08**	1.23 - 3.50
	Others ®		1	
Income	≤ ₹4999®		1	
	₹5000 – ₹9999	1.89	1.39	0.87 - 2.22
	≥ ₹10000	5.71	1.74*	1.11 - 2.74
Kuppuswamy SES	Upper Middle (UM)	14.01	1.96***	1.38 - 2.79
	Lower Middle (LM)	0.06	1.04	0.77 - 1.40
	Upper Lower (UL)®		1	
Family size	Small	2.18	0.81	0.61 - 1.07
	Larger ®		1	
Land holding	0 – 0.99 acre	0.32	1.08	0.82 - 1.43
	≥ 1 acre ®		1	
House type	Kacha	7.13	0.64**	0.47 - 0.89
	Pakka	2.82	1.34	0.95 - 1.88
	Semi-Pakka®		1	
Drinking water	Supply®		1	
	Piped from spring	1.33	1.17	0.90 - 1.52
Toilet	Commode®		1	
	Pit	0.57	0.86	0.58 - 1.27

® Reference; *p < 0.05; **p<0.001

Table 3.49: Result of Multinomial Logistic Regression analysis of being at risk of higher WHtR (vs. Normal WHtR) based on socio-economic and demographic variables among the Limboo individuals

Variables	Categories	High WHtR (vs. Normal)		
		Wald	Odds	95% CI
Sex	Male®		1	
	Female	114.41	4.87***	3.64 - 6.50
Age group	18-29 years®		1	
	30-49 years	45.95	2.78***	2.07 - 3.73
	50-64 years	19.85	2.45***	1.65 - 3.63
Marital status	Unmarried®		1	
	Married	34.99	2.44***	1.81 - 3.27
Education	Illiterate®		1	
	Upto 8th grade	11.81	0.54***	0.38 - 0.77
	≥ 9 grade	11.60	0.53***	0.37 - 0.77
Occupation	Manual	9.55	1.84***	1.25 - 2.70
	Non-manual	16.80	2.88***	1.74 - 4.78
	Others ®		1	
Income	≤ ₹4999®		1	
	₹5000 – ₹9999	1.52	0.76	0.48 - 1.18
	≥ ₹10000	0.04	0.96	0.62 - 1.48
Kuppuswamy SES	Upper Middle (UM)	7.23	1.71*	1.16 - 2.52
	Lower Middle (LM)	0.00	1.00	0.74 - 1.34
	Upper Lower (UL)®		1	
Family size	Small	0.03	0.98	0.74 - 1.29
	Larger ®		1	
Land holding	0 – 0.99 acre	0.39	1.09	0.83 - 1.45
	≥ 1 acre ®		1	
House type	Kacha	1.74	0.82	0.60 - 1.10
	Pakka	5.28	1.55*	1.07 - 2.26
	Semi-Pakka®		1	
Drinking Water	Supply®		1	
	Piped from spring	0.35	1.08	0.83 - 1.42
Toilet	Commode®		1	
	Pit	4.42	0.67*	0.46 - 0.97

® Reference; *p < 0.05; **p<0.001

Table 3.50: Result of Multinomial Logistic Regression analysis of being at higher Waist Hip Ratio (WHR) (vs. Normal WHR) based on socio-economic and demographic variables among the Limboo individuals

Variables	Categories	High WHR (vs. Normal)		
		Wald	Odds	95% CI
Sex	Male®		1	
	Female	9.87	0.21***	0.08 - 0.56
Age group	18-29 years®		1	
	30-49 years	1.87	1.85	0.77 - 4.46
	50-64 years	0.01	0.96	0.36 - 2.53
Marital status	Unmarried®		1	
	Married	0.80	1.45	0.65 - 3.24
Education	Illiterate®		1	
	Upto 8th grade	4.52	2.98*	1.09 -8.18
	≥ 9 grade	0.85	1.49	0.64 - 3.50
Occupation	Manual	0.07	1.16	0.39 - 3.46
	Non-manual	0.12	1.29	0.32 - 5.25
	Others ®		1	
Income	≤ ₹4999®		1	
	₹5000 – ₹9999	0.03	0.90	0.25 - 3.28
	≥ ₹10000	0.01	0.94	0.27 - 3.33
Kuppuswamy SES	Upper Middle (UM)	0.17	0.82	0.32 - 2.14
	Lower Middle (LM)	0.24	1.25	0.51 - 3.11
	Upper Lower (UL)®		1	
Family size	Small	0.42	0.78	0.36 - 1.67
	Larger ®		1	
Land holding	0 – 0.99 acre	0.01	1.03	0.46 - 2.31
	≥ 1 acre ®		1	
House type	Kacha	1.31	0.61	0.27 - 1.42
	Pakka	0.07	0.87	0.31 - 2.47
	Semi-Pakka®		1	
Drinking Water	Supply®		1	
	Piped from spring	1.97	1.81	0.79 - 4.15
Toilet	Commode®		1	
	Pit	0.02	0.94	0.32 - 2.74

® Reference; *p < 0.05; **p<0.001

3.5 THE ROC-AUC ANALYSES OF DIFFERENT ADIPOSITY INDICES AMONG LIMBOO INDIVIDUALS WITH REFERENCE TO PBF AND BMI (WHO 2000).

3.5.1 ROC-AUC ANALYSIS USING PBF (25/30) AS REFERENCE.

The diagnostic properties of NC, WC, BMI, BAI, WHtR, WHR, and CI in detecting excess body fat given by AUC derived using PBF cut-offs of 25% for male and 30% for female Limboo individuals as reference is presented in Table 3.51 and 3.52, respectively. According to AUC of ROC-AUC analysis 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). The ROC-AUC plots are presented in the Figure 3.44a to 3.44n. The cut-offs given by ROC-AUC analysis based on PBF were 36.95 cm and 27.38 % respectively for NC and BAI among male Limboo individuals. The cut-offs observed for NC and BAI among female Limboo individuals were 36.65 cm and 35.35 %. The cut-offs decided for WC, WHtR, WHR, CI were different than the recommended cut-offs, yet observed closer to the obtain values among both males and females of the present study. The respective sensitivity and specificity is also provided in the respective Tables (Table 3.51 and Table 3.52).

Table 3.51: Diagnostic properties of anthropometric indicators of adiposity to detect high percentage body fat (PBF) among the male Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.93 (0.88-0.99)	.000	36.95	99	77
WC	0.94 (0.89-0.99)	.000	86.90	99	83
BMI	0.95 (0.91-0.99)	.000	26.11	99	87
BAI	0.90 (0.81-0.99)	.000	27.38	99	71
WHtR	0.94 (0.89-0.99)	.000	00.54	99	82
WHR	0.86 (0.79-0.93)	.000	00.93	99	71
CI	0.80 (0.68-0.91)	.000	1.26	83	71

Reference rang used for PBF is 25% for male and 30% for female.

Table 3.52: Diagnostic properties of anthropometric indicators of adiposity to detect high percentage body fat (PBF) among the female Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.87 (0.83-0.92)	.000	36.65	68	90
WC	0.92 (0.89-0.95)	.000	88.10	89	79
BMI	0.94 (0.92-0.97)	.000	26.16	86	88
BAI	0.87 (0.82-0.91)	.000	35.35	68	90
WHtR	0.90 (0.86-0.93)	.000	00.60	86	81
WHR	0.73 (0.66-0.80)	.000	00.95	74	67
CI	0.71 (0.64-0.78)	.000	1.31	86	60

Reference rang used for PBF is 25% for male and 30% for female.

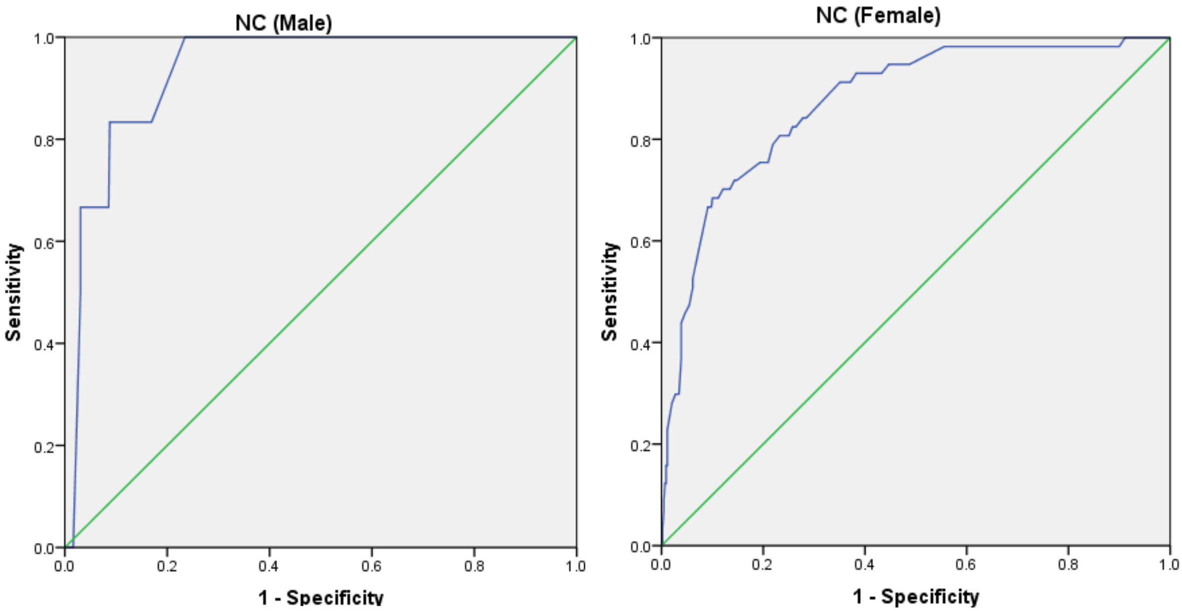

Figure 3.44a & 3.44b: ROC curve analysis for WC among male and female Limboo individuals (25% and 30% for male and female as reference).

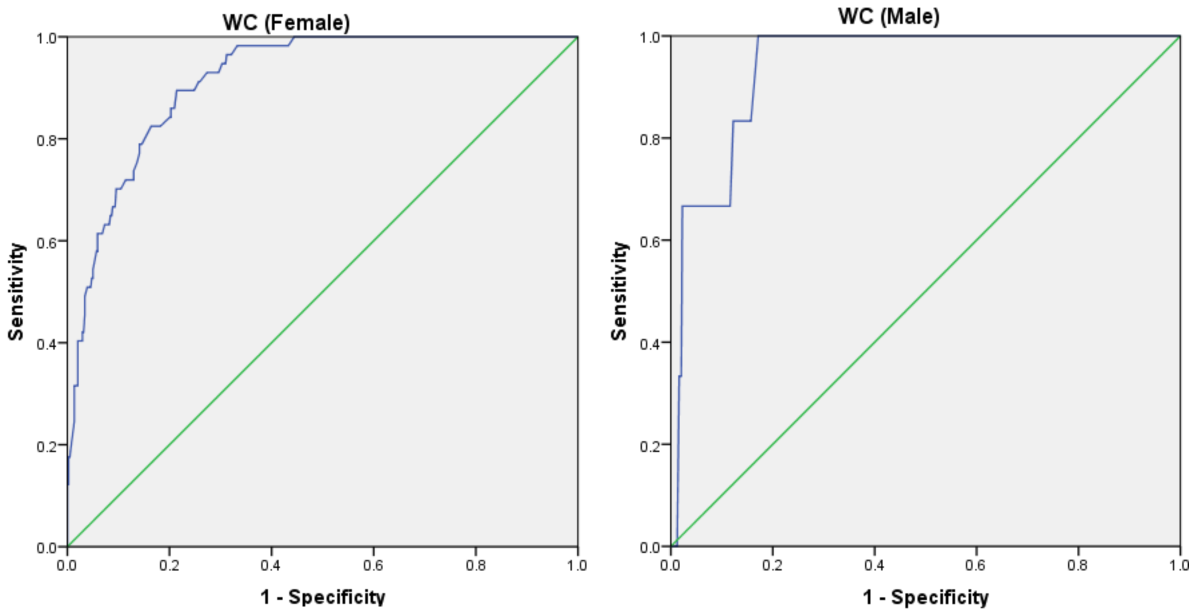

Figure 3.44c & 3.44d: ROC curve analysis for WC among male and female Limboo individuals (25% and 30% for male and female as reference).

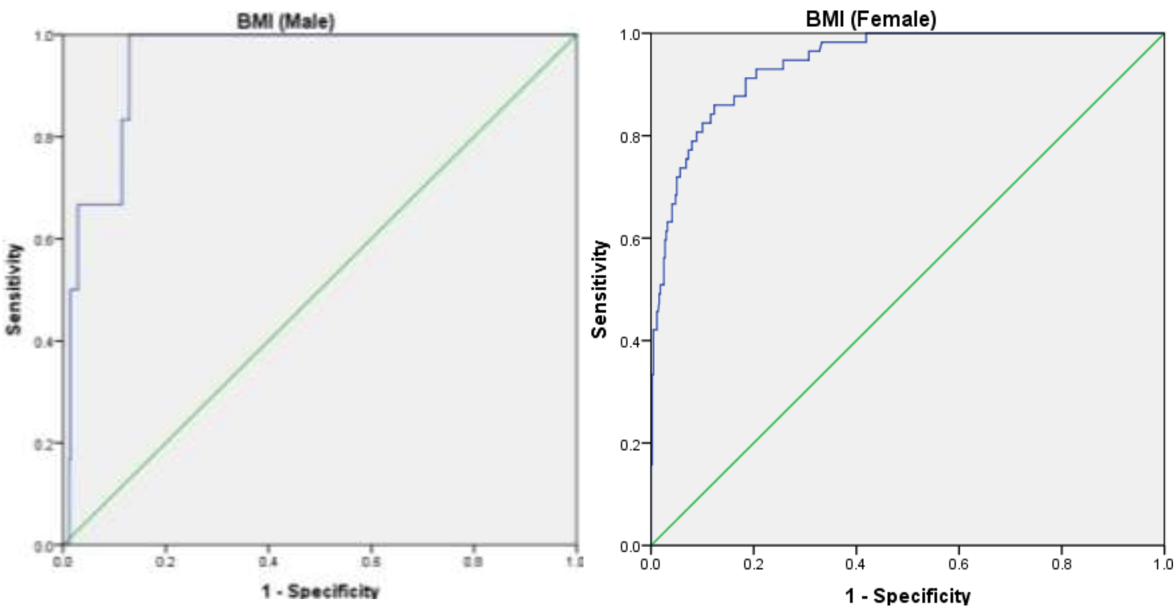

Figure 3.44e & 3.44f: ROC curve analysis for BMI among male and female Limboo individuals (25% and 30% for male and female as reference).

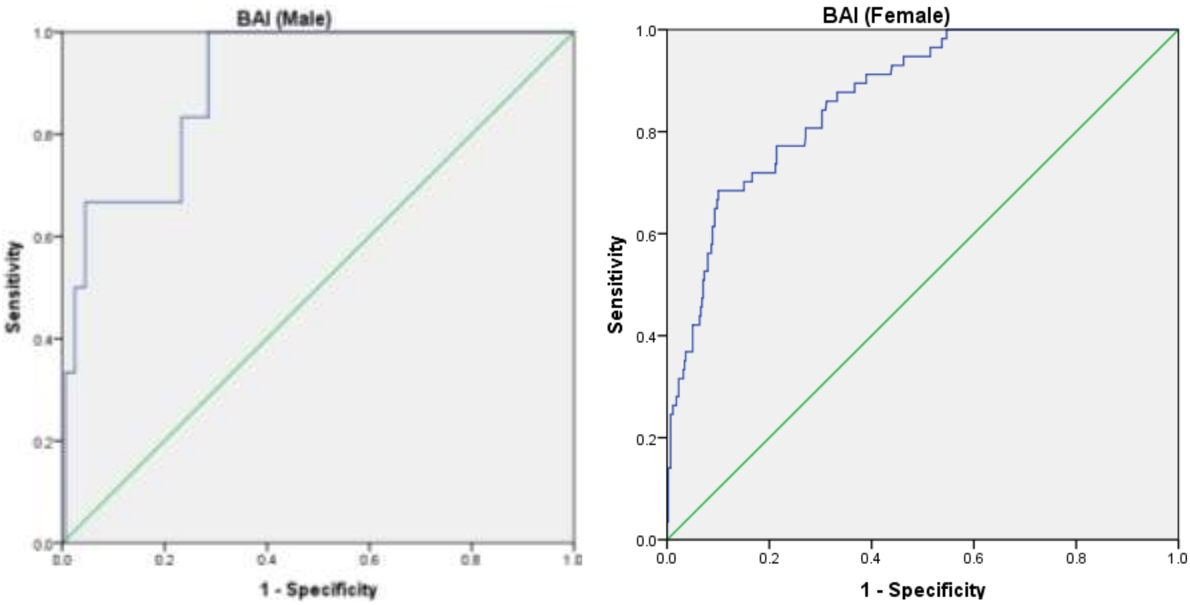

Figure 3.44g & 3.44h: ROC curve analysis for BAI among male and female Limboo individuals (25% and 30% for male and female as reference).

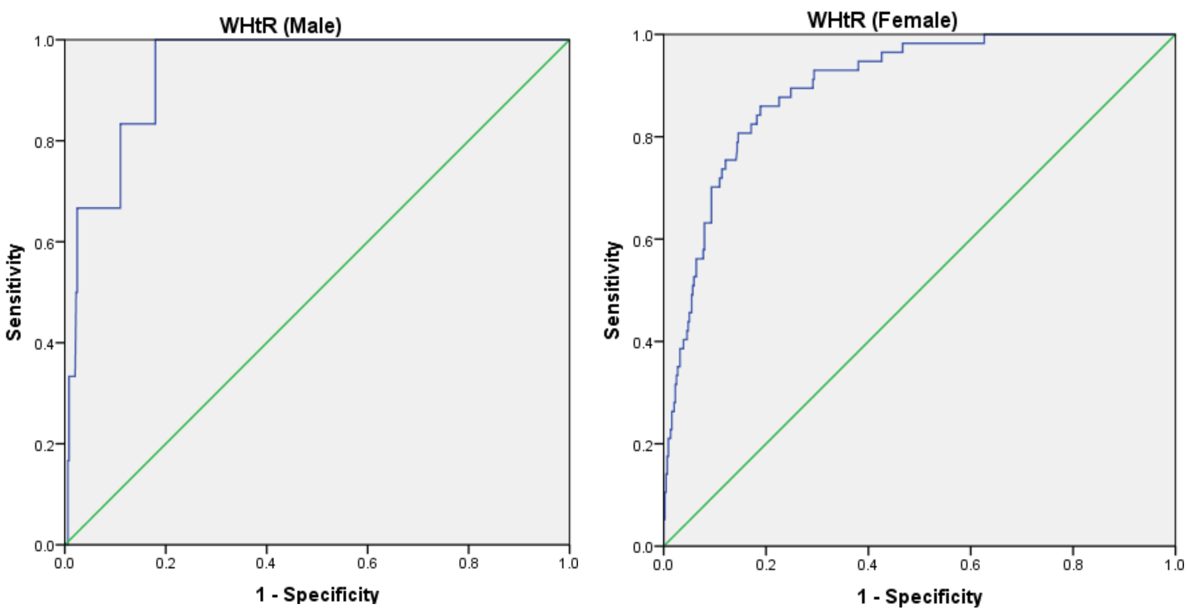

Figure 3.44i & 3.44j: ROC curve analysis for WHtR among male and female Limboo individuals (25% and 30% for male and female as reference).

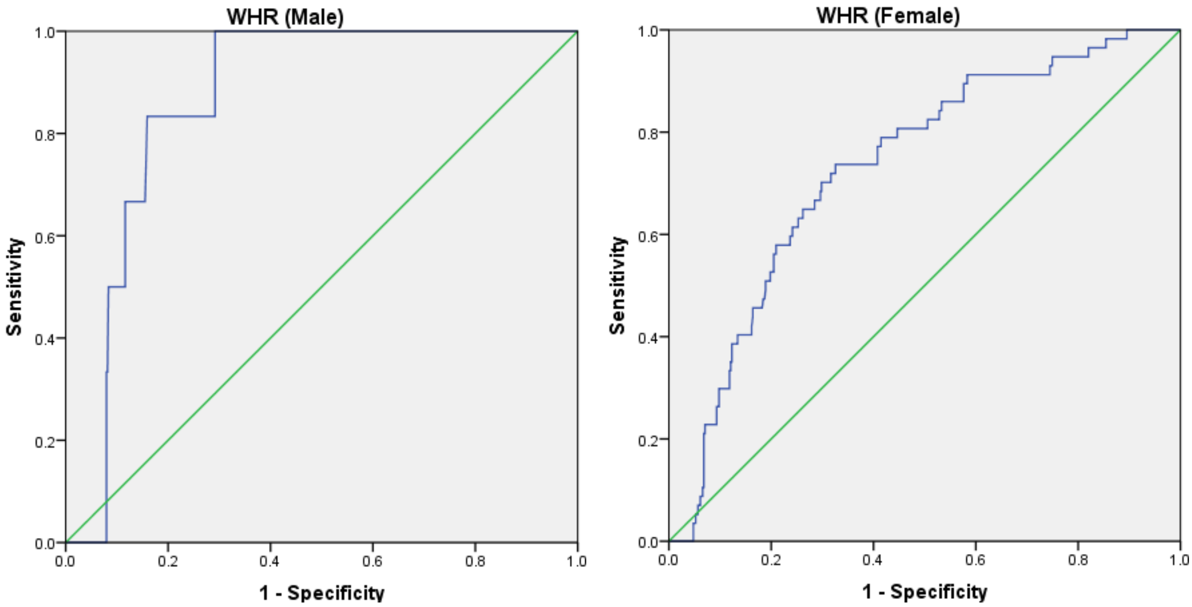

Figure 3.44k & 3.44l: ROC curve analysis for WHR among male and female Limboo individuals (25% and 30% for male and female as reference).

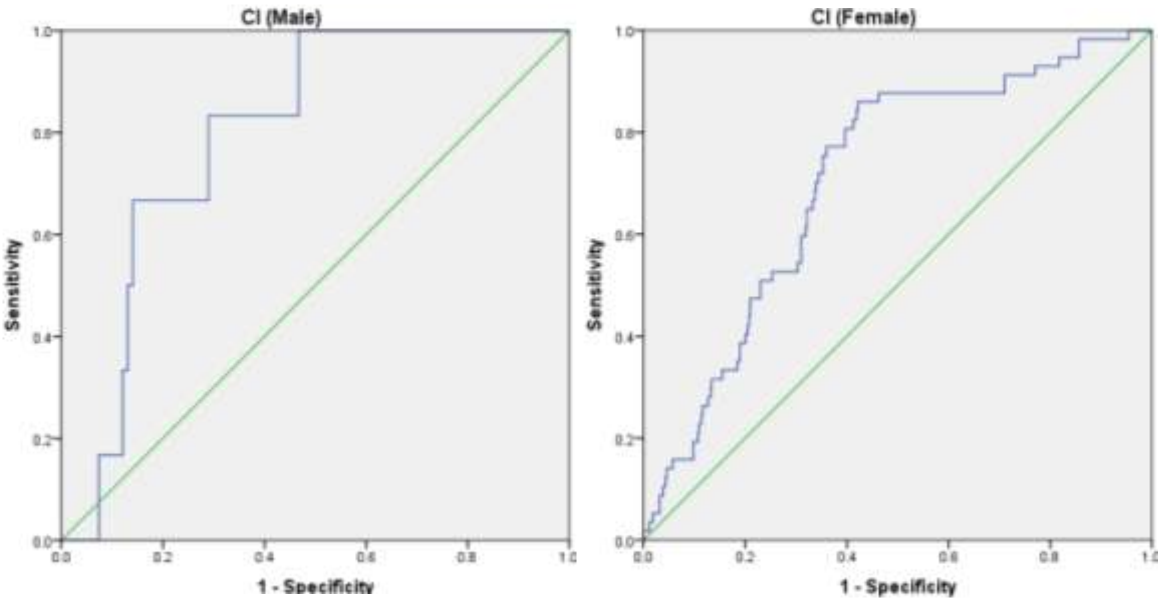

Figure 3.44m & 3.44n: ROC curve analysis for CI among male and female Limboo individuals (25% and 30% for male and female as reference).

3.5.2 THE ROC-AUC ANALYSES OF DIFFERENT ADIPOSITY INDICES AMONG LIMBOO INDIVIDUALS OF SIKKIM WITH REFERENCE TO BMI (WHO 2000) CRITERIA.

3.5.2.1 ROC-AUC Analysis using BMI 23 kgm^2 (WHO, 2000) as reference.

The diagnostic properties of NC, WC, BAI, WHtR, WHR, and CI for detecting high BMI >23 kgm^2 for male and female Limboo individuals are presented in Table 3.53 and 3.54, respectively. According to AUC analysis 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. According to observed AUC, WHtR (AUC 0.91), BAI (AUC 0.91) WC (AUC 0.90) were followed by NC (AUC 0.88), WHR (AUC 0.70) and CI (AUC 0.65) among the female Limboo individuals. The respective plots of ROC-AUC are given in Figure 3.45a to 3.45l. The cut-offs estimated based on BMI > 23 kgm^2 were 35.55 cm and 25.68 % for NC and BAI respectively among male Limboo individuals using ROC-AUC analysis. Similarly, the observed cut-offs for NC and BAI among females were 31.70 cm and 30.90 %. The cut-offs decided for WC, WHtR, WHR, CI were observed closer to recommended cut-off among both males and females of present study. The respective sensitivity and specificity is presented in the respective tables.

Table 3.53: Diagnostic properties of anthropometric indicators of adiposity to detect BMI above 23 kgm^2 among adult male Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.87 (0.84-0.91)	.000	35.55	85	85
WC	0.92 (0.90-0.95)	.000	81.55	80	88
BAI	0.89 (0.86-0.92)	.000	25.68	89	77
WHtR	0.93 (0.91-0.96)	.000	00.51	85	89
WHR	0.76 (0.72-0.80)	.000	00.91	75	64
CI	0.63 (0.58-0.68)	.000	1.22	75	53

Reference rang used was BMI above 23 kg/m^2.

Table 3.54: Diagnostic properties of anthropometric indicators of adiposity to detect BMI above 23 kgm^2 among adult female Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.88 (0.86-0.91)	.000	31.70	75	85
WC	0.90 (0.87-0.93)	.000	82.90	83	84
BAI	0.91 (0.88-0.93)	.000	30.90	90	75
WHtR	0.91 (0.88-0.93)	.000	00.56	81	87
WHR	0.70 (0.65-0.74)	.000	00.90	81	53
CI	0.65 (0.60-0.70)	.000	1.29	71	57

Reference rang used was BMI above 23 kg/m^2.

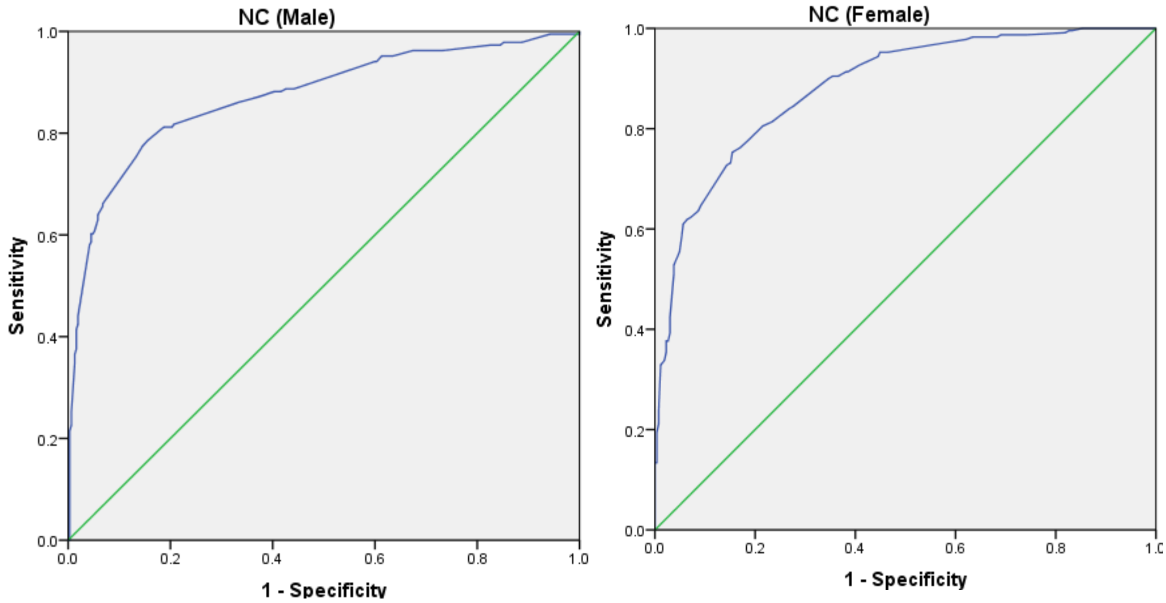

Figure 3.45a & 3.45b: ROC curve analysis for NC among male and female Limboo individuals (23 kg/m^2 as reference).

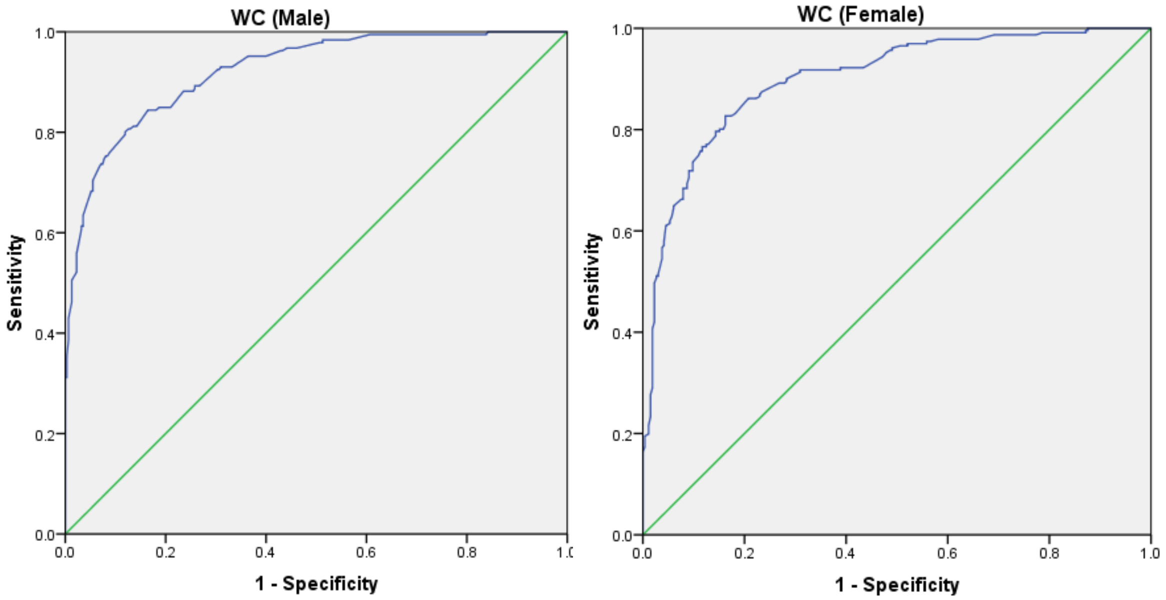

Figure 3.45c & 3.45d: ROC curve analysis for WC among male and female Limboo individuals (23 kg/m^2 as reference).

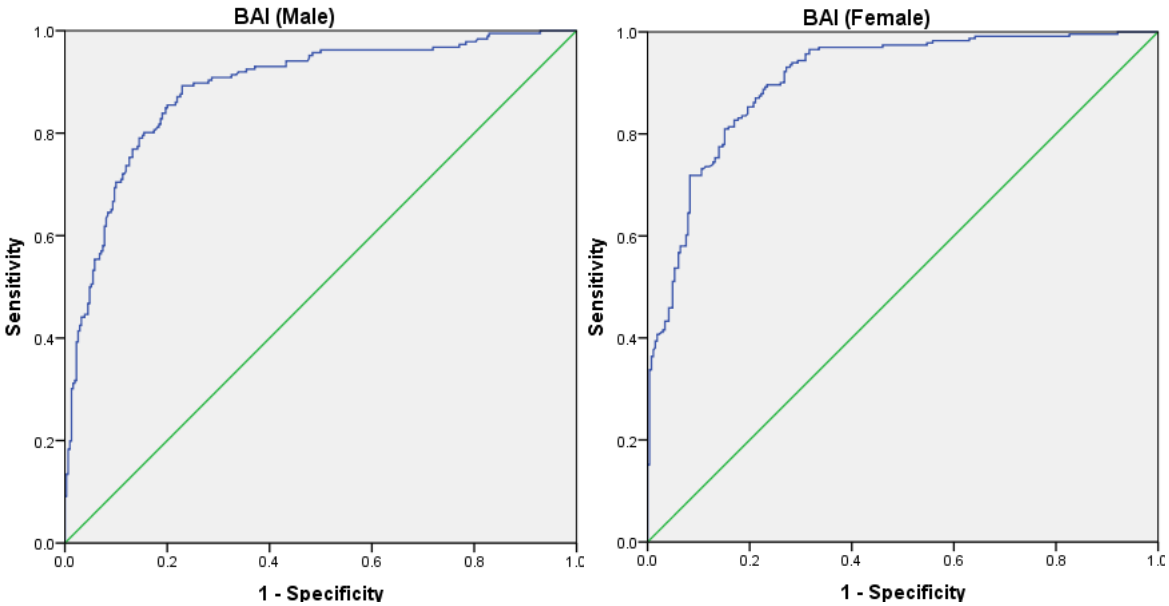

Figure 3.45e & 3.45f: ROC curve analysis for BAI among male and female Limboo individuals (23 kg/m^2 as reference).

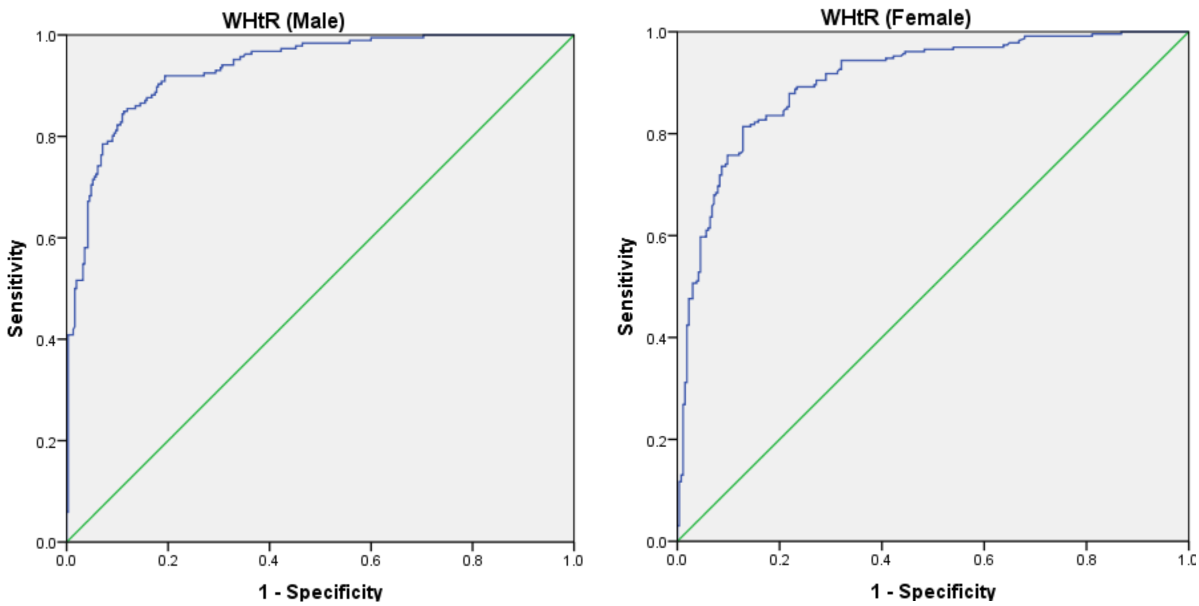

Figure 3.45g & 3.45h: ROC curve analysis for WHtR among male and female Limboo individuals (23 kg/m^2 as reference).

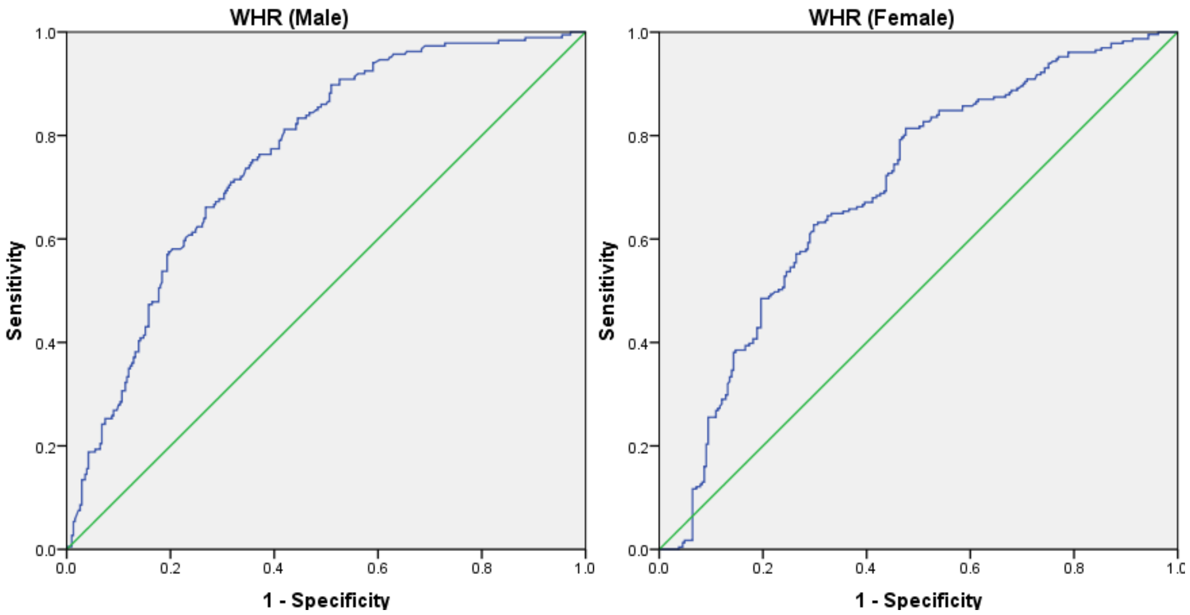

Figure 3.45i & 3.45j: ROC curve analysis for WHR among male and female Limboo individuals (23 kg/m^2 as reference).

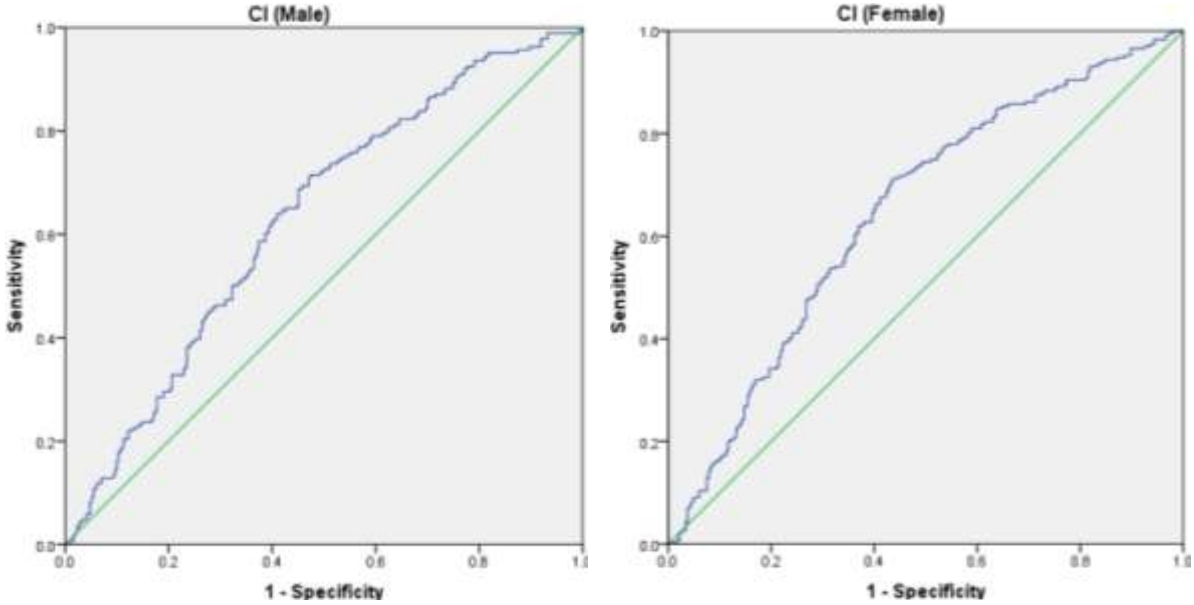

Figure 3.45k & 3.45l: ROC curve analysis for CI among male and female Limboo individuals (23 kg/m^2 as reference).

3.5.2.2 ROC-AUC Analysis using BMI 30 kgm^2 (WHO, 2000) as reference.

The diagnostic properties of NC, WC, BAI, WHtR, WHR, and CI in detecting excess adiposity with respective AUC derived with reference to BMI above 30 kg/m^2 among male and female Limboo individuals are presented in Table 3.55 and 3.56, respectively. 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 female 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). The plot of ROC-AUC analysis is shown in Figure 3.46a to 3.46l. Among male and female Limboo individuals cut-offs obtained using ROC-AUC analysis were 38.25 cm and 33.15 cm for NC and 30.93% and 35.90% for BAI respectively. Interestingly, among the female Limboo individuals BAI (AUC 0.87) was observed as best indicator of adiposity with reference to BMI 30 kg/m^2 followed by WHtR (AUC 0.97), WC (AUC 0.96), NC (AUC 0.93), WHR (AUC 0.79) and CI (AUC 0.77). The cut-offs decided for WC, WHtR, WHR, C-Index were different than the recommended cut-offs yet observed closer to the obtain values among both males and females of present study. The respective sensitivity and specificity is also provided in the respective tables.

Table 3.55: Diagnostic properties of anthropometric indicators of adiposity to detect BMI above 30 kgm^2 among adult male Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.81 (0.61-0.99)	.000	38.25	80	92
WC	0.92 (0.83-0.99)	.000	93.50	80	96
BAI	0.87 (0.70-0.99)	.000	30.93	80	96
WHtR	0.95 (0.88-0.99)	.000	0.58	90	93
WHR	0.84 (0.73-0.96)	.000	0.95	80	83
CI	0.68 (0.50-0.87)	.000	1.27	60	79

Reference rang used was BMI above 30 kg/m^2.

Table 3.56: Diagnostic properties of anthropometric indicators of adiposity to detect BMI above 30 kgm^2 among adult female Limboo individuals

Index	AUC (CI 95%)	p-value	Cut-off	Sensitivity	Specificity
NC	0.93 (0.89-0.96)	.000	33.15	90	83
WC	0.96 (0.94-0.99)	.000	98.10	90	96
BAI	0.98 (0.95-0.98)	.000	35.90	97	90
WHtR	0.97 (0.95-0.99)	.000	0.65	93	94
WHR	0.79 (0.70-0.87)	.000	0.95	83	69
CI	0.77 (0.68-0.86)	.000	1.33	83	67

Reference rang used was BMI above 30 kg/m^2.

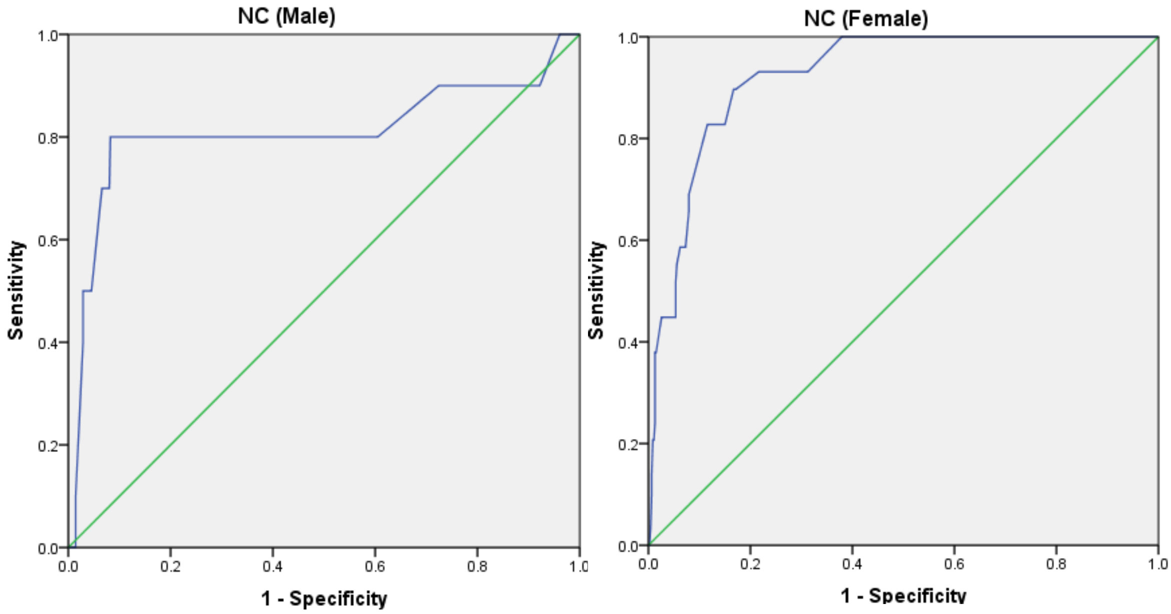

Figure 3.46a & 3.46b: ROC curve analysis for NC among male and female Limboo individuals (30 kg/m^2 as reference).

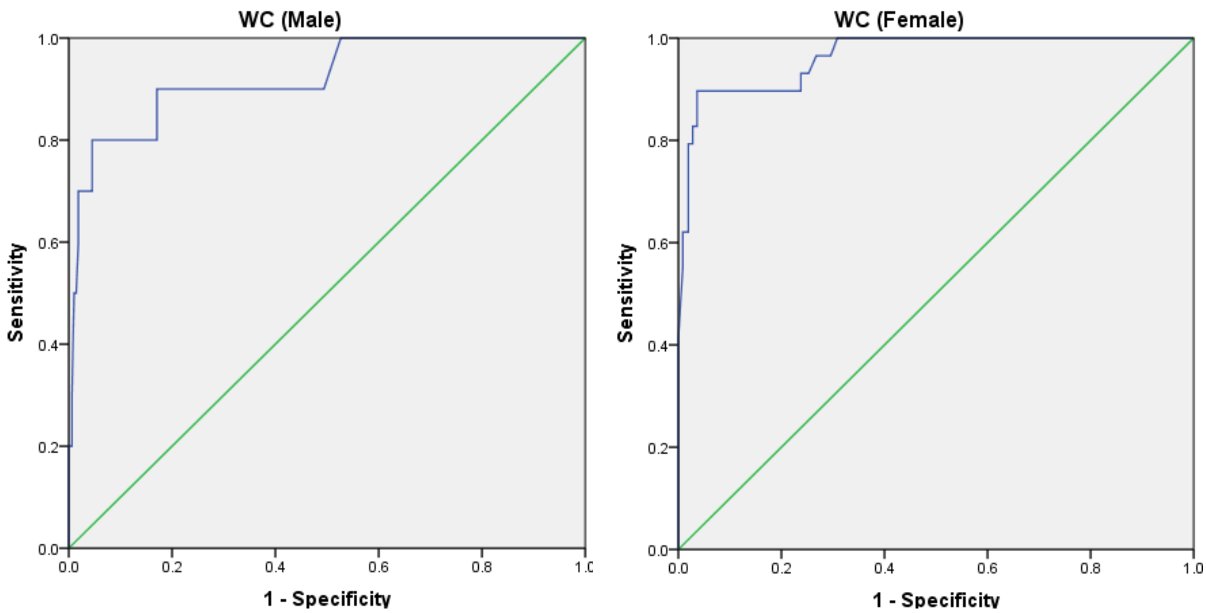

Figure 3.46c & 3.46d: ROC curve analysis for WC among male and female Limboo individuals (30 kg/m^2 as reference).

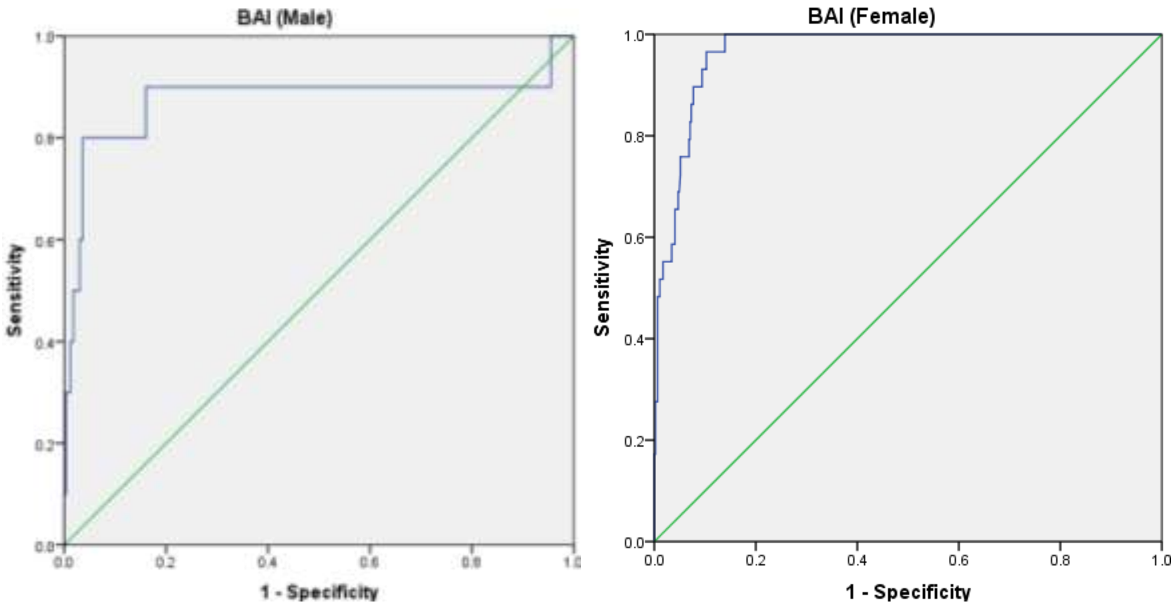

Figure 3.46e & 3.46f: ROC curve analysis for BAI among male and female Limboo individuals (30 kg/m^2 as reference).

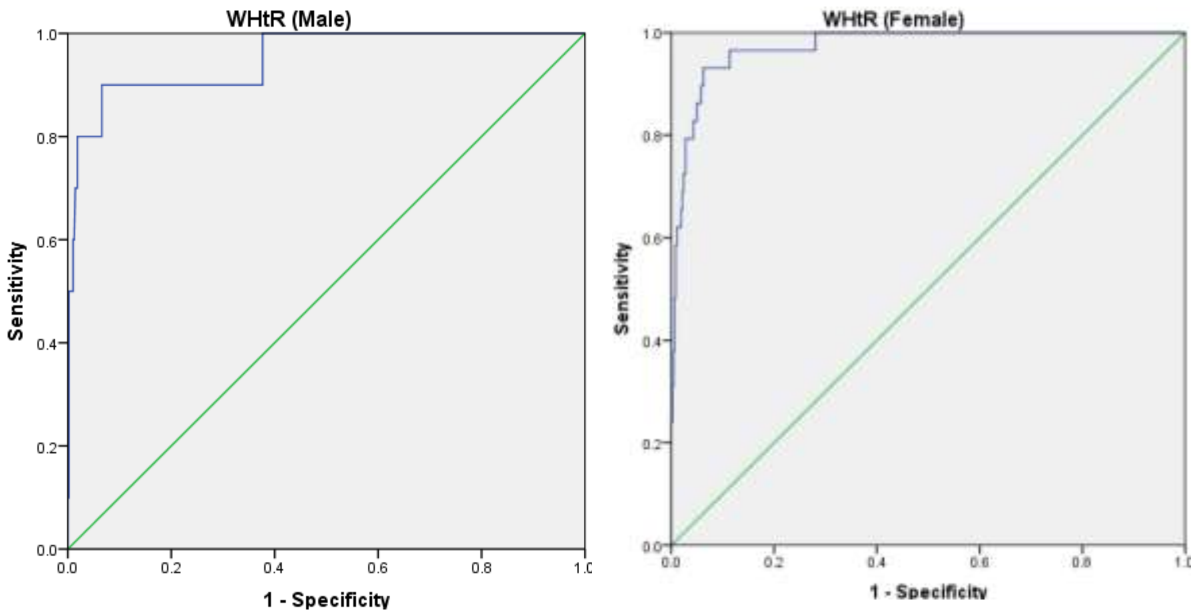

Figure 3.46g & 3.46h: ROC curve analysis for WHtR among male and female Limboo individuals (30 kg/m^2 as reference).

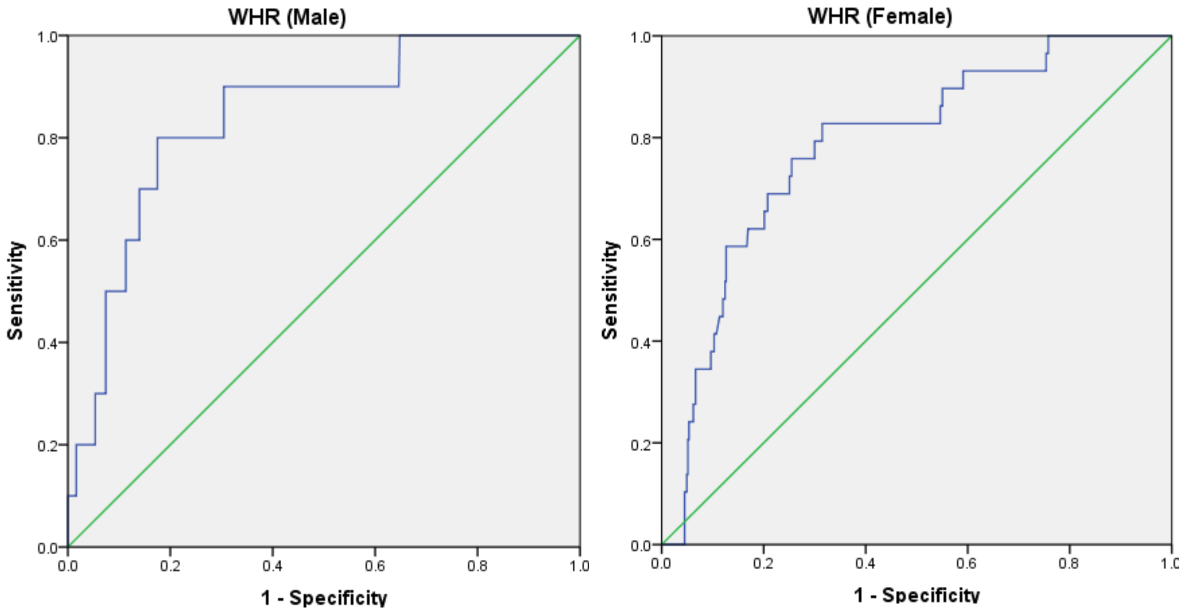

Figure 3.46i & 3.46j: ROC curve analysis for WHR among male and female Limboo individuals (30 kg/m^2 as reference).

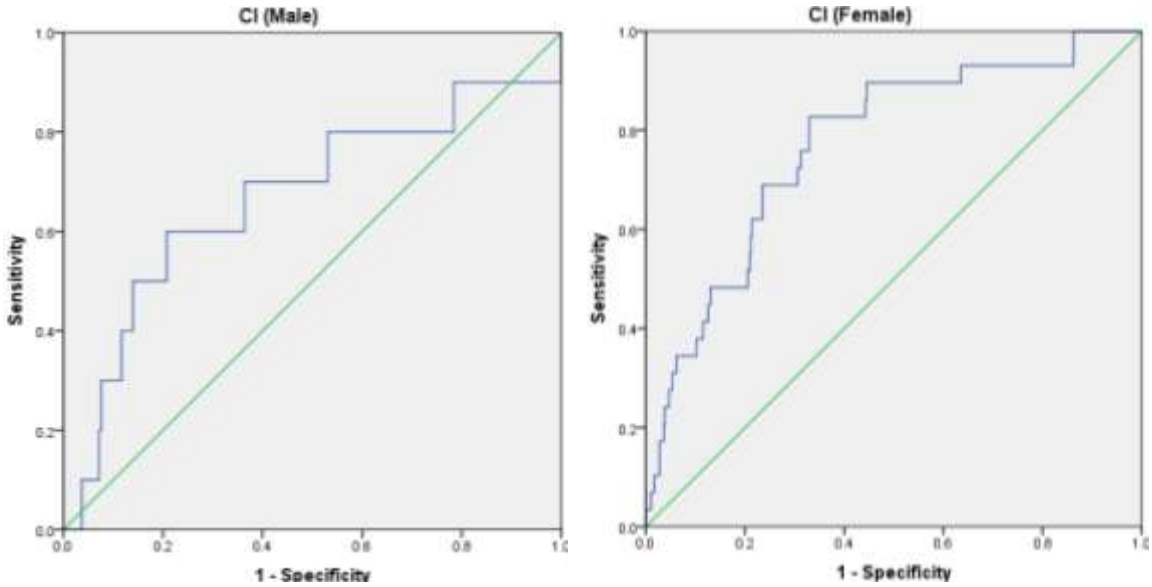

Figure 3.46k & 3.46l: ROC curve analysis for CI among male and female Limboo individuals (30 kg/m^2 as reference).

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).

Chapter 5

SUMMARY AND CONCLUSION

The present study was conducted among the Limboo individuals of West Sikkim. The study was design to assess the nutritional status using anthropometry and body composition. Further, study analysed the association of demographic, socio-economic and life style factors with nutritional status among the Limboo individuals of Sikkim. The participants of the study were the residents of villages of West Sikkim, selected through multistage sampling method. The studied individuals were adults with mean age of 34.73 years ± 12.47. Adults of this age form working section of a population who are responsible for their family economic needs and welfare. The well being of such adult individuals is important as they are responsible for fulfilling the economic needs of other family members in a country like India. The assessment of nutritional status in a homogenous population of Sikkim was never conducted before as per the literature search using *Pubmed*. The prevalence of underweight was assessed utilizing BMI and MUAC. The prevalence of obesity was assessed utilizing BMI classification of WHO (1995) and WHO (2000). Central obesity was assessed using WC, WHtR, WHR, and CI. The distribution of adipose tissue was assessed using skinfolds measurements in addition to above mention indices. To find out the associated demographic, socio-economic and life style factors with underweight, overweight, and obesity, multinomial logistic regression was conducted. The prevalence of both underweight and obesity were also assessed using combination of above mention indices. The comparative discussion of the findings of the present study with the available Indian and non-Indian studies were accomplished.

5.1 SUMMARY FINDINGS

- The anthropometric and body composition measures like height, weight, armspan, RAL, LAL, MUAC, NC, SH were significantly high among the male Limboo individuals compared to female Limboo individuals. Interestingly, the measures of body adiposity such as WC, HC, TSF, BSF, SSF, and SISF were significantly high among female Limboo individuals compared to male Limboo individuals.
- Similarly, indices like CRI, TUA, UMA, BFMA, FFM, and FFMI were observed higher among male Limboo individuals and indices of body adiposity were observed high among female Limboo individuals. The adiposity indices were BMI, BAI, WHtR, WHR, CI, UFA, AFI, PBF, FM, and FMI.
- There was no consistency in the sexual dimorphism observed in the adiposity indices among different populations cited in the present study, which could be the result of increasing obesity among those populations.
- The height, SH and TSF among male Limboo individuals and height, SH, TSF, BSF and SISF among female Limboo individuals were observed declining in 50-64 years. Increase in NC, WC, and HC during 30-49 years age was observed irrespective of sex.
- The measurements like MUAC, BSF, SSF, and SISF among males and weight, MUAC, and SSF among females were high in the 30-49 years age group.
- The derived indices increasing during 30-49 years age among both male and female Limboo individuals were BMI, BAI, WHtR, WHR,

CI, FFM, and FFMI. Only among females declined in BMI was observed during 50-64 year of age.

- The indices like TUA, UMA, BFMA, FM, and FMI was observed changing across age groups of irrespective of sex with peak in the 30-49 years age group and then decline.
- The declined in PBF and UFA was observed irrespective of sex during 50-64 years of age. However, increase during 30-49 years of age was only evident among males.
- The mean height of the Limboo adults of the present study reveals relatively stressful environment during childhood which has implication in the prevalence of high obesity and related diseases. However, many other Indian population heights were observed below the mean height of the Limboo individuals of the present study which suggest diseases environment during childhood among these populations of India.
- The mean BMI reported from south India and urban populations of India were higher than the mean BMI observed in the present study. The reported mean BMI of rural and tribal populations of India were lower than the present study.
- The observed central obesity mean values of the present study were well above the reported mean values of different populations of rural and tribal region of India. A population of Northeast India was reported with cardiometabolic risks even in lower mean values of BMI, WC, WHR, and WHtR than the Limboo individuals of the present study.

- Studies reported from India including the present study observed increased truncal fat deposition using skinfolds, which could be function of increasing adiposity and life style modification.
- The comparison of mean PBF of different Indian populations with the Limboo adults of the present study has shown relatively high adiposity among other populations. This condition specifically among tribal and rural population was alarming, which may lead to sarcopenia as most of these population were undernourished until recently.
- The prevalence of undernutrition observed among the Limboo individuals of the present study was 7.56% according to BMI and 10.18% according to MUAC. The sex specific undernutrition among men and women was 6.85% and 8.27%, respectively as per BMI. The prevalence based on MUAC was 6.45% and 13.91%, respectively among men and women in the present study. The prevalence rate observed was lower compared to tribal and non-tribal populations of India. However, low prevalence does not mean absence of undernutrition. Infact WHO has considered such rate of prevalence of undernutrition as warning sign and worth a concern.
- The prevalence of overweight and obesity was observed 21.37% and 4.03%, respectively among the Limboo individuals of the present study. The sex specific overweight was 18.35% for male and 24.4% for female. Similarly, obesity observed was 2.23% and 5.85% among male and female individuals of the present study, respectively. These results were obtained using traditional classification of BMI (WHO 1995).

The sex difference in the prevalence was significant ($p < 0.05\%$) both in overweight and obesity.

- The prevalence increased when Asia-Pacific classification was used. The corresponding prevalence of Overweight, Obese I and Obese II according to Asia-Pacific BMI classification was 17.14%, 21.57% and 3.93% in the present study Limboo population. The observed overweight was equal among (17.14%) both sexes, and obese I (24.40% vs.18.75%) and obese II (5.85% vs. 2.02%) were significantly ($p<0.05$) high among female than male Limboo individuals.
- The age group 30-49 years was observed with high prevalence of overweight and obesity using traditional BMI classification (WHO, 1995) and Asia-Pacific classification (2000), The Limboo female individuals were affected in most of the age groups except in case of overweight given by Asia-Pacific classification where men were more overweight.
- The prevalence of overweight and obesity was higher compared to the prevalence observed among other population of Northeast, India and closer to the prevalence observed among city dwelling populations of India.
- The central obesity indices have given higher prevalence than the prevalence given by traditional BMI criteria (25.20%) and Asia-Pacific criteria (42.64%). The prevalence of central obesity observed using WC, WHtR, WHR and CI was 34.98%, 65.52%, 97.18%, and 67.54%, respectively. The male Limboo individuals were observed highly at risk given by WHR and female individuals at high risk according to

WC, WHtR, WHR, and CI. The sex difference in the prevalence of central obesity was highly significant ($p<0.001$) among the Limboo individuals.

- The prevalence of obesity given by combination of BMI with WC, BMI with WHtR, BMI with WHR, and BMI with CI among Limboo male individuals was 42.94%, 34.88%, 37.90%, and 21.17%, respectively. The respective prevalence obtained for Limboo female individuals was 10.89%, 46.77%, 46.77%, and 45.16%.
- The normal weight centrally obese individual is normal weight by BMI and obese by central obesity indices like WC, WHtR, WHR, and CI. Such combinations each of central obesity indices with BMI have observed normal weight central obesity prevalence of 16.13% (WC and BMI), 13.91% (WHtR and BMI), 61.09% (WHR and BMI), and 22.38% (CI and BMI) among male Limboo individuals. The corresponding prevalence among Limboo female individuals was 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 combination of WHR with BMI.
- The over fat individuals were less (1.00-7.96%) in the present study as indentified using Niemen (1995), Muth (2009), and commonly used cut-offs of 25% for men and 30% for women. The relatively low PBF in the present study population was observed compared to available studies on Indian and Non-Indian populations.
- The normal weight obesity using BMI and PBF was nearly absent (0.20%) in the present study however, the individuals with Overweight

(male: 0; female: 0.60%), Obese I (male: 0.60%; female: 5.85%) and Obese II (male: 0.60%; female: 4.84%) was found with elevated PBF. Females were mostly at risk in the present study.

- The prevalence of high FMI was 7.96% which was higher than the observed elevated PBF using different criteria in the present study. However, only low FFMI was observed among the studied male individuals and normal FFMI was absent as per the criteria used.
- Limboo individuals of age group 30-49 years were less likely to get underweight in the present study.
- The individuals falling under manual occupation, 30-49 years age group, married individuals, UM SES, LM SES, family monthly income > ₹ 10,000 and females were more likely to be overweight. Similarly obesity was observed with non-manual occupation, 30-49 years age group, 50-64 years age group, upper middle SES and female individuals.
- Central obesity observed using WC was likely to be among individuals of female sex, middle age, old age, married, non-manual, manual, upper middle SES, and family monthly income > ₹ 10000. This also applies to WHtR excluding family monthly income which was not influencing WHtR in either direction.

5.2 LIMITATIONS

- There could be other factors not considered by the present study influencing prevalence of underweight, overweight, obesity and central obesity among Limboo population in the present study.

- The rising overweight and obesity among the various populations is considered as results of changing diets, dietary behaviours, and physical activity. However, these aspects of nutritional assessment were not included in the present study. Further studies with inclusion of such dietary assessment and physical activity level may provide clear picture of factors behind such escalated obesity.
- The use of available cut-offs of PBF may not be adequate because until now there is no cut-offs for PBF recommended by WHO.

5.3 RECOMMENDATIONS

a. Health worker should be trained to understand the different level of obesity and associated risk.
b. The health centre and clinics should introduce use of simple anthropometric indices like BMI and WC, which will be effective in the mitigation NCDs related to obesity.
c. Escalated normal weight central obesity and overall central obesity need immediate attention.
d. Individuals should be educated about importance of diet and physical activity in promoting health and well being.
e. Population based survey on prevalence of NCDs along with data on diet, physical activity, and nutritional status is the need of the hour.
f. The hidden hunger and food insecurity should be understand well and address with proper planning.
g. Planning of urban area should consider the space to promote physical activity.
h. The present study has given cut-offs for NC and BAI which are relatively new measures of adiposity.

i. Further, studies on nutritionals assessment should be conducted among children and elderly.

5.4 CONCLUSION

The prevalence of undernutrition in the present study compared to other populations of India was low. The undernutrition is declining in Sikkim. However, the prevalence observed in the present study was higher than the reported prevalence of NFHS-3 and NFHS-4 for Sikkim. Further, a step towards reduction of undernutrition is important because it is still a warning sign. Overweight and obesity observed in the present study was relatively higher than the reported prevalence of rural and tribal population of India. Obesity predisposed individuals and populations to various NCDs like diabetes, cancer, cardiovascular diseases, etc. Overweight and obesity in the present study was assessed using BMI classification of WHO (1995) and WHO (2000). The BMI classification for Asia-Pacific region (WHO 2000) was put forth because Asians were predisposed to MetS and diseases at lower BMI compared to their European counterparts. This phenomenon is well established among Indian populations. The present study too observed high prevalence of overweight and obesity among Limboo individuals using Asia-Pacific BMI classification (WHO 2000). Susceptibility to NCDs at lower BMI among Indian compared to their European counterparts and high PBF among Indian compared to European counterparts with same BMI was explained by high prevalence of central obesity among Indians. The Limboo individuals of Sikkim studied in the present study was observed with high prevalence of central obesity. The central obesity was 2-3 folds higher compared to obesity given by BMI. The female Limboo individuals were more at risk of central obesity related diseases than male Limboo individuals. The high prevalence was observed among female and middle age individuals. There was high prevalence of normal weight centrally obese individuals who are normal by BMI alone and defined obese by any one central obesity indices like WC, WHtR, WHR and CI. Studies have shown such individuals at high risk of MetS and cardiovascular dysregulation. Interestingly, normal weight obesity define using BMI and PBF was not observed in the present study, which indicates diseases risk among the studied population may be due to visceral fat deposition not total fat. Further, the Limboo population were observed with lower prevalence of elevated PBF by different criteria used in the present study. The condition like sarcopenia was observed among different Indian population, owing to prevalent undernutrition and reported high PBF. The present study speculate propensity to sarcopenia because of low FFMI and not because of high PBF among the Limboo individuals of the present study. The body composition component like FMI was observed high and FFMI was observed mostly low using criteria given by Khongsdier (2005). The sarcopenia can be suspected among the studied population based high FMI and absent of normal FFMI, which needs further investigation. This is the high time for stack holders to take necessary steps for prevention of obesity related death and disability.

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ANNEXURE I

NUTRITIONAL ASSESSMENT OF LIMBOO ADULTS OF SIKKIM

Department of Anthropology

University of North Bengal

Sl. No.	Village Name:	DOI:

Name:		
DOB:	Age:	Sex:
Birth Order:	No. of Siblings:	Marital Status:
No. of Children	Education:	Occupation:

Family Monthly Expenditure:
Monthly Income:
Any Other Earning Member/ Source:
His/Her/Source Monthly income:
Family Monthly Income (sum of above incomes):
Family type: Nuclear ( ) Joint: ( ) Extended ( )
No. of Family Members:
No. of Dependent Family Member: Below 15 years Above 70 years
Land Holding:
House Type: Kacha Pakka Semi-Pakka
Drinking Water: Govt. Supply ( )Piped from Springs ( ) Others* ( )
Hygienic Toilet Facility: Commode ( ) Pit ( )

*Specify; ( ) Tick the appropriate respond

ANTHROPOMETRY

1	Height:	8	Hip Circumference:
2	Weight:	9	Sitting Height:
3	Armspan:	10	TSF:
4	Arm length: L R	11	BSF:
5	MUAC:	12	SSF:
6	Neck Circumference:	13	SISF:
7	Waist Circumference:		