CHAPTER 2
REVIEW OF LITERATURE

Review of literature is very important as it helps the researchers to frame the research topic in context to previous studies. The study of preceding related literature is essential to avoid duplication of the work and to undertake the unexplored area for investigation. Extensive literature review gives a holistic idea about contemporary research in the related topic and adds a new direction to a research problem that had already been investigated. An attempt has been made to review the literature related to the research problem in this chapter.

2.1 GROWTH AND DEVELOPMENT AT ALTITUDE

2.1.1 International Status

Numerous studies have been conducted in different parts of the globe to find out the impact of altitude stresses on human biological traits. To study the inter-population differences in growth, the early naturalists travelled to locales outside of their homelands, where they measured and observed the populations they encountered. Subsequent research produced a considerable data on a range of anthropometric dimensions and indices. However, children were measured only rarely and it was not until much later that we find any significant information about growth. In America, almost all of the early information comes from studies of native North American children and was collected under the direction of Franz Boas and Clark Wissler (Wissler 1938; Boas 1940).

To assess Physical growth various studies have been conducted on populations living at high altitude using WHO and NCHS reference standards (Frisancho and Baker 1970; Stinson 1980; Pawson et al. 2001; Bolanos et al. 2009) and the prevalence of obesity among the children and adolescents who live in these areas (Omori and Greksa 1993; Obert et al. 1994; Mispireta et al. 2007). These studies specify that growth and development of populations that live at high altitudes suffer a negative impact from altitude-induced hypoxia, (Bolanos et al. 2010).
Clegg et al. (1972) observed the effects of two widely differing environments on the growth and maturation of children from a presumed genetically homogeneous Ethiopian population. Major environmental differences included altitude above sea level, temperature, probably rainfall and humidity, together with the incidence of infectious disease. The results indicated that highland children, particularly boys, were taller, heavier and bigger in most physical dimensions than lowland children. In both groups skeletal maturation was retarded (by American White standards) during later childhood; this retardation was more marked in lowlanders. However, there was a marked acceleration of skeletal maturation during early puberty. Haemoglobin values increased much more rapidly in highland children, but surprisingly, differences in chest dimensions were not particularly marked. They concluded that hypoxia of the degree found in the high-altitude group (approx. 3000 m) was not sufficient to affect adversely the growth of children. On the other hand, the increased incidence of infectious disease in the 'lowlands' (approx. 1500 m) and possibly the raised ambient temperature may restrict growth and maturation of children living in this environment. Thus, in contrast to the situation in other high-altitude parts of the world, the highlands in Ethiopia appeared to be more favourable to growth than the lowlands.

Miklashevskaia et al. (1973) found that the high altitude boys in Tien Shan were shorter than their low-altitude counterparts and the high altitude girls showed a similar trend. The high altitude Quechuas or Mestizos exhibited a slow growth in body size compared with the lowlanders. Hoff (1974) showed that the low altitude Quechuas adolescent boys and girls of Peru had greater values in all bodily measurements except chest width and depth which were greater among the high altitude children.

Frisancho (1976) showed that the Peruvian Quechuas of Nunoa were smaller than the American and the sea level Peruvian but had greater circumferences. He opined that the Nunoa males and females had a very prolonged growth period and poorly defined and late adolescent spurt. Pawson (1976) did a comparison between Sherpa (high altitude), Tibetan low altitude Quechua (high altitude) Ethiopian (high altitude) Ethiopian (low altitude) and US White.
The Peruvian population is located at an altitude of 4000 to 4800 m whereas the Nepalese population is located at an elevation of 3475 to 4050 m. Results suggested that the Sherpas more closely resembled the Tibetans than other populations. Quechua males were generally taller than either Tibetans or Sherpas, except those over 13, who were similar in height to Tibetans. Ethiopian males from high and low altitude were consistently taller than other groups but fell short of the height attained by U.S children at the given age. The Tibetans and Sherpas were consistently lighter than the high altitude Quechua boys. Ethiopians (high altitude) were almost always heaviest even though they were much lighter than U.S children. Quechua children had the largest chest circumference; they were surpassed by Ethiopians. On the other hand, the chest dimensions of Sherpas and Tibetans children were generally less than those of other populations especially after the age of 13 years. Moreover, Tibetans had greater overall amounts of body fat than the other populations throughout age distribution studied.

Pawson (1977) showed that stature increased more rapidly among males and females Tibetan children were compared with the Sherpa children. He further showed that Tibetan boys over the age of 12 years were significantly heavier than the Sherpa boys, though there was no difference between individuals under age 12 years. In females, this trend was reversed. He also showed that among males chest circumference was similar among Sherpas and Tibetans and opined that the Tibetans children underwent an earlier pubescence. Thus, from these data, it might be suggested that the cessation of growth occurred at a later age and a longer period of growth existed in the high altitude.

Beall et al. (1977) stated that size differences between high and low altitude populations were larger in adolescence (12-18 years) than in childhood. Hoff and Garruto (1977) examined the effect of high altitude on heart rate and blood pressure of young males in two genetically allied Quechua populations living at high and low altitudes in southern Peru. The data were obtained from Quechua males ranging in age from 12 years to mid-twenties by subdividing into two groups, adolescents (12-18 years) and adults (18 years and
older). It was found that significant differences existed between the high and low altitude Quechua, the later showing greater bradycardia and higher pulse pressure.

The highland Mestizos had a slower growth in stature and weight than the sea level counterparts in Andean highland (Frisancho 1978). In Chile, the high altitude Aymara children were shorter, lighter and leaner but with more expansive and rounder chest than the sea level residents (Mueller et al. 1978). In later study they showed that the Bolivian highlanders were similar in stature, weight and chest morphology compared with the Chilean highlanders but both of them were different from lowlanders. In Bolivia, the high altitude Aymara children of Ancoraimes showed delayed growth in stature and weight, little sexual dimorphism and greater chest dimensions than low altitude US residents (Stinson 1980).

Beall (1981) observed that a delay in stature and weight was manifested by the Mugu population of Nepal. They were found to be shorter and lighter than Quechuas. She also observed that the Mugu males were shorter and lighter than the Bods of Leh in the Western Himalaya, India. Stinson (1982) in her later studies in Bolivia among the upper socio-economic status children of European ancestry found that the growth processes were being affected by the duration of altitude exposure, for instance, children who have lived all their life at high altitude were similar than those who had spent less time at high altitude, but she failed to find any relationship between altitude and chest dimension. Grekka and Hass (1982) showed that high altitude born children of European ancestry in La Paz, Bolivia were significantly fatter and had larger chest circumferences than the low altitude born children.

Picon-Reategui (1982) found that hypoxia has a stressful effect on the physiology of an individual. However, other components of the high altitude environment, such as cold, rough terrain and low vapour tension, may also affect metabolic process and, nutrient requirement. Gonzales et al. (1982) reported that the stature and the weight of children for ages 7 and 19 years were significantly greater in 1980 than in 1945 which might be due to earlier sexual maturation.
Beall (1984) reported that the Upper Chumikbas of Nepal were below the US 10th percentile of stature-for-age throughout the growth and the growth processes were slower and longer. But, compared to other Himalayan populations they were faster-growing population. She also observed that they shared with other Himalayan populations, the characteristics of small body size and a longer growing period. Stinson (1985) compared the chest morphology of Aymara and the French school children in Bolivia and found that chest width and depth of French school children were larger than those in the Aymara. Greska (1986) opined that there was a delay in linear growth among highlanders. He showed that the growth pattern of highland European and Aymaras was very similar to those of lowland US children but quite distinct than those of Quechuas of Nunoa.

Post et al. (1994) conducted a study on Bolivian boys living at high and low altitude. They obtained dietary information by interviewing child and mother by 24 hours recall method. Results revealed that the energy intake of high socio-economic status boys was significantly higher than the intake of lower socio-economic status at both altitudes.

Abolfotouh et al. (1995) studied the growth of school boys in a high altitude area of Saudi Arabia. The results revealed that the weight-for-age were lower than those NCHS references. They also found that weight-for-height was lower than those pertaining to the reference population for all ages. They concluded that the use of NCHS standards is not appropriate for the assessment of growth of schoolboys.

Weitz and Garruto (2004) compared the growth of indigenous Tibetan children and children of Han descent who have been born and raised at the same high altitudes, and under similar socio-economic conditions. Results showed that Han–Tibetan differences in body size do not occur systematically for any measurement. Thus they indicated that there are no differences in general growth between the two groups at high altitude in Qinghai. Both groups grow more slowly than urban children at low altitude in China. It was concluded that genetic similarities cannot be ignored. However, Han–Tibetan differences in thorax dimensions are likely a consequence of population (genetic) differences in the response to hypoxia during growth.
Malkoc et al. (2012) conducted a study to analyse Turkey adolescents living at an altitude of 2000 meters. They compared results with adolescents living at low altitude in Turkey and found that higher values for height, weight and BMI in adolescents living at low altitude could not be attributed to altitude effect. However, the effect of socio-economic status and micro-climate also could not be discarded.

Little et al. (2013) analyzed the effect of altitude on growth status of 11,454 children and adolescent from Oaxaca, southern Mexico from (6 to 14) years. It was found that altitude had negatively affected height, in contrast to that weight which was not affected by the increase in altitude. There was approximately 36% of the reduction in height and an increase of 54% in BMI at high altitude.

Xi et al. (2016) conducted a cross-sectional study on 2,813 healthy children and adolescents aged (6 to 12) years living at an altitude of 3,658-4,500m in Tibet. Results were compared with published data from other population living at high altitude. It was revealed that physical growth and development of children and adolescents in Tibet and Andeans followed a similar pattern. This study concluded that Tibetan and Andean populations had adapted differently to high altitude hypoxia as well as socio-ecological factors such as poor nutrition.

2.1.2 National Status

Malik and Singh (1978) carried out a cross-sectional study on Bods of Ladakh from (11 to 19) years living in Leh at an altitude of 3,4514 meters. Obtained results were compared with other populations living at sea level to find the growth pattern. Results revealed that adolescent spurt was not well defined among Bod highlanders, they grew faster than plain dwelling Indians and were observed taller and heavier at 19 years. Bod adolescents exhibited greater chest circumference than the lowlanders.

Singh (1980) conducted a cross-sectional study on 786 boys and 578 girls among the hill tribe, Gaddis aged from 4 to 20 years inhabiting moderate altitudes and living under slight nutritional stress, from Bharmour, Chamba. It
was found that the peak adolescent spurt was experienced during 13 to 14 and 15 to 16 year age intervals in girls and boys, respectively. The girls finished their growth earlier than the boys. The girls possessed more weight than the boys for similar heights during and after adolescence. Gaddis were found to have bigger chests in relation to stature which might be due to altitudinal adaptation in the Gaddis. Large calf muscles were found to have an association with load carrying in the hills and in corresponding to small amounts of body fat in the Gaddis which might contribute to increasing the mechanical efficiency in carrying loads uphill.

Kapoor and Kapoor (2005) conducted a study to understand the morphological and physiological variations among the temporary and permanent residents of Leh Ladakh. They divided subjects into four categories i.e. Ladakhi Bods, Ladakhi Muslims, Tibetans and temporary residents of Leh respectively. Results revealed that Ladakhi Bods were heaviest and possessed the broadest hip and lower trunk, Tibetans had broadest chest and most developed musculature. Temporary residents were found to be tallest among all the four groups and possessed narrowest chests. Statistically nonsignificant differences were observed in weight among all the four groups.

Malhotra et al. (2006) carried out a cross-sectional study on Spitian boys from 5 to 20 years. They found that the adolescent spurt was delayed in Spitian boys. This seems to be an adaptation to low partial pressure of oxygen. A very late adolescent spurt was seen in chest circumference that might be giving an edge to the high altitude populations. The proportionally larger chest cage size has emerged as the most important morphological characteristic in various studies.

Singh et al. (2007) conducted a cross-sectional study to elucidate the age changes in the frame size from skeletal diameters of boys from 5 to 20 years inhabiting Spiti valley. Skeletal measurements of humerus bicondylar diameter, femur bicondylar diameter, bicromial diameter, and bicrystal diameter were taken on 636 subjects. The Spitian young adults between 18 to 20 years could be designated as on the ‘borderline’ between the small and medium frame size. Further comparison of the mean values of humerus and
Review of Literature

Femur bicondylar diameters expressed in percentage of their adult values amongst themselves indicated that femur bicondylar diameter surpasses in maturity to humerus bicondylar diameter up to 15 years. However, after the age of 15 years, humerus bicondylar diameter is ahead of femur bicondylar diameter in its maturity status.

Tripathy and Gupta (2007) conducted a study among three refugee settlements living at different altitudes to described physical growth age ranged from 2 to 40 years. They found that Tibetans at high altitude were taller and heavier compared to Andean highlanders. Tibetan children and adults of both sexes at low altitude in India were advanced in terms of height, weight, skinfold thickness at triceps and upper arm circumference compared to Tibetans at high altitude. Greater relative sitting height and lesser leg length at high altitude than at low altitudes were discussed in terms of the effect of altitude, temperature, and nutritional status.

Singh et al. (2007) conducted a cross-sectional study among Spitian boys of 5 to 20 years to understand changes in body proportions of different parts. Results suggested that the weight proportional to height was relatively much more up to 7 years of age. The boys were relatively thinner at age of 15 years, they had the least relative body mass. From 15 years onwards, Spitian boys again started putting on more relative weight. The proportional chest circumference was positive during 5 and 8 years of age and thereafter it was negative. It was also inferred that 14-year-old boys possessed the least chest circumference in proportion to height as compared to those at all other ages. It was during late adolescence that they started growing in the chest circumference very fast.

Singh et al. (2008) conducted a cross-sectional study among Bodhs of Lahaul from 11 to 21 years of age to assess the pattern of growth and respiratory functions. They compared Bodhs of Lahaul with Bods of Ladakh. Results revealed that Bodhs of Lahaul and the Bodhs of Ladakh exhibited a faster rate of growth. The Bods of Ladakh and the Bodhs of Lahaul were characterized by a larger chest size.
Bhasin et al. (2008) studied the growth patterns and physiological variable among 2034 adolescents from various population groups of Jammu and Kashmir. The results of the study showed that various Dogra groups have better growth rates and had higher values of physiological variables as compared to their peers. They observed that the physical growth status of various population groups is a proxy indicator of their socio-economic status and nutritional intakes. Population groups of Ladakh region exhibited higher values of various chest measurements and lung functions owing to hypoxia as compared to adolescents from Jammu and Kashmir.

Talwar et al. (2011) investigated growth pattern in body fat, skeletal and circumferential traits along with the regional distribution of fat among Kullu valley. The study showed that the increases in their body mass index were largely due to the fat-free mass than body fatness. Rajput boys of Kullu were taller and heavier than Rajputs of Bharmour and Kanets of Kinnaur at all ages.

2.2 PHYSIOLOGICAL VARIABLES

2.2.1 International Status

Extensive research has been carried out to find the variation in blood pressure and is considered as a subject of concern because high blood pressure is a common risk factor for cardiovascular disease (Nissinen et al. 1988; Kaplan and Opie 2006). It is generally alleged that both SBP and DBP are lower in the individuals living at high altitude (Clegg et al. 1976; Frisancho 1979; Hanna 1999). Early exposure to high altitude leads to increase in blood pressure that is mainly due to increase autonomic or sympathetic activity (Wolfel et al. 1994; Calbet 2003). It is suggested that SBP and DBP gradually decline, after years of living at high altitude, even falling below those observed at sea level (Mirrakhimov 1978; Hanna1999)

Marticorena et al. (1969) found that the long-term residents and natives of high altitude Andes show reduced BP, lower rates of hypertension, and lower cardiac anomalies. Blood pressure was found to be less in some other high-altitude populations like Sherpas (Basu and Gupta 1984), natives of Tien Shan and the Pamir (Mirrakhimov 1971) and the people in the Ambars region
in Ethiopia (Beall et al. 1997). The cause of the decline in BP at high altitude has been attributed to relaxation of the vascular smooth muscle, an increase in collateral circulation, increased vascularization, higher red blood cell level and diseases like respiratory tract ailments (Frisancho 1979, 1993; Heath and Williams 1995; Leon-Velarde et al. 1993). Some studies showed that, high-altitude residents showing higher BP (Harrison et al. 1969; Clegg et al. 1976).

Hoff and Garruto (1977) tried to find out the effect of high altitude on heart rate and blood pressure of young males in two genetically interrelated, Quechua populations living at high and low altitudes from Southern Peru. The data was obtained from Quechua males ranging in age from 12 years to mid-twenties by subdividing into two groups adolescents (12-18 years) and adults (18 years and older). It was found that significant differences exist between the high and low altitude Quechua, the later showing greater bradycardia and higher pulse pressures.

Newman et al. (1984) conducted a study on 1417 healthy, urban school children from a middle-class suburb of Brisbane for age 5 to 18 years. Results revealed that girls had reduced grip strength than their male counterparts at all ages. Adolescent boys of 18 years had mean grip strength 60% higher than girls. It was also observed that 'Handedness' influenced grip strength and was most noticeable in children aged over 10 years.

Muntner et al. (2004) carried out a cross-sectional study on adolescents aged 8 to 17 years from National Health and Nutrition Examination Survey. Results found that among Mexican Americans, when compared with non-Hispanic whites SBP was 1.4 mm Hg higher and DBP was 3.3 mm Hg higher in 1999-2000 compared with 1988-1994. They further concluded that blood pressure has increased over the past decade among children and adolescents which were attributable to the increased prevalence of overweight.

Di-Dzietham et al. (2007) tried to find out the trend of high blood pressure among children and adolescents (8 to 17 years. Sample size of (Non-Hispanic blacks and whites, and Mexican American) was obtained from the United States non-institutional population from 1963 to 2002. They observed that blood pressure and high blood pressure reversed their downward trends
10 years after the increase in the prevalence of obesity. Hispanic blacks and Mexican American had a greater prevalence of high blood pressure and pre-high blood pressure than non-Hispanic whites.

Maximova et al. (2010) evaluated the sex-specific impact of changes in anthropometric characteristics on systolic blood pressure in a cohort of 1293 adolescents in Montreal, Canada. Using sex-specific individual growth models, they concluded that during adolescence although the difference in the increase of height was reasoned for the sex difference in the mean systolic blood pressure changes but the effect of the increase in weight or body fat was similar in both sexes on systolic blood pressure changes.

Zhang et al. (2012) conducted a study among 5,456 students aged between 7 to 18 years from Hainan province, China to assess the nutritional status and the blood pressure and their relationship. Observations declared that a high prevalence of thinness was observed in male and female children and adolescents. This study concluded that thinness, especially mild thinness, was a major public health problem among children and adolescents in Hainan province of South China. Overweight and obesity were strongly associated with pre-hypertension and hypertension among studied students.

Mehdada et al. (2013) aimed to estimate the prevalence of hypertension among 167 subjects aged from 11 to 17 years of adolescents, to assess the relationship of systolic and diastolic blood pressure with body fat mass, body mass index and waist circumference. Results signify that both systolic blood pressure and diastolic blood pressure were significantly higher in overweight and obese adolescents in comparison to healthy-weight groups. Systolic blood pressure was significantly higher in boys than girls. Moreover, the relationship of blood pressure with BMI appeared to be more significant than with WC and BFM.

Espinoza et al. (2014) studied the effects of high altitude on morphophysical patterns, perceptions and attention capacity among students from Putre and Africa, Chile. The study was carried out on 80 students aged 14 to 16 years old from the municipalities of Putre and Africa with each group composed of 20 males and 20 females. Height, weight, BMI, heart rate, and blood pressure were obtained. The results determined that the population
from Putre had less weight and height than students from Africa. Males exhibited a significant decrease in heart rate and females had lower systolic and diastolic BP than in the assessed sea level population.

Song (2014) analyzed the correlation of blood pressure with height and weight in 3363 (1757 boys and 1606 girls) Korean adolescents in the age group 10-19 years). This study concluded that in Korean adolescents, weight had a greater effect on systolic blood pressure than height in both the normal-weight and overweight groups. Diastolic blood pressure was mainly affected by height in the normal weight group whereas weight was the major determinant in the overweight group. It was found that consideration of weight might be necessary for the establishment of reference BP standards.

Zhang et al. (2014) conducted a study, on 38,822 students (19,456 boys and 19,366 girls) aged 7–17 years, to examine the distribution of waist-hip ratio and the relationship with blood pressure among children and adolescents in Shandong, China. The study revealed that WHR levels in Shandong boys and girls were lower than those from German and Pakistani. In both boys and girls, the Z-scores of SBP and DBP were all significantly lower in group 1 than in group 2, indicating that children and adolescents with the high waist-hip ratio to have higher blood pressure values.

Ahadi et al. (2015) carried out a survey on 13,486 children and adolescents (6 to 18 years) to assess the association between breakfast intake with anthropometric measurements and blood pressure among Iranian children and adolescents. It was observed that the prevalence of overweight and obesity among breakfast skippers were higher than non-skippers counterparts. So, they concluded that regular breakfast consumption is significantly associated with lower body fatness and healthier dietary habits.

Weitz and Garruto (2015) compared forced vital capacity of Tibetans with Han, who were born and raised at high altitude aged between 6 to 20 years and had spent their entire lives at Qinghai Provence, china. Their findings suggested that forced vital capacity values of Han boys born and raised at high altitude were generally lower than those of Tibetans through age 15 in girls and 16 in boys. These differences were largely explained by variation in
stature and chest circumference. However, forced vital capacity values among older adolescents and adults of Tibetans were significantly larger than those of Han.

Ahmed et al. (2016) investigated the effects of high altitude on systemic blood pressure among 145 children (high altitude, 3150m) 155 children (low altitude, 500m). Weight and height were measured for Body mass index, triceps skinfold for a percentage of fat mass, waist circumference, and hematocrit value was made for the study. This study revealed that weight and height were significantly higher in high altitude children than their counterparts at low altitude. There was no significant difference in mean BMI values between the two groups. Higher (SBP) and (DBP), hematocrit value, triceps skin fold, waist circumference, and FMP in children were observed among those living at high altitude than in low altitude.

2.2.2 National Status

A cross-sectional study was undertaken by Rao et al. (2005) on 1,525 Khond boys and 1,132 Khond girls aged from birth to 18 years in schools situated in the tribal areas of Visakhapatnam district of Andhra Pradesh. It was observed that there was a progressively increasing trend in all the dimensions with advancement in age. The study revealed that the adolescent growth spurt or highest peak velocity among boys was found to be at (12 and 14 years). Results revealed that blood pressure and pulse rate increased with advancement in age with few fluctuations. It was further concluded that Khond boys and girls were shorter, lighter with a broader chest and head circumference than national standards.

Tripathy and Gupta (2007) worked on 1091 adolescents at four different settlements, one being at high altitude (3,521 m) and three at low altitudes i.e. less than 1000m. They found that age was highly correlated with adult blood pressure for both males and females. It was concluded that lower blood pressure values among Tibetan children and adolescents at high altitude suggest that altitude affects blood pressure.

Singal et al. (2008) assessed the body mass index, blood pressure and hemoglobin among Jat Sikh children adolescent aged (10 to 16) years of Patiala. The study consisted of Jat Sikh children in the age group of 10 to 16
years. This study suggested that BMI values were slightly more in boys in all age groups except at 11 and 15 years. The boys were found to be significantly heavier and taller than girls at most of the age levels from 12 to 16 years. Blood pressure has also been found to be more in boys at all ages except at 12 and 13 years. The hemoglobin level was found to be significantly more in boys at all age groups and after 12 years it had increased more markedly in boys.

Lad et al. (2013) conducted a study on 180 students to find a correlation between the BMI, body fat percentage and hand grip strength along with endurance. Body fat percentage was measured by using bioelectric impedance. It was found that the underweight and overweight groups had a lower grip strength and endurance than the normal weight group in males, but not in females. Hand grip endurance tended to decrease in males as well as in females. The increase in the body fat percentage might decrease the handgrip endurance but not the handgrip strength.

Talwar et al. (2003) carried out a cross-sectional study on a sample of 400 Rajput adolescents (200 boys and 200 girls) ranging in age from 10 to 17 years from Solan district. The study aimed at studying age changes in physiological variables and their relationship with anthropometric variables. The study revealed positive and significant correlations of weight and height with body mass index, SBP, and DBP in both the sexes. BMI correlated significantly with grip strength as well as SBP and DBP in both the sexes. However, both SBP and DBP exhibited a negative correlation with waist-hip ratio among Rajput adolescents.

Brar and Badaruddoza (2013) evaluated the blood pressure of 1225 adolescents aged 10-18 years using anthropometric measurements. They observed that 11 and 12 years of groups were more susceptible for pre-hypertension, whereas, 10 years and 14 years of age were more susceptible for hypertension. Using multivariate regression analysis, it was found that systolic and diastolic blood pressure is significantly associated with weight, BMI and waist circumference.
Verma and Singh (2014) studied the association of FMI and FFMI with blood pressure on 733 school children of both the sexes between age group between 10-18 years old. The study found that relationship of BMI with a mean blood pressure of boys was more than that in girls. They concluded that obesity itself could be cause to hypertension by various mechanisms. The Fat free mass index has a more strong association with blood pressure than the fat mass index in the adolescent population irrespective of gender. The blood pressure was having a positive correlation with lean body mass index than that with fat mass index in all subjects. Though for the reduction in hypertension, reducing body fat may remain a key measure to check on hypertension.

### 2.3 NUTRITIONAL STATUS

#### 2.3.1 International Status

Ramirez (1993) assessed a sample of healthy adolescents from 122 nuclear families to find fatness and fat distribution using anthropometric measurements, bioelectric impedance, and ultrasound images. The results showed that there was significant family resemblance for the level of fatness. There was also a significant resemblance between sibs of the same sex for the fat distribution patterns. The results also showed that subcutaneous fat thickness has a strong genetic component which shows (60-65% of the variance).

Eisenmann et al. (2003) examined the growth status and prevalence of underweight, overweight, and obesity among 263 Hopi children aged from 6-12 years. The results were obtained using age - and sex- specific reference data for body size variables. The results revealed that approximately 23% of Hopi children were classified as overweight and an additional 24% were classified as obese. Only two subjects were categorized as underweight. It concluded that the childhood obesity is major health concern among Native Americans.

Freedman at el. (2005) examined the association of body mass index to levels of fat mass and fat-free mass among 1196 healthy subjects between 5 to 18 years old, with the help of Dual-energy X-ray absorptiometry. The study
Review of Literature

results showed that BMI levels were strongly associated with FMI. The study further concluded that BMI levels among children should be interpreted with caution. It was observed that high BMI-for-age is a good indicator of excess fat mass, and BMI differences among thinner children were largely due to fat-free mass.

Klein-Platat et al. (2005) conducted a cross-sectional study on 2714 adolescents from the eastern part of France. Body mass index and waist circumference were measured. It was found that structured physical activity was inversely associated with waist circumference, an indicator of total adiposity but also more specifically of abdominal fat. This suggests that physical activity had a beneficial effect on youth metabolic and cardiovascular risks.

Bener and Kamal. (2005) analyzed the patterns of growth in height and weight and the prevalence of overweight among Qatari school children aged 6-18 years. It was observed that mean values for height, weight, and body mass index increased with the age for both boys and girls until the age of 18 years. The growth patterns of the Qatari children, aged 6-18 years, appeared to be comparable with those of the NCHS/CDC reference. The weight-for-age centile curves of the Qatari boys tended to be superior to those of the NCHS/CDC reference until the age of 15 years. They observed that the boys were significantly taller and heavier than the girls in all ages.

Funke (2008) conducted a cross-sectional study to determine the prevalence of undernutrition, overweight, and obesity among 419 school going adolescents (182 boys and 219 girls) aged 10-19 years in the Osun state of Nigeria. BMI for age was calculated and the prevalence of underweight, overweight and obesity was investigated. The study found a high prevalence of underweight and overweight in the adolescents, particularly among boys (underweight) and girls (overweight). The prevalence of obesity was found in girls and none of boys.

Amuta and Houmsou (2009) conducted a cross-sectional study on 600 adolescents to assess the nutritional status of school-aged children (6-17 years) in Markudi, Benue state, Nigeria. The study showed that when the data
was compared to NCHS/ WHO standard, mean BMI was inferior at all ages. The prevalence of under nutrition was 50.66% and schools located in the slum parts of Markudi recorded the highest rate of under nutrition. Males were found to have a relatively high rate of under nutrition (57.44%) than females (44.65%). The study further suggested that the average of school children were undernourished.

Khalid (2008) conducted a cross-sectional study of school children and adolescents to find out the prevalence of childhood overweight and obesity in rural, high and low altitude population of southern Saudi Arabia to identify at-risk groups within these group. He identified risk factors for childhood overweight and obesity in Saudi Arabia. Among these, high altitude was a significant and independent factor.

Haboubi and Shaikh (2009) conducted a cross-sectional survey to measure the nutritional status of adolescents of Indian origin living in India and the United Arab Emirates to estimate the prevalence was of stunting and wasting among adolescents with same ethnic background residing in diverse socio-economic and demographic environments. Results indicated that the rate of stunting was higher in Indian adolescents from India (25.5-51%) when compared with Indian adolescents in UAE (3.1-21%). Thinness was also more in those in India (42-75.4%). When compared with adolescents living in the UAE (4.5-14.4%). They found that improved economic conditions were main factors that favour better expression of genetic potential for physical growth.

Przyslawski et al. (2010) conducted a study to assess the relationship between nutritional status, dietary habits and body image perception among 322 male adolescents aged 17-18 years from Western Poland. Results depicted that the mean values of body weight and height were close to 50th percentile. However, 10.7% of males were underweight, 10.7% overweight and 1.3% obese. The tendency to underestimate the own level of fatness among overweight and obese subjects was observed. Thus, they observed that Polish obese and overweight adolescents showed a tendency to
underestimate their level of fatness and distinguish themselves as “average”,
despite possessing an excessive amount of body fat.

Ejike et al. (2010) did a study to determine the patterns of physical growth and
nutritional status of adolescents living in a low-income semi-urban town in
Nigeria on 625 students aged (10-19) years. Results suggested that under-
nutrition was found to affect 19.36% of the adolescents while 13.12% of the
individuals were overweight/ obese. The prevalence of thinness and stunting
were higher in boys than in girls. Boys were also slightly more obese than the
girls. Under- and over-nutrition co-existed in the population and affected more
boys than girls.

Dabone et al. (2011) conducted a study in Ouagadougou (Burkina Faso) to
assess the nutritional status of school going children. The study was carried
among 649 children (48% boys) aged between 7 and 14 years. Nutritional
status was assessed using WHO criteria. The study showed that the
prevalence of stunting and thinness was 8.8% and 13.7 % respectively and it
was found to be higher in peri-urban areas than urban schools. Malnutrition
and micronutrient deficiencies were also widely prevalent among adolescents.

Adesina et al. (2012) evaluated the nutritional status of adolescents using BMI
as basic criteria. The study was conducted on 960 adolescents from 10-19
years from secondary schools of Port Harcourt. Results revealed the
prevalence of underweight, overweight, obesity and stunting were 6.4%,
6.3%, 1.8% and 5.4% respectively. It was concluded that for females, overall
BMI was significantly higher than males while stunting was significantly more
in males than females. High socio-economic class, higher maternal education,
watching television and ingestion of beverages were contributing factors of
overweight among adolescents.

El-Mouzan et al. (2012) conducted a study to assess the magnitude of
regional difference in prevalence of short stature in Saudi children and
adolescents aged 5 to 17 years. They took a representative sample from
three different regions of the Kingdom of Saudi Arabia (North, Southwest, and
Center) to calculate the prevalence of short stature. They found that both school-age children and adolescents showed the significantly higher prevalence of short stature in the South-western region than the Northern and Central region.

Xiong et al. (2012) examined the body composition of 1,458 children (790 boys and 668 girls) between 5 and 18 years in Chinese children and compared the changing pattern with Caucasian and Japanese counterparts. Results indicated that age and gender related changing patterns of body composition in Chinese children might differ at the different growth stage, and differ with those in Caucasian and Japanese children at the same age period.

Thapa et al. (2013) carried out a study on 575 children below 15 years of age attending the medical camp in Humla and Mugu districts from Nepal and assessed their nutritional status. They found that in Humla district, 28.20% children were undernourished, 8.80% wasted and 22.40% stunted. In the age group 5 to 15 years, thinness was found to be 22.40% and 29.40% in Humla and Mugu respectively. Thus, they concluded that malnutrition (underweight, stunting, wasting and thinness) constituted a major health problem among Nepalese children, especially in mountainous regions.

Lazzeri et al. (2013) described the prevalence of 'graded thinness' in children aged 11, 13 and 15 years in ten European countries and USA (n= 158000) and identified the trends in the prevalence of 'thinness' (at age 18 years) by age and gender. Results showed that the prevalence of grades 1, 2 and 3 of thinness was higher among 11-year-old students compared with the 13- and 15- year-olds in all countries. A higher prevalence of thinness was observed in girls than in boys.

Tamanna et al. (2013) evaluated the physical growth as well as nutritional status among adolescent Garo children in Sherpur district on the basis of anthropometric indices. This cross-sectional descriptive study was conducted among 384 adolescent Garo children (boys and girls) aged 10-18 years. Associations of nutritional status with socio-economic status, maternal
working status, family type and family size were determined. Results showed that in most of the age groups, the mean height and weight of both boys and girls were lower than the WHO/NCHS standards. The prevalence of thinness, stunting and underweight were 49.74%, 15.1%, and 7.29% respectively. It further concluded that there was a significant association between malnutrition and socio-economic parameters. Thus, they suggested that socio-economic status, maternal working status, family type and family size are important determinants of nutritional status of an adolescent.

Guedes et al. (2013) carried out a study on 982 girls and 986 boys, aged 7 to 17 years old and assisted by Segundo Tempo Program, from Montes Claros, Minas Gerais, Brazil, to assess the prevalence of low body weight/thinness, overweight, and obesity in a representative sample of children and adolescents from a Brazilian region with low economic development. Low body weight/thinness, overweight, and obesity were defined based on body mass cut-off indexes recommended by the IOTF. They found that in girls, the frequency of low body weight/thinness, overweight and obesity was 4.10%, 18.40% and 3.80%, respectively; in boys, these percentages were 6.30%, 13.20% and 2.9%, respectively. Thus, they concluded that, even in a region with low economic status, the excess body weight was the main problem associated with nutritional health.

Warjri (2014) conducted a study to assess the nutritional status of 3 to 18 years of Khasi children in the state of Meghalaya among (495 boys and 557 girls). Three Anthropometric indices i.e. weight-for-age, height-for-age, and BMI-for-age were used for the assessment of the nutritional status. It was illustrated that the prevalence of underweight for all sexes and ages was found to be 40.11%. There were no differences between the sexes with respect to the prevalence of underweight, although it was slightly higher in boys than in girls and about 52.28% of children were stunted. The prevalence of stunting in the higher age group was much higher than that in the lower age groups for both boys and girls. The study concluded that there was a high prevalence of underweight and stunting with a high prevalence of wasting among children.
Mijinyawa et al. (2014) determined the prevalence of thinness among adolescents in Kano, North-western Nigeria among 718 students (57% females and 43 % males) aged (13 to 19) years. Results showed the high prevalence of thinness among adolescents in Kano, with a slightly higher rate in boys than girls. The rate of thinness was observed to increase with age up to 16 years after which it starts to fall. Older age was found to be independently associated with thinness among subjects.

Rahman and Karim (2014) evaluated the prevalence of under nutrition among 726 rural school-going adolescents (376 boys and 350 girls) belonging to Hindu and Muslim communities from Chownhali sub-district, Serajgonj, Bangladesh. Results showed that the prevalence of stunting and thinness were high and estimated to be 46.6% and 42.4% respectively. The prevalence of stunting was estimated to be 43.1% and 50.3% among boys and girls respectively. The prevalence was highest at the age of 17 years (63.6%) in boys and at age of 15 years (70%) in girls. The mean BMI of girls were more than the boys. The prevalence of thinness among boys was more than the girls. It concluded that gender is a significant demographic factor of under nutrition.

Manyanga et al. (2014) collected cross-sectional data from 23,496 adolescents, 53.60% males and 46.40% females ranging (11 to 17 years) from the Global School-based Student Health Survey in seven African countries. Obtained results revealed that underweight varied from 12.60% (Egypt) to 31.9% (Djibouti), while being overweight ranged from 8.70% (Ghana) to 31.40% (Egypt). Obesity rates ranged from 0.60% (Benin) to 9.30% (Egypt). Females had a higher overweight prevalence for every age group in five of the countries, exceptions being Egypt and Malawi. They suggested that there were several factors which were not associated with weight status suggesting the need to explore other potential risk factors for overweight and underweight, including genetic factors and socio-economic status.
Nwizu et al. (2014) measured percent body fat in adolescents aged 10 to 18 (377 boys and 376 girls). Their study showed the age-related patterns of measures of fat and lean mass in adolescent Nigerians in Lagos. Results stated that overall percent body fat and fat mass were significantly higher in girls. Fat free mass in boys increased consistently with age, overtaking that of girls at 12 years with the gap widening up to 18 years. It was suggested that adolescent females have higher body fat indices while males have higher lean mass indices. Indices of body fat in the current study are much lower than reported for western counterparts.

Jian and Ye (2014) analyzed data from Tibetan children and adolescents in (Lhasa), aged 7-18 years old to assess the prevalence of malnutrition. They found that the rate of occurrence of stunting in Tibet has evidenced a gradual decline. In general, the wasting rate for both boys and girls has also gradually decreased over the period of time. They stated that stunting and wasting rates of Tibetan children and adolescents indicate a gradual declining trend over time. The stunting rates of both boys and girls during early puberty were significantly higher than those during late puberty.

Damie et al. (2015) assessed the nutritional status among 291 adolescents (185 boys and 106 girls) in the age group 10-14 years. Results depicted that the prevalence of stunting was low. Underweight tended to decrease with age and was more prevalent among those chewing khat, and subjects whose father had no formal education. The extent of underweight was high among adolescents.

Oliveira et al. (2016) carried out a cross-sectional study with 403 adolescents aged 10-14 years, from public and private schools. Anthropometric, clinical, and biochemical measurements were obtained to describe the association between FMI and FFMI values in adolescents in the city of Juiz de Fora, Minas Gerais. Results on the nutritional status, showed that 66.5% of the adolescents had normal weight, 19.9% were overweight and 10.2% were obese. The fat mass index was higher in adolescents who had high serum triglycerides, body mass index and waist circumference for both genders. It was concluded that adolescents who had higher anthropometric, clinical and
biochemical characteristics considered to be at risk for the development of cardiovascular disease and had higher values of the fat mass index.

Bustamante et al. (2015) aimed a study to provide height, body mass, BMI and waist circumference (WC) growth charts for 8,753 children and adolescents (4,130 boys and 4,623 girls) aged 4–17 years, from central Peru. The percentile curves for height, body mass, BMI and WC were obtained separately for boys and girls using the LMS method. Results revealed that overall boys had higher median heights than girls. Peruvian children were shorter, lighter and had higher BMI than their counterparts in the U.S. and Argentina. The growth patterns for height, body mass, BMI, and WC among Peruvian children were similar to those observed in North-American and Argentinean peers.

Pysz et al. (2015) evaluated the nutritional status, energy intake, macronutrients as well as the physical activity of 153 students (67 girls and 86 boys), aged 7 to 20 years from 5 orphanages in Krakow (Poland). The results revealed normal body mass among 80% boys and 90% girls. The study concluded that despite the insufficient intake of carbohydrates and fat, students showed the proper body mass index value that is due to excessive intake of protein necessary for maturation process. Additional physical activity was reported to be normal.

Bolanos et al. (2015) examined the physical growth, biological age, and nutritional transitions of adolescents living at moderate altitudes from an urban area of Arequipa, Peru aged 12.0 to 17.9 years. Adolescents living at moderate altitude exhibited stunted linear growth and biological maturation. Adolescents of both sexes showed the presence of double maturation burden.

Bacopoulou et al. (2015) investigated a representative sample of 1610 high school adolescents (12 to 17 years) in Attica, Greece. Results depicted that boys had significantly higher mean in all measures than girls, except for BMI where there was no statistical difference in terms of gender. Body mass index, waist circumference, and Hip circumference showed an increasing trend with age. Waist circumference leveled off in both genders at the age of 17 years. Waist-hip ratio and waist-height ratio showed a decreasing trend with advancing age. Greek adolescents had relatively high levels of abdominal
obesity in early-middle adolescence when compared with International studies.

Bianba at el. (2015) investigated the prevalence of obesity, overweight, underweight, and stunting in native Tibetan and Han Chinese children residential altitudes 3,700 and 4,300m above sea level. Cross-sectional studies of 1207 school children aged 9 to 10 years were conducted and conventional age and sex-specific cut off values were used. The present study found a high prevalence of stunting and underweight among children living in Tibet, and a higher prevalence among native Tibetans living at a higher residential altitude as compared with a lower residential altitude. The study concluded that Native Lhasa Tibetans were taller and heavier than those living at higher residential altitude, and also taller and heavier than Han Chinese living at the same altitude. Lhasa Tibetans (3.50%) and Han Chinese (3.00%) were found overweight and none of Tingri Tibetans were found to be overweight. Stunting and underweight were common among these populations, and an association was found between ancestries and stunting for children living at 3700m in Lhasa.

Damie et al. (2015) assessed nutritional status and associated factors among school adolescents in Chiro town using a cross-sectional study. Out of 319 selected samples, 291(91.2%) participated in the study. This study highlighted that socio-demographic factors were associated with being underweight. While sometimes hand washing after the toilet was found to be a predictor of stunting. Prevalence of underweight was high among adolescents but the prevalence of stunting was low.

Abdelaziz et al. (2015) conducted a study to determine the nutritional status and dietary habits of 1100 school children (5-19). Results depicted underweight and stunting occurred in 10% and 53.2%, respectively. Boys were more underweight (3%) than girls (2.2%). Identified risk factors associated with malnutrition for those aged more than 10 years. They concluded that the child’s nutritional status was strongly associated with the literacy of both parents and family size. The prevalence of malnutrition could be reduced by implementation of school intervention programs for the socio-economic development.
2.3.2 National Status

Reddy and Rao (2000) did a cross-sectional study to assess physical growth, on 1565 Sugali children aged between 1 to 20 years. It was found that all anthropometric measurements except skinfold measurements exhibited uniform increase with age in both the sexes. A regular increase in skinfold measurement was observed with advancing age in the case of girls, whereas, there was slight decrease observed in the case of the boys. The Sugali boys and girls were shorter and lighter than well to do Indian standards. It was also observed that the median height and weight of Sugali boys and girls fall below the 5th percentile of NCHS standards.

Mitra et al. (2002) conducted a cross-sectional study to assess the physical growth status of Kamar children aged 5 to 18 years, in the Raipur district of Chhattisgarh. The study aimed to find out the growth pattern of the Kamar children and was to compare with another Indian tribe and the official data for all India (ICMR). Data was assessed and they suggested that all anthropometric measurements except skinfold thickness exhibited uniform increase with age in both sexes. However, when height and weight of the Kamar boys and girls were compared with the data for other tribes and for all India, the Kamar children indicated lower weight and height and the difference showed to be significant, for almost all ages. It was concluded that poor socio-economic status of this primitive tribe might be one of the reasons for this poor growth pattern.

A cross-sectional study was undertaken on 1,525 Khond boys and 1,132 Khond girls aged from birth to 18 years in schools situated in the tribal areas of Visakhapatnam district of Andhra Pradesh 2004 by Rao et al. (2005). It was observed that there was a gradually increasing trend in all the dimensions with advancement in age. The study also revealed that the adolescent growth spurt of girls (9 and 10) was attained earlier by two years than boys (12+ and 14+ years). Blood pressure and pulse rate increased with advancement in age with few fluctuations. Analysis of the data revealed that all the measurements showed significant differences by sex according to age. Khond boys and girls were shorter lighter with a broader chest and had bigger head circumference than ICMR (1984) National standards.
Venkaiah et al. (2002) investigated a cross-sectional study with the household as a unit of randomization to evaluate the current diet and nutritional status of rural adolescents in India. The outcome measures for nutritional status were the proportion of underweight, stunted and body mass index. They analysed that the extent of under-nutrition was high among adolescents and was higher among boys than girls. Adolescent girls in the rural areas could be at greater risk of nutritional stress because of early marriage and early conception before completion of their physical growth as compared to their male counterparts.

Mukhopadhyay et al. (2005) conducted a cross-sectional study of 559 Bengali adolescents (314 boys and 245 girls) of North 24 Parganas, West Bengal, was undertaken to study their nutritional status. Results stated that the overall rate of under nutrition was 36.49%. Regardless of sex, the rate of under nutrition progressively increased from 31.88% to 39.80% with the advancing age. However, a clear-cut age variations in the change of the rate of under nutrition have been observed in both the sexes. The prevalence of under nutrition varied between boys (41.08%) and girls (30.61%). This study suggested that Bengali adolescents had moderate rates of under nutrition that were lower than those reported in other developing nations including previous studies from India.

Rao et al. (2006) made an attempt to assess the diet and nutritional status of 12,789 adolescents (10 to 17) years from the different tribal areas of India. They utilised the available database collected by National Nutrition Monitoring Bureau (1998-99). It was found that about 63% of adolescent boys and 42% of girls were undernourished. They suggested that a significant association between under-nutrition and socio-economic parameters like type of family, size of land holding and occupation of head of household.

Tripathy et al. (2006) conducted a study to examine the nutritional status of the refugee population with respect to the altitude of residence. Three Tibetan settlements in India with different ecological settings were selected i.e.
Bylakuppe (800m), (Mysore, Karnataka) and Chandragiri (970m) (Gajapati, Orissa). The analysed results depicted that BMI distribution for the Tibetan adult population showed the very small percentage of people (4.8%) in the underweight category of less than 18.50%. The proportion of the population in the normal categories and obese increased with advancement in age. When they compared the results with Mongoloid population of china, Tibetans were found under weight than Chinese counterparts.

Chowdhury et al. (2007) examined fat patterning in a cross-sectional study conducted among 1012 Santal children from Puruliya district of West Bengal. The body mass index, body fat percent, and fat-free mass were also calculated. In the age group 11–12 years in both sexes Maximum gain of body fat and fat free mass was found. Girls had higher fat free mass (18.7 kg) than boys (14.92 kg) between 5 and 12 years of age. Sexual dimorphism in fat patterning resulted out by anthropological variables which have a significant association with fat free mass and percentage body fat. Girls showed a greater subcutaneous adiposity in comparison with boys in the study.

Tiwari et al. (2007) identified the physical growth and nutritional status by cross-sectional study of 551 children aged 4 to 18 years of a primitive tribe of Bharia, Madhya Pradesh. The study showed that in both sexes, there was uniform increase with age, in all anthropometric measurements except skin fold measurements. Substantial changes in age-specific BMI were indicated with fall during pre-school age and rise in adolescence. As per Indian standard, the BMI was normal but malnourished in both sexes when compared to International standard during childhood and adolescence with greater under nourishment in boys than girls as girls reached normal growth patterns after the onset of puberty.

Bhasin and Jain (2007) carried out a cross sectional study to assess the nutritional status of the scheduled tribes, namely Mina, Bhil, Sahariya,
Garasia, Damor and Kathodi of Rajasthan on the basis of body mass index. The data were collected from 2928 individuals (1503 males and 1425 females) belonging to both adolescents (8 to 18 years) and adult age group (19 and above) during the year 1999 - 2001. Results revealed that all populations showed an increase in mean values of BMI with advancing age in both sexes. On the basis of BMI, under nutrition was highly prevalent among adolescents of both genders. High frequency of thinness was clearly indicated by the results of chronic energy deficiency grades. BMI was lowest among Bhils than their counterparts in the other tribes. Mina males and females exhibited a highest mean value of BMI at higher age groups.

Chakrabarty and Bharti (2008) conducted a study to assess the growth and nutritional status of adolescents of the Shabar tribe of Orissa, India. This cross-sectional study was carried out on 328 adolescents falling at the age of 10 to 18 years from Khurda and Cuttack districts of Orissa. Adolescents of Shabar tribe showed a high prevalence of growth retardation and chronic under nutrition. But the nutritional status of these adolescent tribes is better than that of other tribes. The Shabar adolescents were significantly shorter and lighter than the NCHS standards when compared with 50th percentile curves of NCHS standards.

Bhasin et al. (2008) conducted a study to provide the growth standards in the form of centiles for different population groups of Jammu and Kashmir. They also presented selected percentiles for the boys aged 8 to 18 years for male adults. Compared people of Jammu and Kashmir to the Indian national standards given by the Indian Council of Medical Research (ICMR 1972), and showed higher mean values for height and weight in all groups and when compared to the U.S reference standards (Hamill et al. 1979) males of Jammu and Kashmir state were significantly shorter and lighter at all ages.

Vashist et al. (2009) carried out a study to assess the nutritional status of adolescents in urban and rural schools of Rohtak district of Haryana. They divided the population into two strata i.e. rural and urban and further into two sub-strata based on the type of school i.e. government and private in each stratum, they selected 500 subjects per stratum. The results revealed the
mean weight and mean BMI of adolescents in the 13-14 years age groups was more in rural areas than urban areas. However, mean height was similar for this age group in both urban as well as rural areas. They found that the overall nutritional status among the adolescents from rural subjects was poor than that of urban subjects for both genders.

Mondal and Sen (2010) evaluated the prevalence of under nutrition among 726 rural adolescents (376 boys and 350 girls) in the age group 10-17 years, belonging to Rajbanshi, Bengali Muslim, and Bengali caste communities from Darjeeling, West Bengal. The nutritional status was assessed in terms of stunting and thinness. Results revealed that the overall prevalence of stunting and thinness were 46.6% and 42.4% respectively. It was found that overall mean BMI for girls was slightly higher than boys. A higher prevalence of overall thinness was found among boys (53.1%) than girls (32.0%). The study concluded that there were a very high prevalence of stunting and thinness among both boys and girls.

Mandal et al. (2011) investigated the nutritional status of two sub groups of the Bhotia tribe (Marcha and Tolcha) inhabiting in three different altitudes in Chamoli district Uttaranchal. The study revealed that there was the relatively higher value of mean BMI among females than that of males. The highest value for waist circumference was observed in low altitude followed by high altitude. Results indicated that height, weight, hip circumference and waist circumference were dependent on BMI. The probable reason for the poor nutrition status was due to the fact that the Tolcha and Marcha of high altitude consumed lesser amount of proteins, fat, milk and milk products in general than their counterpart from lower and middle altitude.

Das and Bose (2011) conducted a community-based cross-sectional study among 421 Santal children and adolescents (217 boys) having age 7 to18 years. The results of this study exhibited greater mean weight and BMI for girls than boys and the sex difference was not significant. Both boys and girls showed similar mean height. About 44.6% girls and 38.3% boys were undernourished. This study showed that the girls were more underweight than boys. The overall prevalence of thinness was 41.3% among the Santal children.
Prajapati et al. (2011) evaluated the nutritional status of 401 adolescents (195 boys and 206 girls) aged 10 -19 years in Ahmedabad, Gujarat. Height, weight, and BMI was taken. Using WHO growth standards, it was analyzed that 47.4% were stunted and 19.5% were overweight. Overweight was more common in males.

Bisai et al. (2011) examined the growth pattern and levels of underweight and stunting, based on NCHS (z scores), among 1094 (665 boys and 429 girls) rural adolescents aged 11-18 years of Paschim Medinipur district, West Bengal. Height and weight were measured using standard techniques. Based on WHO classification, the study showed that the prevalence of the rates of underweight was high, while those of stunting were medium in both sexes. It also signified that the nutritional status among late adolescents was not satisfactory than early adolescents.

Banerjee et al. (2011) conducted a study to assess the nutritional status among 1,015 adolescents (565 boys and 450 girls) in the age group 10-19 years in rural Goa. BMI was calculated from height and weight measurements. The study found that more boys were under weight than girls and under-nutrition were uniform across all the years of schooling.

Rajkumari et al. (2012) conducted a cross-sectional study on 3356 school children in the age group 12 to 19 years residing in Imphal Manipur, to determine the body composition and its relation with BMI of adolescents. They found that BMI among boys and girls were 18.7 and 19.2 respectively and the difference was statistically significant. Multiple linear regression analysis shows that BMI was significantly associated with waist circumference, weight, fat percentage, total body water and fat free mass among the boys and inversely associated with height, hip circumference, and waist-hip ratio. Thus they concluded that fat percentage was found to be significantly correlated with BMI.

Singh and Devi (2013) determined the nutritional status among 854 Meitei children and adolescents (384 boys and 470 girls) aged 8-18 years. It found the high prevalence of underweight (30.21%) and overweight (3.21%) among children and adolescent boys respectively. Among girls, the prevalence of
both underweight (33.86%) and overweight (5.18%) was higher among children than adolescents. Thus, they found that the overall prevalence of underweight was found to more or less the same among boys and girls, but overweight was higher among girls than boys.

Qamra el al. (2012) carried out a cross-sectional study on 795 Baiga children (453 males and 342 females) of Baiga-chak area of Dindori district in Madhya Pradesh varying between 1–18 years of age. They found that all body measurements except for skin folds increased progressively in each age group showing the insignificant difference between boys and girls in most of the age groups without any peak velocity during a pubertal age in both sexes. It was also observed that skin folds showed an inconsistent pattern with each successive age.

Fazili (2012) conducted a study on school going children in rural block Hajin Bandipora, from various primary and middle-level educational facilities from a rural health block were surveyed. Results exhibited that both mean weight and height were higher in females than males. The prevalence of wasting was observed to increase from lower to a higher age. They found a higher prevalence of underweight (18.6%, 3.66), stunting (11.7%, 6.76%) and wasting (16.3%, 8.18%) in boys than girls. The overall prevalence of under nutrition was 19.2%. They concluded that nutritional status of school-age children were comparatively better even though a large number of children still fell below the cutoff for various nutritional indicators.

Basu et al. (2013) carried out an investigation on a sample of 957 Khasi children aged between 11 to 17 years to derive BMI (kg/m2). They found that mean BMI in Khasi children was below those of national and international reference standards. Girls achieved higher BMI in late adolescence, but boys remained thin throughout adolescence. Under-nutrition was more prevalent in boys than in girls, particularly at age 14 and 15 years. BMI values in pubertal Khasi boys and girls were different from commonly used standards.
Patil et al. (2013) conducted a cross-sectional study on 451 Karad adolescents to examine anthropometric characteristics (height, weight, and BMI). It was found that at all ages 50th Percentile value of BMI was lower than that of WHO (2007) reference and 85th percentile values were higher than the same. The coefficient of determination for weight and height showed the extent to which the variation in these variables could be explained by the studied variables.

Longkumer (2013) conducted a study on 571 Ao Naga children including 289 boys and 282 girls aged 8 to 15 years from Mokokchung town, Nagaland. They tried to ascertain physical growth and nutritional status. This study revealed that the girls were taller than boys till 13 years and the boys became taller thereafter. The prevalence of underweight was 30.12% and the prevalence of overweight was 2.28% among the Ao Naga children, and the girls were found to have a higher prevalence of overweight and the boys had a higher prevalence of underweight. This revealed that both underweight and overweight coexisted among the Ao Naga children, although the prevalence of overweight was not high.

Singh and Mondal (2013) collected data on height and weight on 1,343 (670 boys, 673 girls). Adolescents aged from 6 to 18 years children belonging to Sonowal Kachari tribal ethnic group Assam. Results revealed that the overall mean BMI was found to be significantly higher among girls than the boys. The overall prevalence of thinness was observed to be 25.99% (28.08% boys, 23.92% girls). The prevalence of thinness was generally higher in the early age (6-11 years) but thereafter decreased with age in both sexes. Nutritional intervention in terms of a comprehensive supplementary balanced diet and micronutrient rich was essential.

Dhobale et al. (2013) studied the pattern of BMI of 1,275 school children (10 to 16 years) in association with socio-demographic factors, food habits, and physical activity. Results revealed that the prevalence of underweight and overweight among the students was 23.1% and 6.5% respectively. The prevalence of overweight (13.8%) was seen in children who used more computer, television and video games. Thus they concluded that increase
consumption of dry snacks, bakery products, and non-vegetarian diet along with reduced physical activity affects BMI and hamper the nutritional status.

Thakur and Gautam (2014) assessed the prevalence of under nutrition among school-going boys and compared the findings with international reference i.e. NCHS and WHO. A total of 300 boys of the age group of 5 to 18 years were selected. The study revealed that age wise mean body weight, height, and BMI had increased with advancement in age. Boys were lighter in body weight and shorter in stature than the reference population (NCHS). Similarly, Body mass index of the boys indicated low mean BMI than the reference population (WHO). It was found that 6.3% of boys were stunted, 4.3% were underweight and 3% were undernourished.

Mondal (2014) determined the prevalence of age-sex specific thinness among 1,165 adolescents (602 boys; 563 girls) aged 10-18 years residing in rural regions of Darjeeling, West Bengal. In this cross-sectional study, anthropometric measurements, height and weight were obtained and BMI was calculated. Results indicated that the prevalence of overall thinness was 49.10% (51.16% boys, 46.89% girls) among rural adolescents. The boys were found to be more sufferer than girls in the different thinness grades that included mild, moderate and severe categories.

Mondal and Terangpi (2014) undertook a study to assess the prevalence of under nutrition among tribal adolescents of Karbi Anglong of Assam, among 864 (448 boys). Height and weight were recorded and the body mass index calculated. Overall mean height, weight, and BMI were found to be significantly higher among boys than girls. Prevalence of stunting (51.2%) was found markedly higher than thinness (13.4%). Sex-specific overall stunting was similar among girls (50.2%) and boys (50.1%). Prevalence of thinness was slightly higher among girls (14.9%) than boys (12.05%) (p> 0.05). It was concluded that stunting was present in 51.2% and thinness in 13.4% among tribal adolescents of Karbi Anglong district of Assam, Northeast India.

Kuki (2014) collected anthropometric data from the Chakhesang boys of Sudzulhou Village of Dimapur district. The study comprised of cross-sectional
data on a total of 200 boys in the age group of 7 to 18 years. It was found that
the mean height of the Chakhesang boys showed a gradual increase with the
increase in age, i.e. from age 7 to 18 years. Considering, all the age groups
the minimum and maximum height obtained was 110.2 cm and 167 cm
respectively. From 14 to 15 years, there was a sharp increase in height, which
showed a maximum increase of 6.63 cm. Nutritional status according to BMI,
weight for age and height for age showed that the Chakhesang boys within
the age group of 7-18 years were well nourished and healthy.

Biswas et al. (2014) conducted an anthropometric assessment to evaluate the
nutritional status of the school going boys of Himachal Pradesh between 9 –
11 years of age. Height for age, weight for age and BMI for age was
calculated as per WHO standard to evaluate the prevalence of stunting, under
nutrition and thinness and Z- scores. Results show an increasing pattern for
height, weight and BMI with age in all the age groups. None of the subjects
were classified as severely stunted or under nutrition. The prevalence of
moderate stunting and under nutrition was much lower than the mild category
Malnutrition in terms of stunting and wasting was lower as compared to other
reports from other Indian states. Prevalence of stunting was less than that of
wasting which reflected an acute state malnutrition.

Kosariya and Chakravarty (2015) made an attempt to examine the trend of
growth in height and weight among the Bhunjia (Choukhutia) tribe of
Chhattisgarh State. The study revealed that very few Bhunjia children were
categorized under the normal range where as majority belonged to the
underweight category.

Twara et al. (2015) conducted a study to assess the nutritional status of
school going tribal children using anthropometric indices. The study was
carried out in various schools of Chandawali and Sonbhadra area of eastern
Uttar Pradesh. A total of 1221 children (728 boys and 493 girls) were selected
having age 5-14 years. The results revealed that the degree of malnutrition
was high among these tribal children. Boys were found to be more
malnourished than the girls having a same age group. This study exhibited
that the 51.10% of school going tribal population was undernourished. Weight
was more affected than height by under nutrition.
Thakur and Gautam (2015) studied the nutritional status among boys and girls of a Central Indian Town (Sagar). The study was carried out in order to assess the prevalence of under nutrition among Sagar city boys and girls. A total sample of 612 individuals (312 girls and 300 boys) aged 5-18 years were examined and compared with NCHS reference standards. The results revealed that the girls were heavier and taller than boys up to 15 and 13 years of age and after that boy became taller. Boys showed stunted growth than girls whereas girls were underweight and undernourished than boys. According to CIAF, girls were slightly more undernourished (10.6%) than boys (10.0%). It was concluded that school going Sagar boys and girls had significantly lower weight, BMI and short stature at all ages than NCHS (2005) reference standards.

Sen et al. (2015) identified the upper arm composition as an indicator of body composition and nutritional status of 964 adolescent boys (aged 10-18 years) of the indigenous Rajbanshi population of West Bengal. The results indicated that as the boys approached the higher ages there was significant age-specific variation in BMI, upper muscle area, and upper fat area. The age-specific means of total upper arm area, upper muscle area, upper fat area increased with age. The adolescent boys were below the 50th percentile of the reference population in BMI, upper arm area, upper muscle area, upper fat area, arm fat index.

Rahman et al. (2016) assessed the nutritional status of 400 adolescents (213 boys and 187 girls) from 10- 19 years of age in Hajipur village of Katihar district, Bihar. BMI was calculated from height and weight measurements. It was found that there was a high prevalence of underweight among adolescent girls (36.75%) and prevalence of overweight in boys and girls was 1.25% and 1% respectively. 63.25% adolescents had BMI less than normal value. Moderate and severe malnutrition were higher in girls than boys. Chronic energy deficiency based on BMI (grade I, II, III) in girls was 21.25%, 7.25%, 8.25% and in boys, it was 21.75%, 1.5%, 3.25 % respectively. The study concluded that short stature in adolescents resulting from severe energy deficiency was associated with reduced lean body mass and deficiencies in muscular strength and working capacity.
Atif et al. (2016) conducted a cross-sectional study to assess the nutritional status of adolescents boys covering 500 students from 10-19 years of age from rural and urban schools of Aligarh district, Uttar Pradesh. The results indicated that in rural areas, 12.29% and in urban areas 8.59% of overall stunting was prevalent. Overall 4.51% students in rural areas were found to be suffering from severe stunting than 0.39% in urban areas.

Khatun et al. (2016) carried out a cross-sectional study of 1,068 Bengali Muslim boys (n=522) and girls (n=546) aged 10-17 years of Deganga, Barasat, North 24 Parganas, West Bengal, India. This work was undertaken to study their age and sex differences in nutritional status. They found that overall rate of undernutrition was 41.67%. The rates of undernutrition of boys varied between 23.33% among 16 years old to 72.73% at age 13 years. The rates of undernutrition of girls varied between 11.43% among 15 years old to 58.90% at age 11 years. The prevalence of undernutrition (combining all ages) varied between boys (52.49%) and girls (31.32%). In general, the study provided evidence that the Bengali Muslim adolescents had moderate rates of undernutrition.

Sarkar and Sai (2016) organized a cross-sectional study to ascertain the current nutritional status of rural adolescent Bengali boys of Tripura. The study was done using multistage cluster sampling method on 550 school going boys aged 8-16 years. Using standard techniques, height and body weight were measured. By employing WHO reference data, it was found that the overall prevalence of stunting and thinness (21.15 and 40.32% respectively) was higher while overweight was lower (4.30%) among Bengali boys and in general they had lower rates of undernutrition.

Rahman and Tripathi (2016) determined the nutritional status of 954 adolescents (539 males and 415 females) ranging in age from 10-18 years in the urban and rural area of Kanpur. Cross-sectional study was done using simple random sampling method, pre-tested and pre-designed schedule and height and weight were measured. It revealed that the 52.09% (45.51% urban and 50.81%) adolescents were under nourished. More females (56.9%) were underweight than males (44.3%).
Thakur and Gautam (2016) carried out a cross-sectional study on 2,558 individuals; consisting of 1,284 boys and 1,274 girls from birth to 20 years to assess the level and extent of under nutrition and obesity among the boys and girls of Hathin block, district Palwal, Haryana. It was found that 4.8% boys and 4.6% girls were underweight, 6.8% boys and 6.3% girls were stunted, 3.5% girls and boys were undernourished, whereas 1.5% boys and 1.9% girls were overweight and 2.2% girls and boys were obese. During early childhood underweight (5.6% boys and 7% girls) and stunting (6.9% boys 7% girls) was higher than >5 years of age. Among children below 5 years of age, a total of 4.4% boys and 3.3% girls were underweight and 6% boys and 6.8% girls were stunted. They concluded that there is the dual burden of malnutrition and it is a serious problem. Prevalence of overweight and obese was also found higher in poor and middle-class families.

2.4 SOCIO-CULTURAL VARIABLES

2.4.1 International Status

Videon and Manning (2003) carried out analyses on 18,177 adolescents, to provide national estimates of the frequency and determinants consumption of fruits, vegetables, and dairy foods. They observed that almost one in five adolescents reported skipping breakfast on alternate days. A large percentage of adolescents reported eating less than the recommended amount of vegetables (71%), fruits (55%), and dairy foods (47%). Adolescents with better-educated parents had better consumption patterns than those with less-educated parents. Adolescents who perceived themselves to be overweight were significantly more likely to have poor consumption patterns.

Fasting et al. (2008) examined the association of physical activity, dietary habits and smoking status with body weight and blood pressure of Norwegian adolescents. The data were collected from 8408 adolescents aged 13 -19 years who participated in the population-based study. It was concluded that in this population, low level of physical activity and smoking were associated with higher mean diastolic BP and higher odds of overweight and obesity. The
paradoxical associations between healthy dietary habits and overweight and obesity are most likely an effect of reverse causality.

Zong and Li (2014) conducted a study to find the correlation between economic development with physical growth among Chinese children and adolescents. It was found that growth of children and adolescents improved in tandem with economic development. The largest increase in height was during puberty; under-nutrition declined among children less than 5 years of age, but in 2010 underweight and stunting was still common in poor rural areas. A large increase in obesity was also observed in both urban and rural areas, but especially in large cities and, more recently, in small and medium-sized cities and affluent rural areas.

Artiningrum et al. (2014) conducted a study to assess the physical growth of school age children. The focus of their research was to evaluate the age-related body size variation in Sasak children living at different altitudes on the island of Lombok, Indonesia at low, medium, and high. They showed that children living at low altitude were taller and heavier than children of the same age living at medium and high altitudes. Until the onset of puberty, the children at medium altitude have similar stature and weight to those residing at high altitude, but they are shorter and lighter thereafter. There were significant differences in the height and weight of girls in different altitude locations, but no significant difference for boys. The effect of SES on child growth was compared between Sasak and other populations in Indonesia. In general, the Sasak children were shorter and lighter than children of the same age in urban populations, and relatively similar in size to the children in rural populations. Indicators of socio-economic status such as family income and parental education were shown to be more influential factors in the differentiation of physical growth between populations than the altitude factor.

Zsakai and Bodzsar (2014) examined the body structure of children and adolescents living in different socio-economic backgrounds. It was found that among the numerous factors that influence the pattern of children’s growth
and development, was of the utmost importance socio-economic environment. The inequalities among the socio-economic strata in the Hungarian society have increased during last decades.

Assefa et al. (2015) conducted two rounds of community-based cross sectional study in 2010 in Jimma zone, Ethiopia. Data was analysed through Univariate and Multivariable linear regression to assess socio-demographic factors and its association with underweight and stunting among adolescents. It was found that socio-demographic characteristics were found to be associated with underweight and stunting. The study showed a positive correlation of stunting with gender, household, place of residence, household size, income, educational status, employment status. Age of the adolescents, gender, educational status, employment status and type of the last school attended are associated with underweight.

2.4.2 National Status

Venkaiah et al. (2002) conducted a cross-sectional study with the household as the unit of randomization of the nine States. The information on the socio-demographic profile was collected in all the 20 households, while anthropometric data such as weight, height and clinical signs of nutritional deficiency was collected on all the available adolescents in the selected households. It was found that anthropometric and socio-economic information on 12,124 adolescent boys and girls and dietary information on 2579 individuals was analyzed. The prevalence of under nutrition was higher (53.1%) in boys than in girls (39.5%). The extent of stunting was higher (42.7%) among adolescents belonging to the scheduled caste community. In the case of girls, the extent of underweight was considerably less in each age group than their male counterparts.

Chakrabarty et al. (2012) conducted a study to understand the household economic condition and nutritional status among the Shabar tribe living in a protected forest area of Orissa. They had a sample of 154 families from three
Shabar villages were investigated to collect household information and included, adult height, weight, and household dietary survey. Per capita food consumption and body mass index were also computed to understand the association. The study showed that 52.02 percent of families from lower economic sub-groups were not able to get optimal calories. Consumption of calories among females was significantly lower in the lower economic group compared to their economic counterparts. Higher percentages of under nutrition were higher observed among females than males.

Jain et al. (2012) estimated the prevalence of overweight and obesity in relation to socio economic status and eating habits among 500 school going children (13-17 years) in Bhilai Nagar, Chattisgarh. BMI was calculated from height and weight measurements and pre-tested questionnaires were used to collect the data. It was found that overweight (23.8%) and obesity (8.4%) were very high and alarming for both sexes which were due to eating habits like junk food, chocolate and eating in front of TV among low to high socio-economic status. It also suggested that under nutrition rates were also high (10.2%) in children.

A review of the literature revealed that although a number of studies have been conducted on growth and development of children and adolescents in India yet, recent studies on these aspects of regional populations from high altitude are scanty. In view of this, the present study has been undertaken on Shin adolescent boys of Gurez valley to evaluate their growth and nutritional status in context with high altitude and prevailing socio-cultural practices.