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Allometric Model Study of Inter Limb Growth: A Case Study of Children From Jessore District

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ALLOMETRIC MODEL STUDY OF INTER LIMB GROWTH: A CASE STUDY OF CHILDREN FROM JESSORE DISTRICT

A

Thesis

Submitted to the

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Declaration

I do hereby declare that the dissertation entitled "Allometric Model Study of Inter Limb Growth: A Case Study of Children from Jessore District" submitted to the Department of Statistics, University of Rajshahi, Bangladesh, for the degree of Master of Philosophy in Statistics. This study is a unique and original work of my own. No part of it, at any form, has been submitted to any other University or Institute for any degree, diploma on other similar purposes.

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Certificate

This to certify that this dissertation entitled "Allometric Model Study of Inter Limb Growth: A Case Study of Children from Jessore District" is an original work from primary collected data done by Md. Shahjada Ali Nawaz, Department of statistics, University of Rajshahi, Bangladesh, for the degree of Master of Philosophy in Statistics under my supervision.

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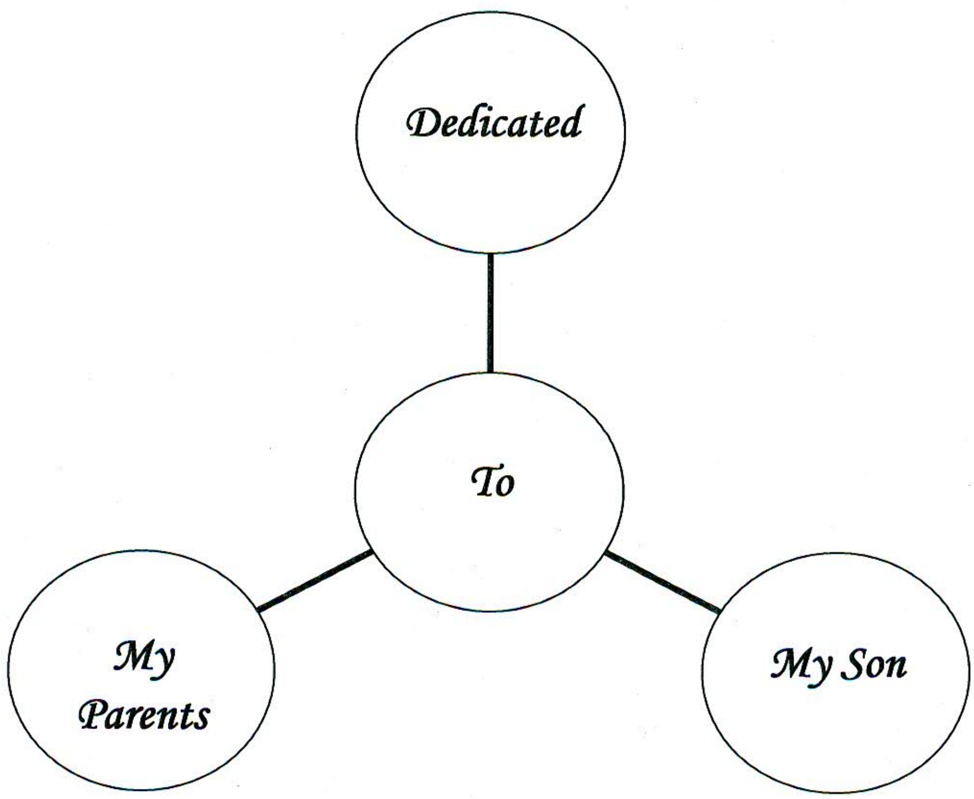
Dedicated
To
My
Parents
My Son

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The Author

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Abstract

The aim of this study was to investigate the allometric growth of inter-limbs of males and females. All the subjects were student of primary school of urban and rural area at Jessore district in Bangladesh. The age ranges of the subjects were between 6 to 12 years for males, 6-11 years for females. Longitudinal data on body and head dimensions (stature, weight, sitting height, leg length, chest circumference, left and right upper arm length, elbow-wrist length, left and right tibia length, left and right upper arm circumference, head length, head breadth and head circumference) were measured from 2006 to 2009. The study started with 117 children. There was about 24% loss of the sample size. Finally we were 89 subjects. Descriptive statistics, growth chart and allometric growth model were used. Allometric relationships between body and head dimensions were obtained through log-linear regression analysis. Growth of head dimensions (head length, head breadth and head circumference) was negatively allometric with respect to stature for males and females, i.e., growth rate of head dimensions were smaller than growth rate of stature. Growth of body dimensions (leg length, tibia length, arm length etc.) were positive allometry with respect to stature implying growth of these body dimensions were greater than that of stature but the growth of sitting height with respect to stature were negative allometry. Growth of leg length and upper arm length with respect to stature were isometry for urban females. Growth of urban males and females were greater than rural males and females in stature, weight, sitting height, leg length, chest circumference, head length, head breadth and head circumference. Average stature differs more than 5 cm between urban and rural females, 4 cm for urban males and females. Average weight differs more than 4 kg between urban and rural males, 6 kg for urban and rural females. An in-depth further study should be taken into accounts for searching the reason of this regional difference.

Abbreviations

BMI = Body mass index

CDC= Centre for Disease Control

DZ = Dizygotic

GOV= Government of Bangladesh

LMS= Least Mean Squared

MIA = Maximum increment age

MZ= Monozygotic

NCHS= National Centre for Health Statistics

OLS= Ordinary least square

PB-1= Preece-Baines-1

PHV= Peak height velocity

RU=University of Rajshahi

SB= Siblings

SD= Standard deviation

SES= Socio economic status

WHO= World Health Organization

Chapter one

Introduction

Chapter- One

Introduction

1.1: Prelude

The study of human growth and development is an integral part of the scientific study of human biological structure, function and diversity. Anthropometry as a part of human biology has no restrictions concerning the anatomical parts of regions of the human body. Measurements such as, relationship between different parts of body, and proportional aspects can be established and compared for different sexes and ethnic groups.

The scientific study of human physical growth and maturation has a long illustrious history involving leading scientists from many countries. Although much has been learned, much remains to be achieved. It is depend upon the recruitment of young scientists and successful implementation of new studies, particularly in developing countries where the growth and maturation of many infant and children are retarded due to some causal factor and with their individual countries environment. Scientific interest in growth may have its origin in anthropology and medico biology.

Growth is the process that produces variations; it is therefore not surprising to find that biological anthropologists have a long history of studying human variation and growth in numerous populations and within many temporal frameworks (Goldstein 1979). Understanding variation in growth patterns among populations permits a better comprehension of observed morphological differences (Eveleth and Tanner, 1976). Moreover, this curiosity has not only been about population-wide growth, but also about growth as an ontogenetic process.

The relationship of the growth of one part of an organism to the growth of another part or the growth of the whole organism is called allometry. The term also applies to the measure and study of such growth relationship. Allometry comes from the Greek word 'allos' which means 'other', so allometric means 'Other than metric'. Allometry is of two types- Isometry and Non-Isometry. Isometric growth, where the various parts of an organism grow one-to-one proportion, is rare in living organisms. If organisms grow isometrically, young would just like adults, only smaller. In contrast, most organisms grow non-isometrically; the various parts and organisms do not increase in size in one-to-one ratio. One of the best-known examples of non-isometric growth is human growth. The relative proportions of human body change dramatically as the human grows.

Many human biologists have been interested in the relative size of different parts of human body, and it has been maintained that the relationship between the size of a part and the size of the whole human body is the best described by some kinds of exponential (logarithmic) functions. This kind of relationship is usually known as allometric. Power law of the equation of the type $y = bx^{a/c}$ (allometry) were first developed by Galileo in his Discourse, published while under house arrest in 1638. He noted that the bones of larger animals grow thicker at a faster rate than they grow longer compared to the same bone in smaller animals. Power law of the equation of the type $y = ax^b$ (allometry) were first used in biology just before 1900 when Dubis (1898) and Lapique (1898) showed that data on brain weight was better linearzied by log-log than by arithmetic plots. After taking log on the both sides of equation $y = ax^b$, then this equation become $\log y = \log a + b \log x$. The widespread applicability of this technique to growth and adult size-change effects was demonstrated in Huxley's (1932) Problems of Relative Growth. Many human biologists used this equation to find the rate of growth of any dimension with respect to the organ of that dimension or any other organ usually body size (stature). The coefficient 'b' that is, the slope of the line of regression of the dependent variable y is regressed on the independent variable x, and represents the increment in a dimension corresponding to a unit change in stature. The constant 'log a' is defined the initial growth of the dimension. The value of the coefficient 'b' gives the ratio between the specific growth or increment rate of the dimensions y and x. The meaning of the allometric coefficient, 'b' is defined as follows: if the coefficient is 1.0, it indicates that the dimension maintains a constant proportional or isometric relationship. If the coefficient is less than 1.0, the dimension is negatively allometric. Negative allometry implies that taller individuals have relatively shorter dimension than shorter individual. If the coefficient is greater than 1.0, then dimension is positively allometric. Positive allometry implies that taller individuals have relatively longer dimension than shorter individuals.

Growth study in stature, weight and head dimensions is well documented, but other body and head dimensions (such as sitting height, leg length, tibia length, upper arm length, elbow length, head circumference etc.) for living are not enough. It is necessary to apply an appropriate mathematical technique which is able to make relationship between the growth of body dimensions and growth of stature, also to make relationship between the growth of head dimensions and growth of stature. Ohtsuki and Ito (1980) applied allometry technique to find the secular change in head dimensions of Japanese females with respect to stature. Allometry technique is a good mathematical equation, which enable us to find the relative growth in head and body dimensions with respect to stature. Now it is advantageous to apply allometry technique to find the relative growth in head and body dimensions with respect to stature of Bangladeshi males and females of age 6 to 12 years.

Human growth of the physical dimensions of the body is highly regulated process. The post natal growth is comparatively of higher rate immediately after birth, and rapid declaration until four years of age. The infancy-childhood growth are additive in two components-infancy and childhood. Studies of child growth are conducted for reasons: to assess the environmental conditions in which the growth of a child occurs, and for the understanding of general pattern of physical development and their determinants. Patterns of growth have considerable impact on human biological diversity.

A major growth spurt occurs at the time of puberty. Usually kids enter puberty between age 8 to 13 years in girls and 10 to 15 years in boys. Puberty lasts about 2 to 5 years. This growth spurt is associated with sexual development, which includes the appearance of pubic and underarm hair, the growth and development of sex organs, and in girl, the onset of menstruation.

By the time girls reach age 15 and boys reach age 16 to 17, the growth associated with puberty will have ended for most teens and they will have reached physical maturity.

Maturation of a child is a "multi-track" process: it involves maturation of the skeleton, somatic growth, change in body composition, etc. Accordingly, a variety of indices have been used to measure the rate of maturation of an individual.

Child growth is the result of the interaction of many regulatory factors, both hereditary and environmental. Optimal growth can be achieved only when all these factors work in harmony.

1.2: Some Important Indicators of Child Growth

1.2.1 Growth Curves: One of the fundamental approaches to the analysis of longitudinal data is curve fitting. Fitting curves to individual growth records permits the extraction of a maximum amount of information about an individual child's growth, and individual curves can, of course, be compared and contrasted. Further, when fitted growth- curve parameters are available for a large number of children, mean parameters and variation around them are convenient way of summarizing a large amount of data for comparison of growth patterns between sexes or between populations (Thissen et al.,'76). Thus, fitting curves provides a convenient means of characterizing individual or group differences in the pattern of growth.

1.2.2 Percentiles: The most widely used growth charts are constructed by measuring many boys and girls of all ages and breaking the range of their statures and weights into percentiles. These percentiles are represented on the growth charts. Age in years is marked along the bottom of the chart. Stature in centimeter/inches is marked along the left side. The 50th percentile is the average stature for any given age.
The normal range should be emphasized. The diagramed percentiles are generally P_5, P_{10}, P_{25}, P_{50}, P_{75}, P_{90}, P_{95} respectively.

The 5^{th} and 95^{th} percentiles added to specific charts the limits for length and height are considered as lowest and highest percentile growth.

1.2.3 Body Proportion: Measurements of stature, sitting height and indirectly leg length (stature minus sitting height) together is called body proportion.

1.2.4 Body mass index: In order to assess secular growth changes in stature, weight, and weight for stature as expressed by BMI= weight/stature^2.

1.2.5 Total body fat: Total body fat calculated from body density which predicted from trochanteric adipose tissue thickness. Total body fat increases in women than in man with their age, but not in infancy and childhood.

1.2.6 Increment of growth: Increment means progress. Increments can provide more sensitive information about the normality of growth progress than status at an age or at a series of ages. The Increments should be calculated for 6-month interval during the age of 6 to 12 years.

1.2.7 Z-Score: The deviation of an individual's value from the mean value of a reference population divided by the standard deviation of the reference population (or transformed to normal distribution).

1.2.8 Growth factor: There are various types of growth factors role in human body, such as genetically, hormonal, nutritional, physiological, environmental, seasonal effect etc.

1.2.9 Types of growth: Infant and children's growth are normal and abnormal. Abnormal growth means catch-up or catch down growth in the growing period of children.

1.3: Importance of the Study

Physical growth and maturation are important partly because they are normal physiological processes that are essential for the well being of the human organism. Aspects of growth and maturation can be used as 'indicators' of genetically determined variation, environmental factors or pathological processes.

Physical growth is measured, in general, in four dimensions weight, stature, head circumference and skeletal growth. Patterns of growth in head circumference are an important index of brain size, particularly during infancy when cranium is thin. It is also an important predictor of fat free mass.

Weight and weight gain (or loss) are important, particularly during childhood, because their association with disease. Skeletal growth is responsible for accumulation of adipose tissue-a risk factor for cardiovascular disease and diabetes. Stature is also important during childhood because slow growth in stature indicates the presence of an influence that is retarding the physiological process of normal growth. In addition it assists the interpretation of weight, particularly as a ratio weight/stature^2, popularly known as BMI (Body mass Index). Some other measures like arm circumference, chest circumference, etc. are also in use to asses the nutritional status while measures of different limbs and their relative growth are in use to asses the over all balanced growth of human body.

According to (Hill; 2008) normal development of growth charts are part of the normal ongoing monitoring of the new born infant development is the simple measurement of weight, length/stature and simple motor skills compared to large data sets of clinically normal infants. International child growth chart of new standards 2006 for infant and young child released (27 April, 2006) by the WHO provide evidence and guidance for the first time about how every child in the World should grow.

The new standards prove that differences in children's growth to age five are more influenced by nutritional status, feeding practice, environment and health care than genetics or ethnicity.

Earlier growth charts had been prepared independently for children of different countries and nationalities using large numbers of clinically normal children who tend to be taller and heavier than many other countries. The physician and people all over the world use that growth chart of WHO which is not symmetrical growth reference for the children of each and every country. So, every nation should have standard growth charts of their own.

There are two factors that cause the gradual growth of human child. One is genetically and other is environmental. Human growth study is meaningful for two reasons. Firstly, Mongolian population such as China, Japan, Korea-countries are too much shorter in comparison to the western and the American population. So to develop the average height population Ergonomics study started institutionally in Japan. Secondly, usually to ascertain the dose of medicine to children, age is supposed to be standard. But when same dose of medicine is put on equal aged infants or Childs whose growth are catch up or catch down or abnormal growth then the dose of medicine may react in those infants or Child's body or may not work at all. So nowadays, practice of prescription of medicinal dose according to the growth of children has already been started in developed countries.

Animal birth and gradually pre-natal and post-natal growth is a super natural event. Just like that human infant born and gradually grows day by day. We all know that infant or children grow, but accurate and quantitative study of this growth began very late in the history of natural science. So the knowledge about the child growth depends on the idea by observing external experience. In this field, as in all others areas the concepts of time and magnitude play a primary part but the simple methods of qualitative observation do not provide decisive results. Advances in our knowledge with centauries it have come through the introduction of precision by put up short techniques in the collection and measurement of observations, and the application of graphic, numerical, statistical analyzing methods.

Pediatrics in our country use the CDC growth chart. It is important to the people of Bangladesh to understand the growth charts of ours which follow our child's growth over time or to find a pattern of our child growth. By using the charts they will be plotting their child's weight and height at different ages and seeing if he/she follows a growth curve at any time. Even if their child is at the 5th percentile for his/her weight, which means that 95% of kids of his/her age weight more than he/she does. If he/she has always been at the 5th percentile, then he/she is likely growing normally. Through the child growth is consistently supposed to be in the normal range (between the 10^{th} and 90^{th} percentile). It would be concerning and it might mean there was a problem with his/her growth if he/she had previously been at the 50th or 75th percentile and had now fallen down to the 5th percentile.

Also remember that children between the ages of 6 and 18 months can normally move up or down on their percentiles, older children should follow their growth curve fairly. But sorry to say that we have no such growth charts at our disposal.

- Height, weight and changes of various organs parameters are more important for significant growth and sexual development to the physician who observes and wishes to control individual growth and physical development. To establish a medical judgment of an individual's state of health, if they compare their measurements with reference data or standard curve values of growth in our country. Suitable standards must be based on surveys of height, weight, and sex characteristics of the population to which the child belongs.
- Secular changes in growth patterns are important indicators of the health status of a population. Influence by hygienic, cultural, and economic conditions, they are related to changes in morbidity and mortality in our country. Because Secular

changes are clearly perceptible in variables such as height, weight, chest circumference, head circumference etc and sexual maturity which provide the biometric data for studies of growth trend shifts.

- Longitudinal growth and maturation have important social implications. A logical concomitant of changes in stature is, for example, that clothing, furniture, and tools have to be redesigned, and that the architecture of homes, schools, and workshops has to be adapted. An earlier development of maturation characteristics accompanied by an earlier onset of biological adulthood, will undoubtedly affect legislation, jurisdiction, and education.

Allometric growth characterizes probably all living beings. It means differential growth and refers to developmental patterns of growth which is not uniform, that is, not all parts of the organism develop at a same rate. An example, known to all who look at babies and adults and note the difference therein, is head size. While it is true that an adult head is larger than a baby's head, it is in fact relatively (in relation to the baby) smaller. A late fetus has an enormous head in relation to its body length. Differential growth accounts for the changing proportion of head size. Perhaps an equally obvious instance of allometry is leg length in humans. The fetal and newborn babies have short, chubby, and ineffectual legs. The proportion of leg length to body length is low. About half of the adult height is accounted for by leg length. Obviously, legs accrue length disproportionately compared with body length. So, allometric growth model can be used to find change in head and body dimensions of child and adults.

Chapter Two

Genesis of the Study

Chapter- Two

Genesis of the Study

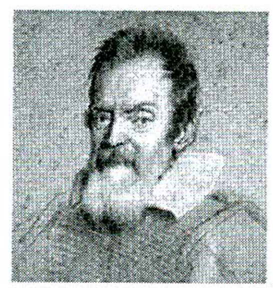
2.1: Review of Literature

Fundamental Mathematical Concept

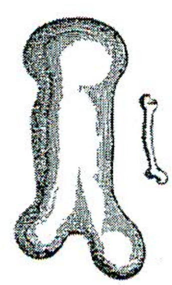
$$y = bx^{a/c}$$

Allometric Growth

Developed by:



Galileo Galilei



Galileo developed the idea of allometric growth in his Discourse, published while under the house of arrest in 1638. He noted that the bones of larger animals grow thicker at a faster rate than they grow longer compared to the same bone in smaller animals.

Primary Reference

Galilei, Galileo. 1638. Discoursi e demonstrazione matematiche intorno á due nuove scienze. Leiden: Elseviers. (1950. Discourses and mathematical demonstrations concerning two new sciences: The first day, and parts of the second day, the third day and the fourth day. Chicago: Chicago University Press

Frederic Cuvier probably gave the first example of relative growth (Brain/body studies: Interspecific and intraspecific comparisons). Cuvier observed that in closely related mammals the bigger the animal the smaller the relative size of the brain (Gayon; 2000). However, it is only at the end of the 19th century that a quantitative formula was proposed for this strange phenomenon. In 1897, Eugene Dubois (1858–1940), the Dutch naturalist who coined the expression 'pithecanthropus,' published a remarkable article on the relation between the weight of the brain and the weight of the body in mammals. Dubois wanted to develop a quantitative tool that could discriminate between two factors that determine the brain volume: (1) the 'degree of cephalization' (reflecting the position of a given species on a scale of evolutionary progress); (2) size since, in related species, the brain will be relatively smaller in a bigger species of animal. These two requirements are reflected in his final formula (Dubois, 1897) for the expression of the relation between the weight of the brain 'e' (for encephalon) and 's' (for soma): $e = c{\cdot}s^r$ where: c is the 'coefficient of cephalization' and r, is the 'coefficient of relation' (Dubois thought that the relative size of the brain was in fact more or less proportional to the surface of the body, that is r = 0.66) This was obviously a power function. Moreover, 'e' and 's' were easily measurable, and 'r' could be inferred from comparisons between related species. From these comparisons, Dubois calculated the value of r as being between 0.51 and 0.55. One year later, a young French physiologist, Louis Lapique applied Dubois' formula to the comparison of the relative weights of brains between individuals belonging to a single species, the Dog (Lapique, 1898). He obtained a value for the coefficient of relation 0.25. In the following decade, Lapique wrote a number of other articles on the relative weight of the brain both within and among species. He systematically obtained coefficient of relation values that were close to 0.25 for intraspecific comparisons, and close to 0.5– 0.6 for interspecific comparisons. In 1907, Lapique gave an impressive graphic representation of what he called Dubois' formula, in the case of interspecific comparisons (Lapique, 1907). This representation is based upon the fact that the power function $e = c \cdot s^r$ is strictly equivalent to the logarithmic equation $\log e = r \log s + \log c$. With logarithmic coordinates, comparisons between related species obeying Dubois' law will lie on a straight line. Because Lapique accepted Dubois' conclusion that the coefficient of relation was always equal to approximately 0.55, his graphic representation of the relative weight of the brain in related mammals consists of a series of parallel straight lines. Lapique called these lines 'isoneural lines'. The equations have the same 'exponent of relation' r (that is the same slope); the only difference between them is the coefficient of cephalization c. On the same diagram, Lapique also drew a series of dashed lines with a 45^0 slope. These lines are purely theoretical. They corresponded to what would happen to a series of animals in which the absolute ratio between brain and body weight was maintained. Lapique did not comment further on this representation, but it should be noted that this is exactly the kind of graphic representation that was the basis of S. J. Gould's reflection on allometry sixty years later. This leads us to our first conclusion. Around 1900, Dubois and Lapique's research on the relation between brain size and body size involved a mathematical and graphical tool that exactly corresponded to what was later called allometry (inter- and intraspecific allometry, or Gould's 'static allometry'). This tool was then commonly applied to iterspecific and intraspecific comparisons of adults. Lapique tried to apply this tool to a small number of other nervous or sensory organs (medulla, or eye size; see e.g., Dhe´re´ and Lapique, 1898; Lapique, 1910). Neither Dubois nor Lapique was interested in individual growth. It should be observed that they were convinced that the slope of the logarithmic curves was always the same: 0.25 for intraspecific comparisons, and 0.5–0.6 for interspecific comparisons. They thought that this was an empirical law, with no clear theoretical basis.

Dubois and Lapique's line of research was biometrical. The following approach was experimental. From the early 1900s onwards, a number of biologists observed that in many animals, secondary sexual characters grew relatively larger over an individual's lifetime. Albert Pe´zard made the first experimental and quantitative study of the subject. In a doctoral dissertation that was completed before the beginning of World War 1st (1914) but published only in 1918, Pe´zard studied the development of sexual characters in cockerels. Plotting the lengths of spurs and comb against overall body size, he showed that there was an obvious 'discordance' between the curves of body size and comb size, whereas the growth of the spurs approximately followed the bird's general development. Pe´zard provided many diagrams illustrating this phenomenon. He also proposed a new terminology: Growth that follows the general development of the organism can be termed '*isogonic growth*', and growth that is special or conditioned can be called '*heterogonic growth*' (Pe´zard; 1918). 'Heterogonic growth' remained the commonest expression for individual relative growth until the introduction of 'allometry' in 1935, especially in the English literature. Pe´zard's monograph was a remarkable experimental study, which influenced many people working in a wide range of areas: the physiology of sex of course, but also embryology, endocrinology, biometry. It showed clearly that the relevant variable was not time, but body size. Furthermore, his use of graphs made the significance of the data particularly clear. There was, however, an important absence in Pe´zard's work. He did not propose any hypothesis about the algebraic form of the law of heterogonic growth of the comb. In 1924, in a book entitled *Sexuality and*

Hormones, Christian Champy, another French physiologist, proposed such a formula. In this book, he coined the expression 'Dysharmonic growth' for 'an extremely general phenomenon', which he claimed to have discovered: the continuous increase of the relative size of secondary sexual characters as a function of body size (Champy, 1924). The book provided impressive illustrations of this phenomenon, especially in insects. Champy explained this phenomenon by a sexual hormone causing an increase of the rate of mitotic cell divisions in certain parts of the body. For this reason, he argued that the relative growth process was adequately described by a parabolic curve (Champy, 1924). 'Disharmonic growth' followed thus a law of the form: $\boldsymbol{V = at^2}$ where V is a measure of the secondary sexual character, and t is body size (Champy, 1929). In this formula, the relative growth of an organ is obviously a function of body size. This equation is not exactly similar to a power law, but it is a special case of it. Later on, in 1931, Teissier observed that Champy's law was indeed a good approximation for the insects he had used to verify his formula. In *Dynastes*, the power law is indeed a parabolic law. Neither Pe´zard nor Champy referred to the classical biometrical works of Dubois, Lapique and others on the relation between brain and body size. But their work on individual relative growth was crucial to the emergence of the general concept of allometry.

Huxley and Teissier (1924–1936): Huxley's first paper on relative growth appeared in 1924. He tried to answer a question raised by Thomas H. Morgan, a year earlier, on the abdominal width of female fiddler crabs (***Uca pugnax*). Morgan was puzzled by the very large abdomen of some of these animals, and wondered whether this character resulted from their genetic make-up or from the law of growth. Working on Morgan's data, Huxley argued in favor of the second hypothesis, and, on this occasion, used for the first time Pe´zard' terminology of '*heterogonic*' and '*isogonic*' growth. Although this paper did not provide the law of heterogony which made him famous a few months later, it did provide a simple method for detecting heterogonic growth: 'The best method of detecting and analyzing heterogonic growth-rate is by plotting the percentage size of the part in question against the absolute size of some dimension of the whole body' (Huxley, 1924*a*). In the case of Morgan's data on the fiddler crab, it was plotting the ratio of abdomen breadth/carapace breadth (A/C) against carapace breadth (C). If the slope of the curve does not vary as C increases, the character is isogonic; if it varies, this means that the growth-rate of the abdomen varies. Huxley provided a sketched graph. The graph contained three curves; two of them represent the law of growth of two classes of crabs. Another represents the mean growth of all crabs. One curve shows a typically *isogonic* growth (A/C varies continuously and regularly). Another curve shows an *isogonic*, then *heterogonic*, growth. Third curve describes the whole population. Nevertheless, this paper did not say anything about the law of heterogonic growth, which was the object of a second paper, published a few months later in *Nature.* This was a short note, not much more than a page, but it is certainly Huxley's most significant scientific contribution in terms of empirical research. In this paper, Huxley (1924*b*) stated a law of heterogonic growth for the chelae of fiddler crabs. This law is a power law of the form: $\boldsymbol{y = bx^k}$ where: y is the magnitude of the differentially growing organ; x, the body size; k, the constant differential growth-ratio; b, the constant (origin index). The essential theoretical feature of this formula is the following: what is constant (k) is not a ratio of two sizes but a ratio between two growth-rates. Furthermore, Huxley said, the power law can be expressed equally well as a logarithmic equation: $\boldsymbol{\log y = k \log x + \log b}$. Under this form, it provides a remarkably easy method for detecting and proving the existence of heterogonic growth: with logarithmic coordinates, the heterogonic growth of an organ will appear as a straight line. At this point, it is worth asking what Huxley's debt to the various authors discussed above was. In his 1924 paper, Huxley quoted Pe´zard and Champy, but there was no allusion whatsoever to the brain/body studies. In his 1932 synthetic book on ***Relative Growth***, he occasionally quoted some late papers by Dubois and Lapicque, but never the crucial papers discussed here. Moreover he did not allude to them when he solemnly introduces his mathematical formulation of the notion of 'constant differential growth-ratio'.

Georges Teissier's started to works on relative growth and later on interested both in systematics and biometry. He published on relative growth in 1926 on a function of body size in various insects. Like Lapicque, Teissier proposed a formulation of relative growth with the aid of a power law. In his subsequent papers on differential growth (1928*a*, *b*, *c*, 1929), Teissier continued to refer to Lapicque. But he also began (1928*a*) to refer to Huxley and to use a differential growth formula, which was formally identical to Huxley's. Still he never said that Huxley had discovered it. Finally, in his doctoral dissertation of 1931, Teissier devoted a full paragraph to the history of relative growth. There he acknowledged the important role of Huxley, but denied that Huxley had discovered the method of describing differential growth with the aid of a power law and logarithmic coordinates. He said that this method of description of relative growth had been discovered in 1897 and 1898 by Dubois and Lapicque (Dutch and French respectively), and that they had applied it to the study of the variation of characters such as brain size or the area of the retina, as a function of body size in vertebrates (Teissier, 1931). Did Teissier deliberately quote Lapicque instead of Huxley in his first paper, in order to avoid recognizing Huxley's priority? This is possible, but he does not think it is the case. More simply, Teissier was biometrically oriented, he was originally interested in inter- and intraspecific comparisons in adults, and it was only a little later (in his doctoral dissertation) that he came to be interested also in individual growth (Teissier, 1931). Whatever the case, the lesson of this story is that the discovery of the concept of constant differential growth ratio is a complex one. Huxley certainly played a major role in it, in interpreting individual growth in terms of a power law. But he did not discover a formula that had never been previously thought to apply to differential growth in general. This being said, at the end of the 1920s and in the 1930s, a veritable industry of differential growth has rapidly developed. The power law was verified in innumerable examples, and became a standard tool for the study of simple as well as complex patterns of development, with different parameters for simultaneous allometric curves in the same animal, critical points, etc. Many examples of this kind of study can be found in Huxley's and Teissier's synthetic books published in 1932 and 1934 respectively.

Huxley's and Teissier (1936) decided to abandon the terms they had each previously used: 'allometry' replaced Huxley's 'heterogony' and Teissier's 'dysharmony'; 'isometry' replaced 'isogony' and 'harmony'. They also agreed on a common symbolic formulation of the law: $y = bx^a$ the comparison of the French version and the English version, and the correspondence between the two authors show that most differences are unimportant. There is however one major difference. It concerns the constant 'b'. For Huxley, this constant had no biological significance whatsoever. His 'b' was no more than the value of y when $x = 1$. This constant was therefore arbitrary, and depended only on the choice of the measuring-unit. Since this unit could be such that the allometric relation did not exist for a given value of x, the 'b' parameter had no biological signification. Teissier did not agree. He felt that 'b' could be given a biological meaning if attention was paid to the statistical nature of the data. For this reason, he introduced into the French version the following sentence: 'from a statistical point of view, it represents the mean value of the ratio *y*/*x* for all the observed individuals' (Huxley and Teissier, 1936*a*). Huxley did not put this sentence in the English version. In another paper published in 1936, Teissier provided a remarkable example of the biological meaning of the coefficient 'b'. He showed that local populations of a given species could have allometric equations for a certain organ that differed only by the coefficient 'b'. If for example the growth of the chelae of a lobster could be described by two successive allometric equations, and if the only difference between the two local races was in the 'b' coefficient of the second equation, this meant that one of the races initiated the second phase of growth earlier, in younger animals. This disagreement between Huxley and Teissier proved extremely important for the further history of allometry.

Allometry is a modern evolutionary theory in growth. A lot of work has been done in the 1980s and 1990s on the physiological and embryological mechanisms that act as proximate causes of allometry (Stern and Emlen, 1999). This would be a fascinating subject; it is frequently argued that the Modern Synthesis neglected morphology and embryology. This is partly true, and thus partly false. What they will try to show here is that allometry was a major opportunity for those responsible for the Modern Synthesis to take into account morphology and embryology. Allometry was certainly not a major theme in the early phase of the modern synthesis (1940s), but it became quite important in the 1950s and 1960s among biologists who were obviously working within the paradigm of the modern synthesis and Stephen Jay Gould as an exemplary model of this attitude. A complete historical description would obviously include many other authors. However Gould can be seen as the person who most aptly recapitulated and renewed the subject. Thus, Gould show how insofar as he worked on allometry, played a major role in the completion of the Modern Synthesis. Strangely enough, Huxley (1942), in his Evolution: *The Modern Synthesis*, did not say much about allometry. He devoted to this subject are essentially a compilation. No clear idea emerges as to the possible important theoretical problems raised by allometry for the modern synthesis. Huxley, like many others involved in the Synthesis, was probably embarrassed by the idea that, if allometry was really a very important phenomenon in evolution, then it challenged the overall adaptationist orientation of the synthesis. In 1949, however, Norman Newell, an invertebrate paleontologist who later tutored Stephen Jay Gould, published an important article on phyletic size in invertebrates in the journal *Evolution.* A few passages are devoted to allometry. They were sketchy, but obviously important for the author. Basically, Newell rejected the common view according to which allometry implies non adaptive or orthogenetic evolution. Newell used three arguments; all related to the so called constant parameters of the allometric equation. Firstly, he claimed that the parameter a (the constant differential growth-ratio) is in fact modifiable by natural selection. Secondly, the constancy of a (which Newell calls 'k') can in certain cases be attributed to natural selection. Following Simpson, Newell mentioned the example of the relatively wider limb bones of larger land vertebrates. Here we have an allometric curve with an exponent approximately equal to 1.5. This is obviously due to natural selection: 'Large animals without a proper relation between limb and body size would not survive' (Newell, 1949). Thirdly, the 'b' parameter can also change as a consequence of natural selection. The main themes of Gould's approaches were as follows: (1) Clarification of the meaning of the constant b in the allometric equation. (2) Clarification of the relation between allometry and adaptive evolution. (3)

Clarification of the relations between the various modes of allometry. Although this was not clear from the outset, these three themes were in fact closely related. Concerning the 'b' parameter, Gould, like Teissier, whom he significantly quoted that it has a biological significance, and indeed a major one. In interspecific or intraspecific allometry, changing 'b' means generating a new regression line, which is parallel to the previous line, but is shifted one way or another. Gould's question is thus: from a dynamic point of view, how are certain species able to transcend their allometric curve, and jump to another one? In particular, how can they preserve their overall shape that is the absolute value of the ratio between one particular organ and the global size of the organism when size increases? From a mathematical point of view, such a process means that a certain lineage would be able to shift from one allometric curve to another along a line of slope 1. Gould (1971) diagram is very similar to Lapique's representation of 1907, with its theoretical lines of slope 1 going from one allometric curve to another. For Dubois, moving from one ''isoneural'' line to another could be accomplished by a sudden change in the ontogeny. Dubois thought that mammals had increased the absolute brain/body ratio by successive doubling of the number of neurons in early embryogenesis. The second possible mechanism is acceleration or retardation of development in the course of phyletic evolution. In contrast with Dubois's schema, this hypothesis does not imply sudden change, but a gradual evolution that involves intraspecific selection or selection between closely related species. For Gould, allometry, when it exists, is most often a non-adaptive source of evolutionary change. Such a change is a mechanical consequence of the increase in size, an increase that is itself adaptive. Thus allometry will most often be a source of biological diversity. But once the increase of size has taken place, organisms have to compensate for the non-adaptive effects of allometry.

In constant environments in particular, allometric parameters ('b' as well as 'a') will be subject to natural selection. The treatment of allometry relies on bivariate analysis. However, modern analysis of the evolution of shape relies on extensive use of multivariate analysis.

Allometry is a modern evolutionary theory in human growth. Bacallao et al. (1992) studied on multivariate allometry model fitted to Morphometric Harmony of four skin fold in a sample of 250 newborn. Harmony is identified with the attribute of small variability of a function of morphometric dimensions. The chosen function defines allometry if it is linear in the natural logarithms of the variables. The existence of a harmonic relationship among the skin folds, which is independent of weight, total body mass index, and several other maternal variables, is indicated. However some evidence that suggesting a possible correlation with the nutritional condition of the mother. The analysis showed that the multiple allometry model adequately describe the harmonic relationship among four skin folds in the newborn.

Wales (1998) had shown that short-term human growth is non-linear (allometric) unpredictable. It is therefore not possible in clinical practice to predict future growth from short-term measurements although it is valid to compare dose and efficacy of growth suppressing and promoting therapies in carefully designed studies. Longitudinal studies of increasing intensity and the use of new and as yet undiscovered technique of measurement and analysis are still required to look deeper and deeper into the biology of the growth process.

In Shea (1989) and Alberch (1990), heterochronies are described as perturbations of a 'common pattern of growth allometry', either in growth duration (prolonged or truncated growth) or in growth speed (retarded or accelerated growth). The multivariate approach to allometry allows us to obtain the ontogenetic shape changes, which are shared by humans and chimpanzees. This fundamental concept of heterochrony (perturbations of a common growth pattern) disappears when inadequate metric methods are used (Klingenberg, 1996). The common growth pattern of the skull makes reference to similarities in craniofacial development in mammals, and more particularly in apes and humans (Enlow,1968; Enlow and Hunter, 1970; Bromage, 1992).

Ohtsuki and Ito (1980) applied allometric technique to find the secular change in head dimension with respect to stature. Recently some researchers have used allometric technique to look for secular changes in lon bones and early maturation with respect to stature (Jantz and Meadows, 1995; Jantz and Jantz, 1999). Hossain, G. (2002) has used this technique to find the secular changes in head dimensions of Japanese adults.

The history of child growth and development study is not very old. In between 1927-32, several research center and institutes were developed on the multidisciplinary study of child growth of which Fells Research Institute (1929), Institute of Human Development (Berkeley), The Child Research Council (Boston) are important. White House Conference (1933) on Child Health and Protection recommended the need for such studies. The idea behind such studies was partly to shield children from the worst effects of the Great Depression and partly to acquire further knowledge to determine the effects of the Great Depression and the possible remedial effects.

Various kinds of research on the growth of human body and organs

In the developed countries like America, Europe, German, Russia, Cuba, England, Spain etc Comas Juan (1930), in his famous book Physical Anthropology has discussed the growth of various organs of human body at age 0-18 years.

Ali and Ohtsuki (2000) estimated the maximum increment age (MIA) in height and weight of Japanese boys and girls during the birth years 1893-1990 using the published data of the Ministry of Education, Science, Sports and culture in Japan. They found that the estimated MIA shows an overall declining trend, except in birth year cohorts in 1934-1951.

Chinn et al. (1989) had studied of secular trend in height by using the data of Primary School Children from schools participating in the National Study of Health and Growth in 1972, 1979 and 1986. About 50% of the trends from 1972-1979 for English and Scottish boys and girls were accounted for by changes in family size, with some contribution from increase in parental height and from birth weight, but almost none from changes in social class distribution. Estimates for 1979-1986 showed that the trend towards increased height in five to eleven years old children.

Tsuzaki et al. (1990) studied the difference in head circumference between Japanese and Caucasian Children. The subjects consisted of a total of 42,392 Japanese children between zero and four years of age surveyed from 1940 to 1980, and those data were compared with those of American and British children. They found that, there was a significant ethnic difference in head circumference, as large as one channel of usual percentiles, between Japanese and Caucasian children. The results indicated that smaller head circumference in Japanese children primarily reflects smaller stature of the Japanese.

Lindgren and Hauspie (1989) have conducted a longitudinal study of physical growth of Swedish School Children, born in 1955 and aged 10 to 18 years. They have shown the secular changes in height, weight and weight-for- height as expressed in BMI. From the samples of Swedish School Children born in 1955 and 1967 they have compared average heights and weights over 10-15 years. The main findings were that both boys and girls had been gaining more weight than height, especially around the ages at which peak velocity generally occurs. Since the increasing height of children born in 1967 gradually diminishes after age at peak height velocity, it seems that the height difference during puberty mainly reflects an earlier maturation of these child's, compared to the child's born in 1955.

Henneber and Louw (1998) have discussed on the patterns of physical growth (height, weight, length of body segments, circumference, widths and functions of grip strength, reflexes and pulse rates) "Cape Coloured" School children. Data were collected on selected urban and rural groups with maximum contrasting socio-economic status (SES). The heights and weights of pre-pubertal urban children match American reference data, but post-pubertally they decline some what, whereas these measurements of the children consistently put down standard deviation below the urban group. Skin folds thickness of urban children match or exceed the American reference, implying that their nutritional needs are being met well. Functional Indicators of rural children are much poorer than those of urban children.

Rosique and Rebato (1995) had studied on regional differences in the growth of Spanish children by fitting the Preece-Baines-1 Model to cross sectional stature data. The function parameters and derived biological variables were used to compare children from seven different studies. Regional differences in growth are interpreted as a result of a geographic variation among Spanish provinces in demographic, public health and nutritional conditions. There are differences between urban samples depending in region. Adult stature and the pattern of growth differ between urban and rural populations from the interior lands. Males from urban Extremadura, Barcelona and the Basque country show the tallest adult statures. Adult statures of males from Segovia, Extremadura emigrants and Cuenca are not only the lowest but the growth pattern shows delay in estimated ages at take-off and PHV compared to the other populations. Estimated age at PHV is later for all male samples compared to Vizcaya, except for the sample of Barcelona-1. Females from Barcelona-2, Segovia and the Basque country show the tallest adult structure. All of the female samples except that of urban Extremadura, have an earlier estimated age at PHV compared to the sample from Vizcaya.

Greulich (1976) analyzed on three hundred and sixteen (35%) of the American-born Japanese children whose height, weight and skeletal age where recorded in 1956-57 were reexamined as young adults between 1968 and 1974, when they were found taller, heavier and shorter legged than men and women in Japan who were born in the same years as they. These differences between the American-born and the native Japanese adults were relatively smaller than they had been during childhood, due to both an acceleration in the growth rate of the native Japanese and a concomitant decline in that of the American-born Japanese during the intervening years. A comparison of their 1956-57 data with Kondo and Eto's findings in Los Angeles in 1971 shows that there have been very little increase in the size of California-Japanese children between 6 to 20 years of age, at 10-year intervals from 1900 to 1970, disclosed the changing rate at which they grew during different of that period. Those curves and other data discussed in their paper provide additional evidence of the biological superiority of the human female as compared with the male.

Mohammad et al. (1999) have investigated BMI from weight and height data obtained from the 1990-1992 National Health Survey, a random cluster sample survey of 1 in

1000 families in Iran. Weight-for-height percentiles of children and adolescents aged 2 to 18 in Tehran have been computed relationships between weight for age and height for age Z-score. The resulting percentiles are compared to weight-for-height percentiles for BMI (weight/height^2) charts. From the investigation of the data points age by age revealed that the normal range of BMI for age is effectively equivalent to the normal range of weight-for-height by age.

Ashizawa et al. (1994), estimated the diversity of adolescent growth, spline-smoothed individual velocity curves of stature, body weight and chest circumstance of 44 girls in Tokyo, of which menarche was recorded correctly. Additionally, 25 variables of ages at peak velocity, intensities, sizes and weight at the peak and at menarche, and terminal height are obtained.

McGregor and Billewiez (1982) described of heights and weights for more than 25 years for two neighboring Gambian villagers have been used to the pattern of growth. Height growth curves from the age of 5 to 25 years were fitted for 55 boys and 62 girls. The curves indicate that puberty is much delayed in Gambian adolescent in comparison to British and West Bengal data.

Norgan et al. (1982) anthropometrically measured 105 coastal and 115 highland 17-48 year old new Guinean men and women. The two groups experienced different physical, biological and social environments, the highland group being less exposed to new influences. Highland men had greater body weights and fat-free masses than coastal men but stature, body density, skin fold thickness and fat mass were similar in the two groups. In the women, there were significant negative correlations of age with body weight, skin fold thickness and fat-free mass and fat mass which contrasts with the changes seen in European populations.

Malina et al. (1985) had calculated relationships among ages at attaining 17 or 21 indices of maturity were considered in a longitudinal sample of 177 Polish boys examined at annual intervals from 1961 to 1972. Maturity indicators included ages at peak velocity for stature, sitting height, leg length and weight. All inter correlations among the development indicators were positive.

Rao and Reddy (2000) made a cross-sectional study on 1565 Sugali children (854 boys and 711 girls), aged 1 to 20 years. Anthropometric measurements included height, weight, skin fold measurements at triceps etc. They had found that the Sugali boys and girls are shorter and lighter than well-to-do Indian standards. The median heights and weights of Sugali boys and girls fall below the 5th percentile of NCHS standards. Finally, the results were discussed with a comparative view point.

Malina (1979) had broadly examined and discussed about the children of today are taller and heavier and mature earlier than children of same chronological ages several generations ago. The secular trend, however, is not universal. Data showing a secular trend in growth and maturation are derived largely from Europe, Australia, Canada and the United States and from Japan. His review considers secular changes in growth, maturation and physical performance.

Livshits et al. (2000) studied 681 Israeli boys and girls, including 355 regular siblings (SB), 112 pairs of dizygotic (DZ) and 51 pairs of monozygotic (MZ) twins, was measured for body weight, length and head circumference at birth and during the first year of life. Variance decomposition analysis was used to simultaneously assess the contribution of gender, gestational age, additive genetic factor, common sibs' common intrauterine environmental effects on total variances of each studied trait separately. All these sources of variations were statistically significant.

Hoppa and Garlie (1998) estimated between comparisons of measurement of height from the late 19th to mid 20th century in Toronto School children. Comparison of the Toronto growth profiles to other published 18th and 19th century growth data demonstrates that the secular trend in the Canadian children is a reflection of the continued global trend towards increased height. The implications of this changing pattern over time are discussed in the context of changing urban health and nutrition in the greater Toronto area.

Togo and Togo (1982) had conducted a research on stature and body weight in five siblings based on monthly measurement data. Time-series of stature, body weight and their increments per month was made and resulting in three components a trend and cycle factor, a seasonal factor and an irregular factor. Significant seasonal variation was found in both stature and body weight. Trend factor in increment indicates that growth rate of stature or body weight are fluctuating, instead of being smooth, suggesting that from birth to maturity acceleration and declaration occur alternatively, like repeated retardation and sub sequent catch-ups.

Beunen et al. (1981) had estimated the relative importance of skeletal age, chronological age in explaining body measurements and relative importance of skeletal age, chronological age, height, weight and their interactions in explaining motor fitness components are reported. The interaction between skeletal age and chronological age as such or in combination with height/weight has the highest predictive value except for trunk strength (leg lifting) and functional strength (bent arm hand).

Galllo and Mestriner (1980) had presented the values for height, weight, circumference for 2, 115 Somalis aged from birth to 18 years. Height and weight means are plotted on American Standard Charts. The circumferences are compared with variables in Americans and European descent. The difference of the Somali means when compared with the International Growth Standard Charts suggested the construction of local growth charts to use in Somalia.

Ali and Ohtsuki (2000) had discussed longitudinal growth in stature for 509 males and 311 females characterized from early childhood to adulthood. A triphasic generalized logistic (BTT) model was used. Growth parameters are derived from the estimated distance and velocity curves for each individual. A set of estimated growth parameters, including adult stature, was selected to develop equations, through the forward stepwise regression method, for the prediction adult stature for Japanese boys and girls.

Cole and Roede (1999) was found the distribution of body mass index (BMI) in Holland from the nationally representative grown survey in 1980, when obesity was uncommon. Forty-one-thousand boys and girls age 0-20 years. BMI percentiles based on the original height and weight data were derived using the LMS method. They had shown, median BMI the familiar pattern of a rise in the first year, followed by a fall, then a second rise after 6 years.

Ashizawa et al. (1994) estimated to make clear the diversity of adolescent growth, spline-smoothed individual velocity curves of stature, body weight and chest circumstance of 44 girls in Tokyo, of which menarche was recorded correctly, were provided. Additionally, 25 variables of ages at peak velocity, intensities, sizes and weight at the peak and a menarche, and terminal height were obtained. On an average, take-off for height occurs at age 8.5, then that for weight at 8.8, for chest circumference at 9.1.

Nagamine and Suzuki, (1994) had studied on 96 Japanese college men and women for the criteria of body composition, skin fold thickness and body density, to apply these to the evaluation of the nutritional status in young Japanese men and women, and to compare them between races. They had found the correlations between body density and skin folds are highest in the abnormal region for men and in the sub scapular region for women. Of the correlation between body weight, body surface area and fat-free mass has the highest coefficient with density.

Matsuo et al. (1990) studied on controversy exists regarding possible international and interracial differences in head circumference of children. They wanted to see if there was a difference in head circumference between Japanese and Caucasian children. They concluded that there is a significant ethnic difference in head circumference, as large as one channel of usual percentiles, between Japanese and Caucasian children. The results indicate that smaller head circumference in Japanese children reflects smaller stature of the Japanese.

Kaplowitz et al. (1991) had discussed on Longitudinal Principal Components (LPC) analysis was used to assess growth patterns in children from rural Guatemala in order to determine their methodology regarding correlates of growth compared to more traditionally used methods, based on attained size and increments. Components indices representing percentile level and percentile shift, attained size, and 3 to 36 month increments of growth was calculated multiple regression. They found from regression results were similar, higher nutritional intakes associated with more rapid growth.

Gyenis (1997) had shown his study that a positive secular trend had been continuing in University students in Hungary between 1986 and 1990. There was another socioeconomic characteristic of the analyzed measurements in the sample: students who were born elsewhere in the country had lower values, both in height and weight, than those students born in Budapest in the 15 successive classes studied.

Shani et al. (1994) studied on weights of apparently normal hearts were obtained from 1,344 male and 313 female adults from the Chandigarh region of Northwest India. On home a medico-legal autopsy was performed. Oartial correlation between heart, weight and supine length were significant.

Kim (1982) had discussed in the growth status of 845 (boys 403, girls 442) Korean school children born and raised in Japan aged between 6 and 17 years in 1978. Height, weight, chest circumference and sitting height of Korean school children in Japan were compared with those of Japanese children. Korean school children in Japan were slightly taller at every age for more favorable environment in Japan.

Chiaki et al. (2004) they studied and construct a chart of body proportion of girls and boys in Japan from Nationwide students. They have found that, Japanese boys (13.5-17.5 years old) were taller and have relatively longer legs than Japanese girls in the same age group. In boys, the percentile values reached the lowest at 13.5 years, then increased slightly. In girls, the percentile values remained constant after 11.2 years, which is different in boys.

Tosellis et al. (2005) studied on the growth of human migration populations. They have studied on the growth pattern from birth to 24 months and the body composition of Chinese infants born and living in Bologna. Weight and height values are higher in Chinese children than in Italians. So, they have found the supporting hypothesis that Chinese children born and living in Italy grow in an appropriate environment their growth potential.

Cameron et al. (1994) had conducted a study on adolescent growth in height, fatness and fat patterning was investigated in sample of 79 rural South African black children studied longitudinally from 6- 18 years. Data were analyzed relative to peak height velocity (PHV) to identify the phenomenon of “compensatory” growth in height during adolescence and to describe changes in fitness and fat patterning, Statistically significant differences in fatness and centralization between males and females did not occur until about 2 year after.

Kasai et al.(1995) had studied on changes in the stature, weight and peak at maximum increments in Chinese urban girls 7-17 years of age between the 1950 and 1985 in Chinese cities. An overall increasing trend is apparent for stature and weight. Girls in 1985 attained peak growth earlier, by 1.08 years and .40 year per decade.

Already it has accomplished research on human growth in various countries in the world. Probably most of the works have been executed on human growth in Japan. On the other hand, the principal purpose or target was on the basis of such work in the developed countries to detect the nutritional status of both the babies and mothers. By this time, three reports in Bangladesh have been recently published, two of which have been observed and directed by NGO’s in Bangladesh and other one has been published by Pervin (2008), researcher under supervison of Prof. Abul Basher Mian and Prof. Md. Ayub Ali, University of Rajshahi.

Very few researches on human growth for Bangladeshi children were addressed (Huffman et al., 1995; Taylor et al., 1993; Karim and Taylor, 1997, 2001). Pervin (2008) collected longitudinal data on 11 pre-selected variables of child growth during the period of 25 May, 2002 to December 2006 for a group of children from birth to 48 months of age from Rajshahi city of Bangladesh and she has found variations of within and between the sexes. She was also found an interesting findings, that is right and left wrist-elbow length differs by more than 2 cm among the children of the study area.

2.2: Research Gap

It is evident from literature review that there is limited research to support a prescribed frequency for performing anthropometrical measurements in order to identify children with physical growth disorders in general. In particular, there have no such significance research which is related to growth monitoring of Bangladeshi school going children. So, Serial measurements data of stature, weight, sitting height, leg length, head length and head breadth etc, as part of scheduled well-child visits are required for this purpose. It is to be mentioned that the ideal number of health maintenance visits either by NGO's or Government initiatives has not been established till now for the Bangladeshi children. In Canada, their current recommendations are that they be organized according to the immunization schedule with additional visits within the first month and followed by additional observations at regular intervals up to 2-6 years of age. For the early identification and referral of a child whose abnormal stature or rate of weight gain may indicate a problem that might require treatment. In cases where a growth problem is suspected or a child's response to therapy is being monitored, more frequent measurements may be required.

Growth charts are a graphic representation of body measurements that aid in the assessment of body size and shape, and the observation of trends in growth performance. They are used in the assessment and monitoring of individual children and in screening whole population. Growth charts are not diagnostic and may be used in conjunction with other information when evaluating a child's health. There is an important distinct between a growth reference and growth standard. A reference simply describes its sample without making any claims about the health of its sample, where as a standard represents 'healthy' growth of a population and suggests a model or target to try and achieve the given charts. Growths charts currently use describe existing growth patterns and are therefore references, not prescriptive standards.

The Government of Bangladesh (GOB) is committed to improving the health of its people, particularly for mothers and children. Health services are mainly provided here through public hospitals and private hospitals & clinics, the nature of services being curative, preventive and promotional, especially health care for women, mother and children. Bangladesh dose not have a national pediatric surveillance system for collecting anthropometrical and nutritional data; therefore, national growth charts do not exit for Bangladeshi children.

Many researcher have applied the allometric technique to find relative growth (Huxley and Tessier, 1936; Sholl, 1948; Shepherd et al., 1948; Gould, 1966; Ohtsuki, 1980; German and Meyers, 1989; Ravosa, 2000; Martinez et al., 2000; Leonart et al., 2000; Schleucher and Withher, 2001). Ohtsuki and Ito (1980) applied allometric technique to find the secular change in head dimension with respect to stature. Recently some researcher have used allometric technique to look for secular changes in long bones and early maturation with respect to stature (Meadows and Jantz, 1995; Jantz and Jantz, 1999 and Klepinger, 2001). Hossain G (2002) has used this technique to find the secular trends in head dimensions with respect to stature over time. This approach will be used in this research to compare the relationship in head and body dimensions with respect to stature for rural and urban children and also for male and female children.

2.3: Objective of the Study

The main objective of this research is to study Allometric growth in children from Jessore district together with the longitudinal growth study on stature, weight, sitting height, leg length, arm length, head length, head breadth etc followed by construction of some important growth charts to monitor the growth of a child and that may be used to compare the growth of urban and rural children and also it may be used to compare the growth standard of Bangladeshi school going children with other standard population.

The details of objectives are:

i) to study stature of primary school going children by age and sex, 6-11 years,

ii) to study weight of children by age and sex, 6-11 years,

iii) to study sitting height of children by age and sex, 6-11 years,

iv) to study leg length of children by age and sex, 6-11 years,

v) to study head length of children by age and sex, 6-11 years,

vi) to study head breadth of children by age and sex, 6-11 years,

vii) Constructing of child growth reference charts of :

a. Stature for age,
b. Weight for age,
c. Sitting height for age,
d. Leg length for age,
e. Chest circumference,
f. Head length,
g. Head breadth,
h. Head circumference,
i. Upper arm length (left & right),

j. Elbow length (left & right),

k. Tibia length (left & right),

l. Arm circumference

ix) to estimate various allometric growth models among the above variables.

2.4: Organization of the Study

There are six chapters in this thesis. Chapter 1 is Introduction, which contains prelude, indicators of child growth and importance of the study.

Chapter 2 is the Genesis of the study that contains literature review, research gap, objective of the study and organization of the study.

Chapter 3 is the materials of the study. It contains selection of study area, sampling design, problems of data collection, and selection & measurements of variables.

Chapter 4 is the methods of the study. It contains descriptive statistics and allometric model.

Chapter 5 is the main chapter of the study consisting of research findings and discussion of the results.

Chapter 6 is the concluding remarks consisting of major findings, limitations of the study and scope for further research.

A bibliography is appended at the end. The questionnaire of the study is affixed in the appendix.

Declaration, title page, acknowledgement, table of content, list of figures, abstract and abbreviations are appended at the beginning of the thesis.

Chapter Three

Materials of the Study

Chapter- Three

Materials of the Study

3.1: Selection of the Study Area

We have Jessore district as our study area. Jessore district is situated on the south west side in the Map of Bangladesh. It is the oldest district of Bangladesh. The river *Bhairab* is passing throw this district. It lies between $22^0 48^{/}$- $23^0 25^{/}$ north latitude and $88^0 90^{/}$- $89.35^{/}$ east longitude (Geology.com). The area of Jessore district is 2570.42 square kilometers and total population is 24,71,554 (census on January 23 to 27, 2001).

Map of Bangladesh and Jessore district are appended for showing various important locations.

Bangladesh Map

Map of Jessore District

3.2: Sampling Design

In this study area of Jessore District, there are 08 Upazilas. One Upazila is chosen at random and it is found to be as "Jessore Sadar". There are 135 primary schools in Jessore Sadar Upazila and they are divided into Urban School and Rural School. Urban area has 35 primary schools and rural area has 100 schools. Three primary schools from Urban and four primary schools from Rural are chosen at random. Data was collected longitudinally from November 2006 to November 2009. Children from class I in the year 2006 of every selected school were considered as the sample observations.

Different growth information of all the children is taken from the direct measurements taken at their School and parent's information is collected from their residence. A questionnaire is used (please see in the appendix).

If any subject (child) was absent in the school then we had to go to their own residence or grandfather's or other relative's house as necessary. All measurements have taken with minimum pressure by instruments. Every measurement was repeated two or three times and the average value was considered as the data.

Name of the selected schools are appended below:

For Urban area;

(i) Polytecnic primary school,

(ii) Jessore Shikkha Board Model School & College, and

(iii) Badsha Foysal Institute.

For Rural area;

(i) Chawlia Govt. Primary School,

(ii) Rupdia Shaheed Smrity Kinder Garten School,

(iii) Zirat Govt. Primary School, and

(iv) Paddabila Govt. Primary School.

3.3: Problem of Data Collection

This study is a longitudinal growth study of Bangladeshi primary school going children. In this study the growth measurement of child have taken by 6 - 12 years of age at regular interval of six months properly and timely.

Longitudinal study is time-consuming and laborious, and it is quite difficult to observe particular subjects at regular intervals over a long period of time without any interruption.

During the study, we have lost about 24% of the sample due to migration of the parents. To confirm the birth date of the child, it was a problem that in rural area, most of the parents did not remember.

3.4: Variables Selected

In this research we have selected the following quantitative variables for the study:

- Stature
- Weight
- Sitting Height
- Leg Length
- Chest Circumference
- Right and Left Tibia Length (Length from Knee to Ankle)
- Upper Arm Length (Right and Left)
- Elbow-Wrist Length (Right and Left)
- Arm Circumference (Right and Left)
- Head Circumference
- Head Length
- Head Breadth

3.5: Measurement of Variables

We have used some instruments in our research, such as: (a) Weight machine, (b) Spreading Caliper, (c) Length measurement Tape, Steel scale etc.

Stature: We have taken stature (cm) of children by measurement tape. With his/her heels together by standing situation (near wall where setting measuring tape) touches a steel scale with the top of the head and measuring tape, we have to measure the total distance between steel scale and the floor. We have taken stature measurement of children at every six months.

Weight: At every six-month we have taken weight of children by our weight machine by standing position. Weighing has done with child clothed only in lightweight. In the latter circumstance the measurements has taken corrected as possible as accordingly by adjusting the machine to read zero.

Sitting height: Measured with the child's back stretched up straight as he/she sits on a table top with his/her feet hanging down unsupported over the edge; the back of his/her knees should be directly the edge of table. Gentle traction was applied under the chain; the muscles of thighs and buttocks should be uncontracted. The head was held vertically, in contact with the back at the sacral and inter scapular regions.

Leg Length: Subtracting sitting height from stature we found leg length.

Chest Circumference: Measured at the marked union of 3^{rd} and 4^{th} stern brae, at right angles to the axis of the body, at tend of a normal expiration.

Right and Left Tibia Length (Length from Right Knee to Ankle): The Child stood on a flat surface. The measuring scale was held vertically and the distance measured from the standing surface to tibia.

Upper Arm Length (Right and Left): The external superior border of the head of radius was marked, and the length from this mark to inferior border of the acromion process was taken.

Elbow –Wrist Length (Right and Left): By keeping child's both hands horizontal and vertical position like as 90^0 angle and both hands are parallel, now by measuring steel scale measured the distance between at the end point of elbow and at the ending point of wrist.

Arm Circumference (Right and Left): By keeping child's both hands horizontal and vertical position like as 90^0 angle and both hands are parallel as a normal we have taken the measurement of arm circumference. The midpoints between the distances of shoulder and elbow by measuring tape.

Head Circumference: To measure head circumference it is necessary with the round over the head comparatively highest sloping place and upon just of the ears, glabellas or eye brows by measurement tape. The plane of the tape must be the same on both sides of the head. The tape is pulled tightly to compress hair and obtain a measure that approximates cranial circumference. We have taken measurement by this technique.

Head Length: The measurement of head length has taken by Spreading caliper. The maximum length in the sagittal plane from glabella (the most salient point between the eyebrows) to the most salient point on the occiput. Pressure is exerted to compress the tissues.

Maximum Head Breadth: The greatest transverse diameter of the head of a child is called head breadth. The measurement of head breadth has taken by spreading caliper. This is usually found at a point over each parietal bone (each point is termed the euryon).

Chapter Four

Methods of the Study

Chapter- Four

Methods of the Study

"By Statistics we mean aggregate of facts affected to marked extent by multiplicity of causes mimetically expressed, enumerated or estimated according to reasonable standard of accuracy, collected in systematic manner for a predetermined purpose and placed in relation to each other" – Prof. Horace Secrist

4.1: Descriptive Statistics

The mean, standard deviation and other descriptive statistics for various body and head dimensions of rural and urban children were calculated as

Mean: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ (1)

Where n = total no. of observations.

Standard deviation, $\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$ (2)

Mean of the composite series as:

$$\bar{x}_c = \frac{n_1\bar{x}_1 + n_2\bar{x}_2 + \ldots + n_k\bar{x}_k}{n_1 + n_2 + \ldots + n_k} \quad (3)$$

And standard deviation of the combined series as:

$$\sigma_c = \sqrt{\frac{n_1(\sigma_1^2 + d_1^2) + n_2(\sigma_2^2 + d_2^2) + \ldots + n_k(\sigma_k^2 + d_k^2)}{n_1 + n_2 + \ldots + n_k}} \quad (4)$$

(where notations are of usual assumptions)

Percentile: The i^{th} percentile is given by

$$P_i = L + \frac{\frac{N}{100}\times i - F_c}{f}\times c \quad (5)$$

Where

P_i = i^{th} percentile,

L = Lower limit of i^{th} percentile class,

N = Total number of observations,

F_c = Cumulative frequency of class preceding of i^{th} percentile class,

f = Frequency of i^{th} percentile class, and

c = Class interval of i^{th} percentile class.

4.2: Allometric Model

Huxley (1932) proposed an allometric equation to find the rate of increment of one dimension of an organ with respect to another of the same or other organ, usually total body size. Huxley pointed out that if two parts (y and x) grow in accordance with the

equation, $\frac{dy/dt}{y} = b\,\frac{dx/dt}{x}$ (6)

Then $\frac{dy}{dx} = b\frac{y}{x}$ (7)

or, $\frac{dy}{y} = b\frac{dx}{x}$ (8)

Integrating on both sides

$\log y = b \log x + c$

$or,\ \log y = b \log x + \log a$ [let integral constant, $c = \log a$] (9)

Where a and b are constant

$or,\ \log y = \log ax^b$

$\Rightarrow y = ax^b$ (10)

Which is log linear relationship (eq. 9) equivalent to non-linear relationship (eq. 10). Here the dependent variable y, which represents a dimension whose increase, is considered relative to that of the independent variable x, which may represent a different dimension of the same organ or more commonly a measure of total body size. The logarithmic function (eq. 9) can represent a rectilinear plot of the original variables using logarithmic coordinates. Where, 'b' is the slope of the regression line, which represents the rate of increment of y with respect to x, and the constant 'log a' is the intercept on the y-axis, which represents the point of initial growth (Huxley and Tssier, 1936). The slope is determined by the ratio of the y-coordinates and x-coordinates; that is, the ratio of the specific growth rates of y and x. This is mathematically denoted by

$$\tan \theta = \frac{y}{x} \qquad (11)$$

If the absolute distance of y and x-coordinates are same then the specific growth rates of x and y are equal; that is;

$$\tan \theta = 1 \qquad (12)$$

$$\theta = 45^0 \qquad (13)$$

that is, the angle between regression line and x-axis is 45^0. This is called isometry. If the value of θ less than 45^0, then the slope is less than 1, which indicates that the y/x ratios decrease with increasing absolute magnitude of x. This is called negative allometry. If the value of θ greater than 45^0, then the slope is greater than 1, which implies a differential increase of y relative to x. This is called positive allometry.

Using OLS method we can estimate the slope of allometric model. For this, we have to check the OLS assumptions.

To find significant difference in various growth of head and body dimension between rural and urban children, male and female children, statistical test (t – test and Z- test) will be used in this study.

Chapter Five

Results and Discussion

Chapter- Five

Results and Discussion

5.1: Longitudinal Growth of Bangladeshi Primary School going children

The longitudinal data on stature, total body weight, sitting height, leg length, tibia length, upper arm length, elbow length, upper arm circumference, head length, head breadth, head circumference and chest circumference, of Bangladeshi primary school going children for 6 to 12 years of age was collected individually from Jessore district. The measurements of stature, weight, sitting height, leg length, tibia length, upper arm length, elbow length, chest circumference and head circumference were recorded to the nearest centimeter and the measurements of head length and head breadth were recorded to the nearest millimeter. Firstly their age specific mean value for males, females, urban males, urban females, rural males and rural females are calculated using SPSS program and shown in various figures. After confirming OLS assumptions in the log linear model, allometric growth model is fitted. From the fitted model relative growth of sitting height, leg length, tibia length, upper arm length, elbow length, head length, head breadth and head circumference in body and head dimensions with respect to stature were found. They are discussed below:

5.1.1: Growth of Stature

Age specific mean value of stature for males and females are shown in figure 5.1.1a. It is found that at age intervals 6.51 – 7.00, 9.01 – 9.50 and 9.51-10.00 males are shorter than females but for other age intervals males are taller than females. The maximum sex difference in stature is observed to be 1.40 cm, 138.51 cm for male and 137.11 cm for female with standard deviations 7.51 cm and 6.65 cm, respectively.

This implies, mean stature velocity for male children are comparatively larger than females, and also stature of males are more consistent than females.

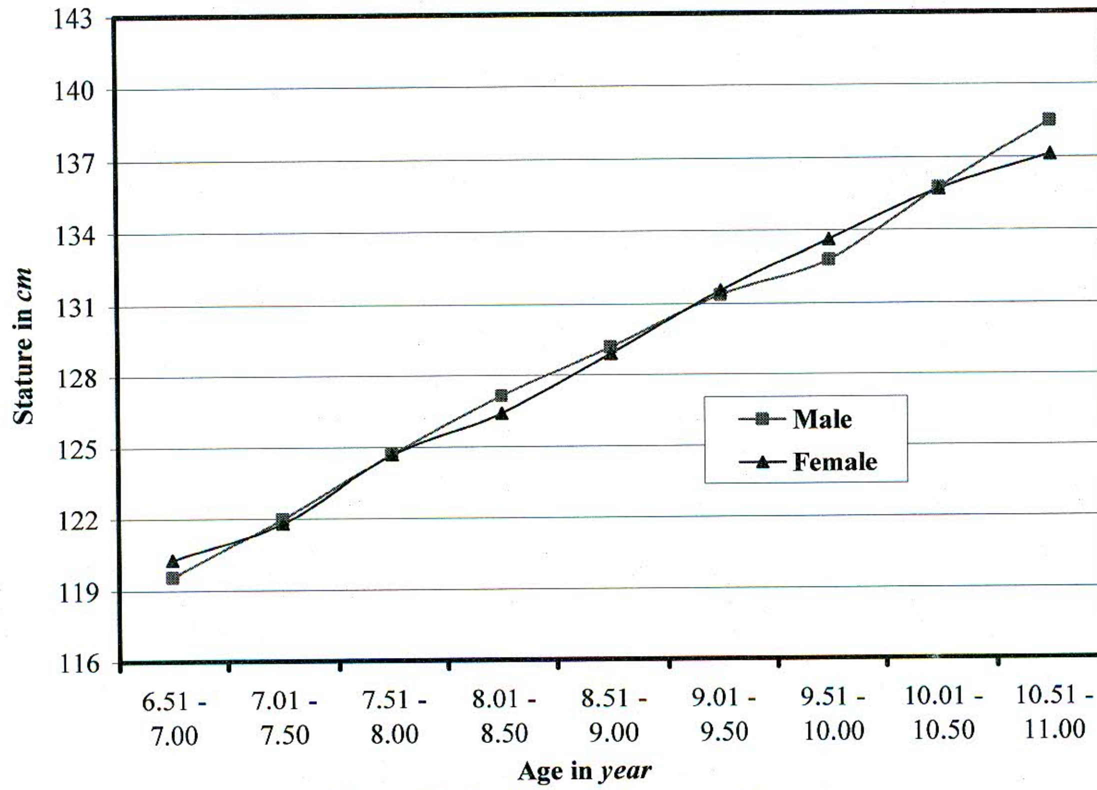


Figure 5.1.1a : Stature of males and females

For Urban Children

Stature of urban males and females are presented in figure 5.1.1b. The figure indicates that at age interval 7.01 - 8.50 years urban males are taller than urban females but for other age intervals males are shorter than females. The maximum sex difference in stature is observed to be 2.89 cm, 138.19 cm for males and 141.08 cm for females with standard deviations 7.74 cm and 6.31 cm, respectively. This implies, mean stature velocities of urban females are comparatively larger than males, but males are more consistent than females.

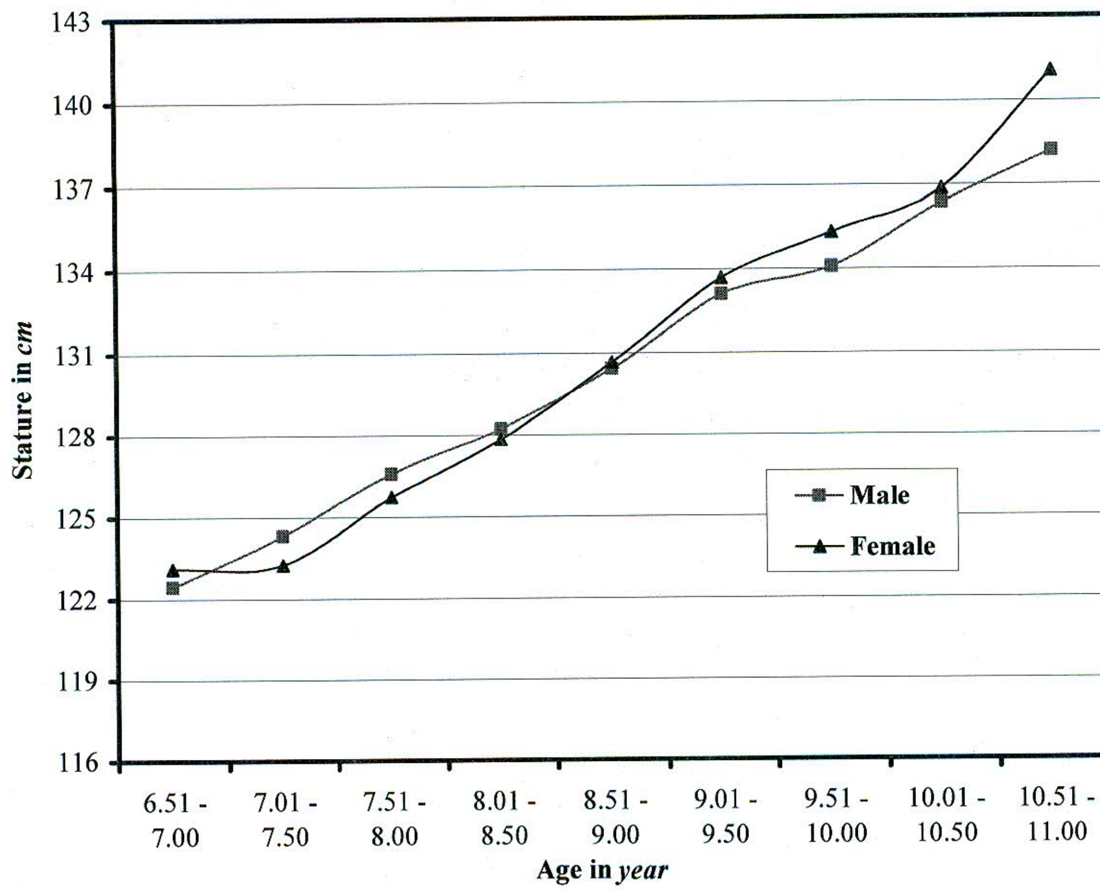


Figure 5.1.1b : Stature of urban males and females

For Rural Children

The Longitudinal data on stature of rural males and females are shown in figure 5.1.1c. It is found that at age interval 7.01 - 8.00 and 9.51 – 10.00 on average rural females are taller than rural males but for other age intervals rural males are taller than females. The maximum sex difference in stature is observed to be 3.40 cm, 138.74 cm for males and 135.34 cm for females with standard deviations 7.82 cm and 6.33 cm, respectively. This implies, mean stature velocity for males is comparatively larger than females, and also stature of male are more consistent than females in rural. This figure also indicates that within the age of 6.50 – 8.00 years, growth in stature is uniform for both rural males and females, the age of 8.01 – 10.50 years, growth in stature is more or less uniform but an increasing diversity is observed in the growth of males for age of after 10.50 years.

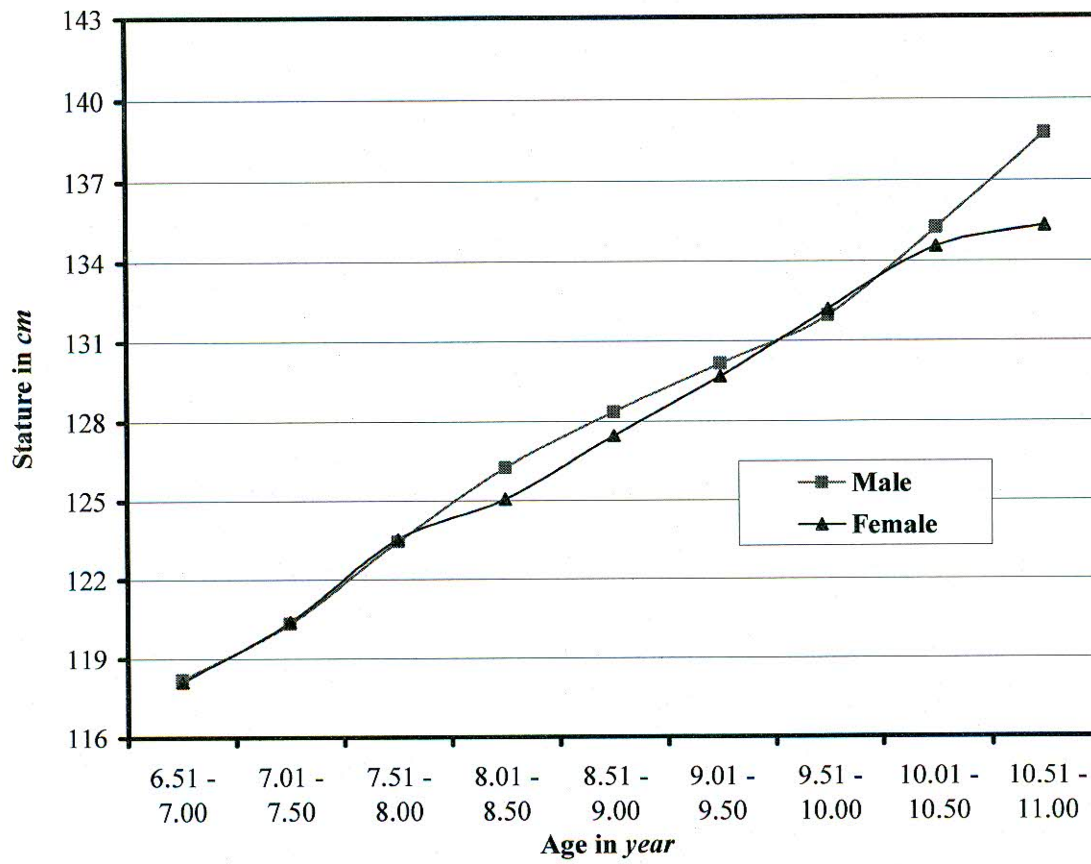


Figure 5.1.1c: Stature of rural males and females

Regional difference in Males

Statures of urban and rural males from 6 to 11 years of age are shown in figure 5.1.1d. This figure shows that at age interval 10.51 – 11.00 rural males are taller than urban males but for other age intervals urban males are taller than rural males. The maximum regional difference in mean stature is observed to be 4.24 cm, 122.45 cm for urban males and 118.21cm for rural males with standard deviation 4.00 cm and 6.06 cm, respectively. This implies, mean stature velocity for rural males is comparatively larger than that of urban males, and also stature of urban males are more consistent than rural males. This figure also indicates that at age of 6.50 – 7.00

years, mean stature of rural males is 4.24 cm less than urban males but at the age of 10.51 – 11.00 years, stature of rural males is exceed the urban males.

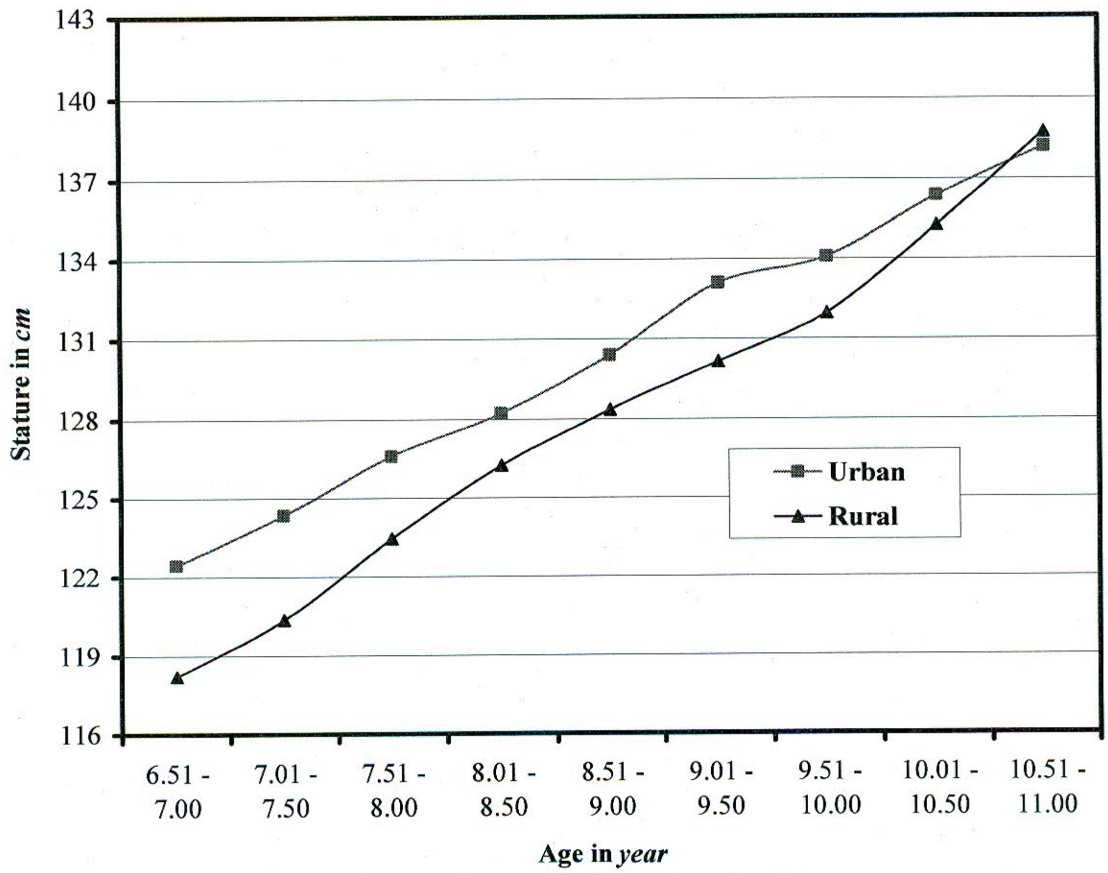


Figure 5.1.1d : Stature of urban and rural males

Regional difference in Females

The age specific mean values of stature for urban females and rural females are shown in figure 5.1.1e. This figure highlighted that at age interval 6.51–11.00 urban females are taller than rural females. The maximum difference in stature is observed to be 5.73cm , 141.08cm for urban female children and 135.34cm for rural female children with standard deviation 6.31cm and 6.33 cm, respectively. This implies, stature growth velocity for urban female children and rural female children are same, but statures of urban female are more consistent than rural. This figure also indicates that females of urban are taller than rural females and there has a significant difference

($p<0.05$). There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the issue.

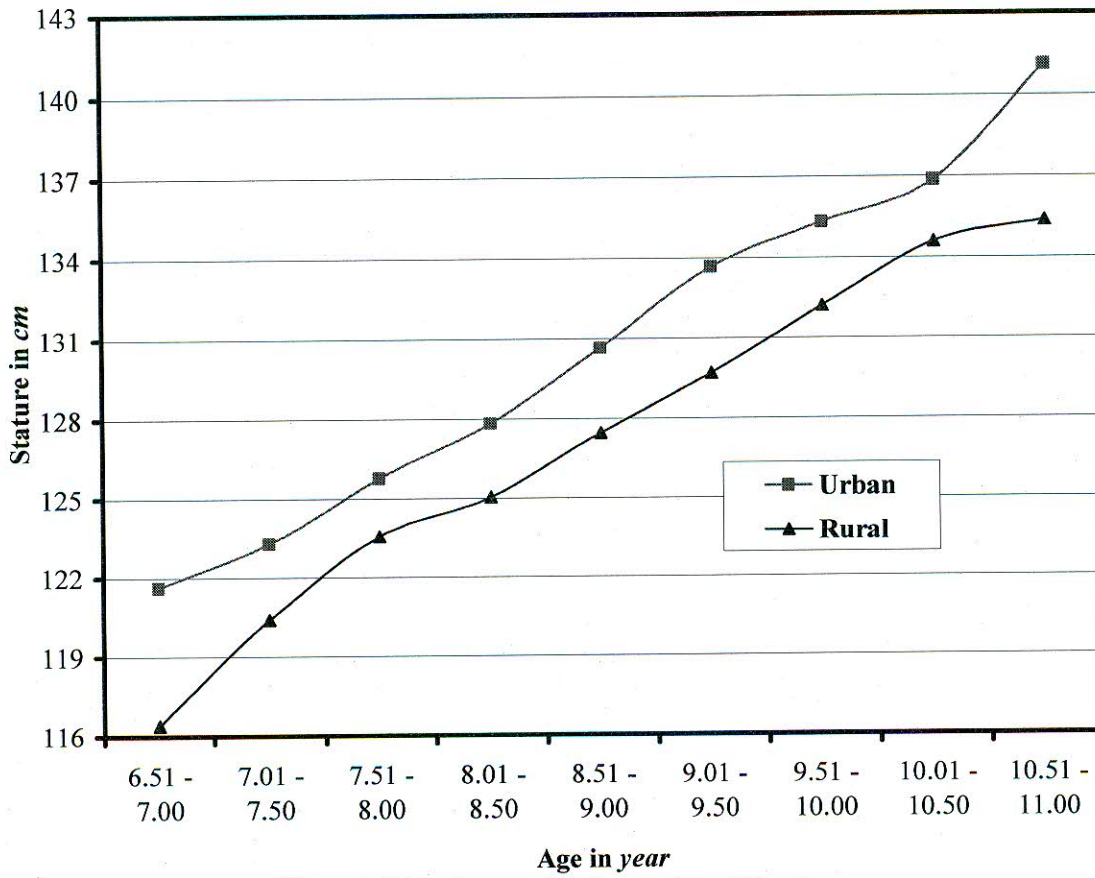


Figure 5.1.1e : Stature of urban and rural females

Growth Allometry of Stature

Growth allometry of stature with respect to sitting height is given below:

Stature= $1.386(Sitting\ height)^{1.076}$, for males

Stature= $1.976(Sitting\ height)^{0.976}$, for females

Stature= $2.016(Sitting\ height)^{0.986}$, for urban males

Stature= $3.056(Sitting\ height)^{0.889}$, for urban females

Stature= $1.031(Sitting\ height)^{1.148}$, for rural males

Stature= $1.187(Sitting\ height)^{1.114}$, for rural females

Growth allometry of stature with respect to leg length is given below:

$Stature = 5.947(Leg\ length)^{0.747}$, for males

$Stature = 4.971(Leg\ length)^{0.790}$, for females

$Stature = 6.484(Leg\ length)^{0.728}$, for urban males

$Stature = 4.357(Leg\ length)^{0.823}$, for urban females

$Stature = 5.763(Leg\ length)^{0.754}$, for rural males

$Stature = 5.505(Leg\ length)^{0.765}$, for rural females

The allometric coefficients (slopes) indicate that for males growth of stature with respect to sitting height is positively allometric but tending to isometry, while it is negative allometry for females. This implies growth rate of stature is greater than sitting height for males but this rate of stature is smaller than sitting height for females. It also indicates that growth of stature with respect to sitting height for urban males and females follow negative allometry, which means growth rate of stature is smaller than that of sitting height, but for rural males and females it shows reverse situation comparative to urban. Why this reverse situation appeared between urban and rural areas demands for further study. It is found that for both males and females growth of stature with respect to leg length follow negative allometry which means growth rate of stature is smaller than that of leg length.

5.1.2: Weight Study

The Longitudinal data on weight of Bangladeshi primary school going children from 6 to 11 years of age was collected individually and their age specific mean value for males and females are shown in figure 5.1.2a. It is found that at age interval 10.51-11.00 on average the males are heavier than females but for other age intervals females are heavier than males. The maximum sex difference in mean weight is observed to be 2.24 kg, 19.76 kg for males and 22.00kg for females with standard deviations 2.76 kg and 6.05 kg, respectively. This implies, mean weight velocity for females is comparatively larger than males, and also weight of males are more consistent than females.

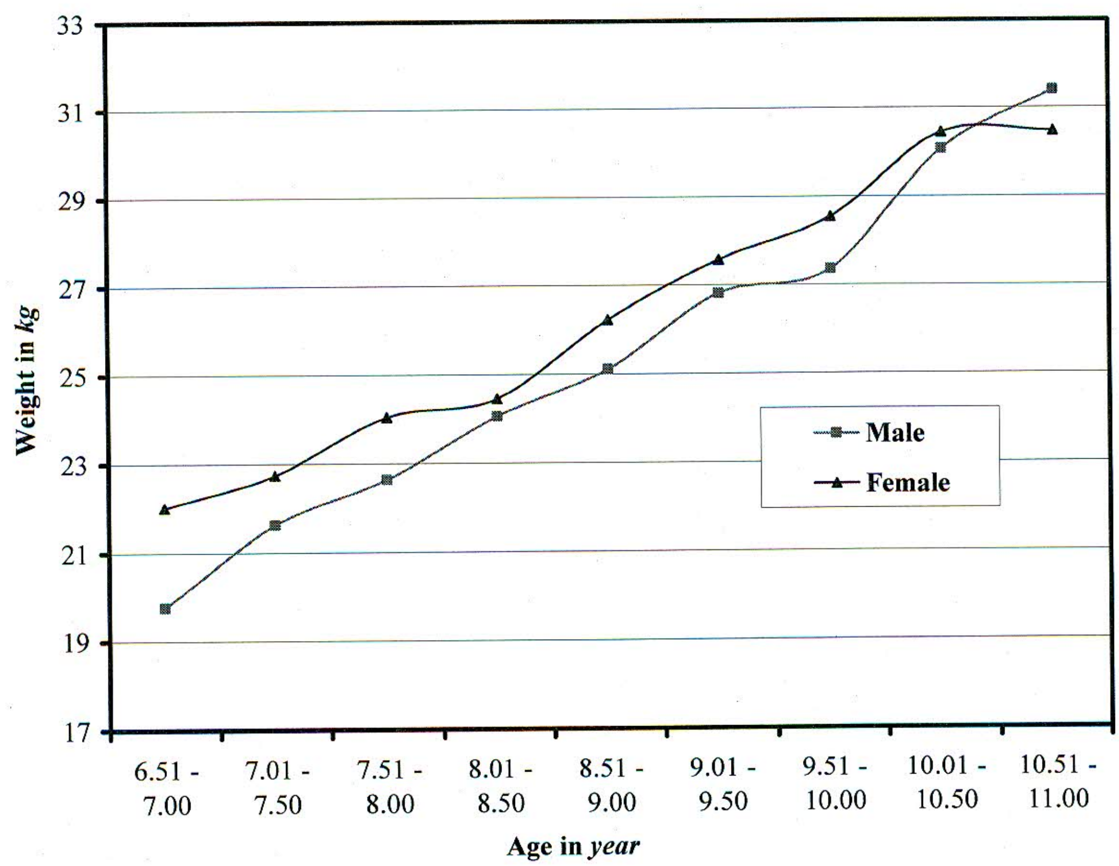


Figure 5.1.2a: Weight of males and females

For Urban Children

Weight of urban males and females are shown in figure 5.1.2b. This figure shows that at age intervals 10.01 - 10.50 and 10.51-11.00, the males are heavier than females but for other age intervals females are heavier than males. The maximum sex difference in mean weight is observed to be 4.78kg, 21.67kg for males and 26.44kg for females with standard deviations 1.76kg and 6.61kg, respectively. This implies, mean weight velocity for females is comparatively larger than males, and also weight of urban males are more consistent than urban females. This figure also indicated that at age interval 6.50- 7.50 females of urban are heavier than males and there has a significant ($p<0.05$) difference and at age interval 8.01- 10.51 growth of weight of male and females are more or less similar but at age interval 10.51-11.00 weight of males are exceed that of females.

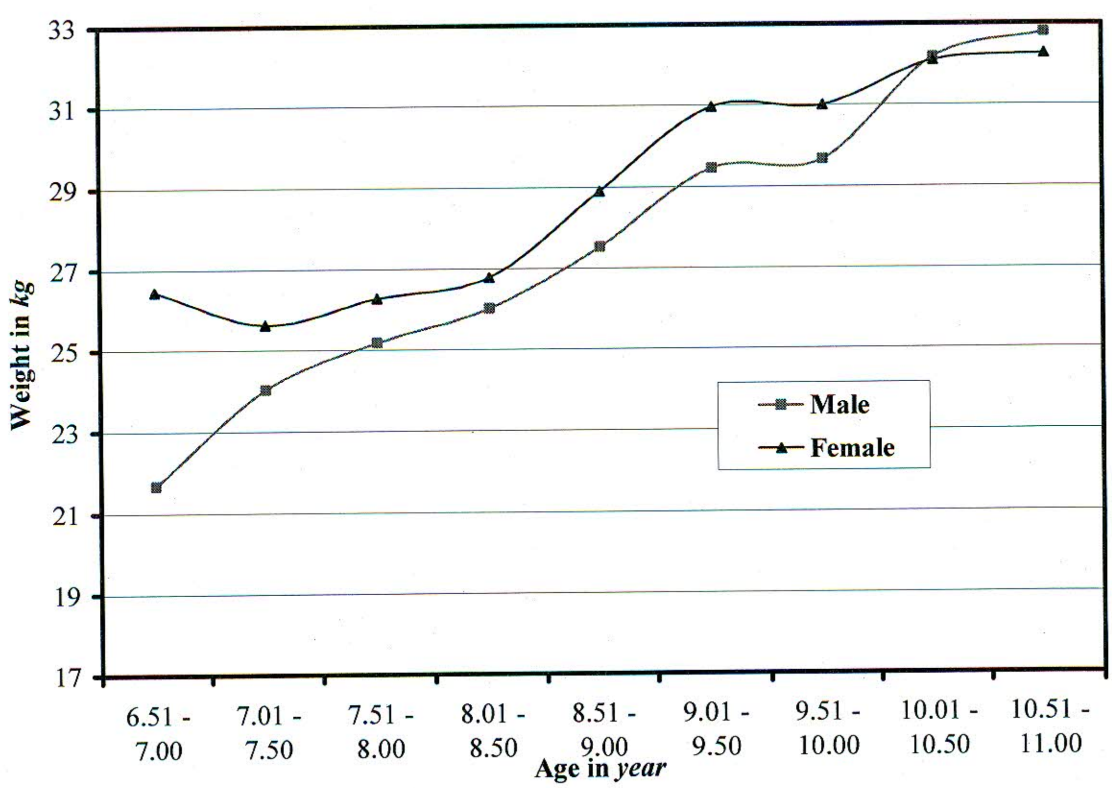


Figure 5.1.2b: Weight of urban males and females

For Rural Children

The longitudinal data on weight of rural males and females are shown in figure 5.1.2c. This figure indicates that at age intervals 6.51 - 7.00, 8.01 - 8.50, 9.01 - 9.50 and 10.51-11.00, on average rural males are heavier than females but for other age intervals females are heavier than males. The maximum sex difference in weight is observed to be 0.78kg, 30.45kg for male and 29.67kg for females with standard deviations 5.70kg and 6.24kg, respectively. This implies, mean weight velocity for females is comparatively larger than males, and also weight of males is more consistent than female's in rural area in Bangladesh. This figure also indicates that the growth of males and females in rural are closely related and there has no significant difference.

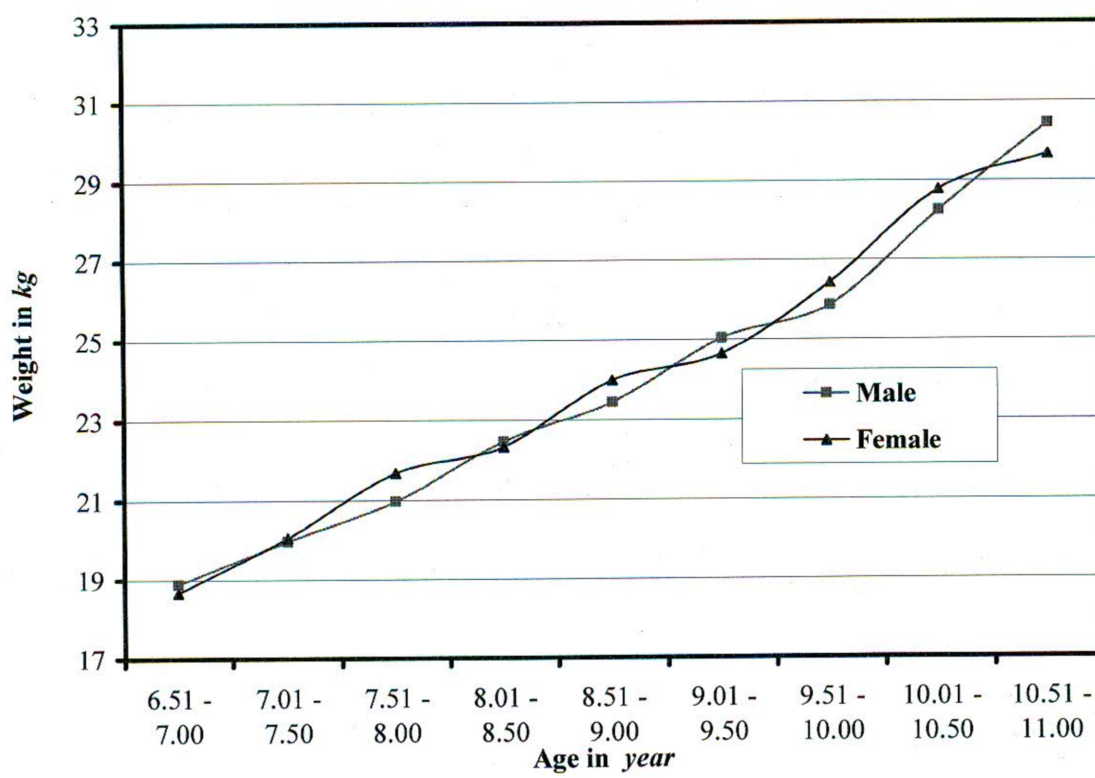


Figure 5.1.2c: Weight of rural males and females

Regional difference in Males

The age specific data on weight of urban and rural males are shown in figure 5.1.2d. This figure divulged on average the urban males are heavier than rural males. The maximum difference in mean weight is observed to be 4.22 kg, 25.18 kg for urban males and 20.97kg for rural males with standard deviations 3.47kg and 2.21kg, respectively. This implies, mean weight velocity for urban males is comparatively larger than rural males, and also weight of rural males are more consistent than urban males. An important finding of this figure that urban males are heavier than rural males and their differences is statistically significant ($p<0.05$). There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the issue.

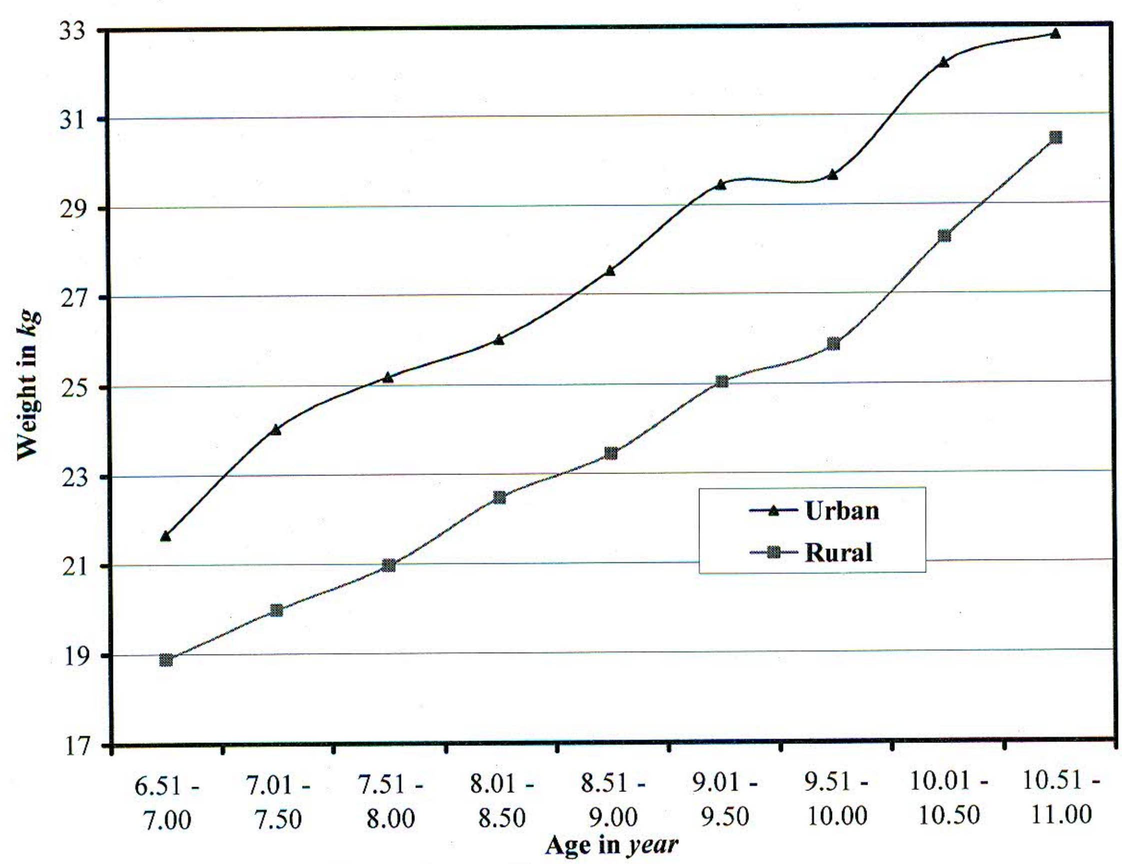


Figure 5.1.2d: Weight of urban and rural males

Regional difference in Females

Weights of urban and rural females are shown in figure 5.1.1e. This figure indicates that at age interval 6.51–11.00 urban females are heavier than rural females on average. The maximum difference in mean weight is observed to be 5.83 kg, 23.50 kg for urban females and 17.67 kg for rural females with standard deviations 8.89 kg and 2.36 kg, respectively. This implies, mean weight velocity for urban females are comparatively larger than rural females, and also weight of rural females are more consistent than urban females This figure also indicates that urban females are more heavier than rural females and there has a significant difference ($p<0.05$). There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the issue.

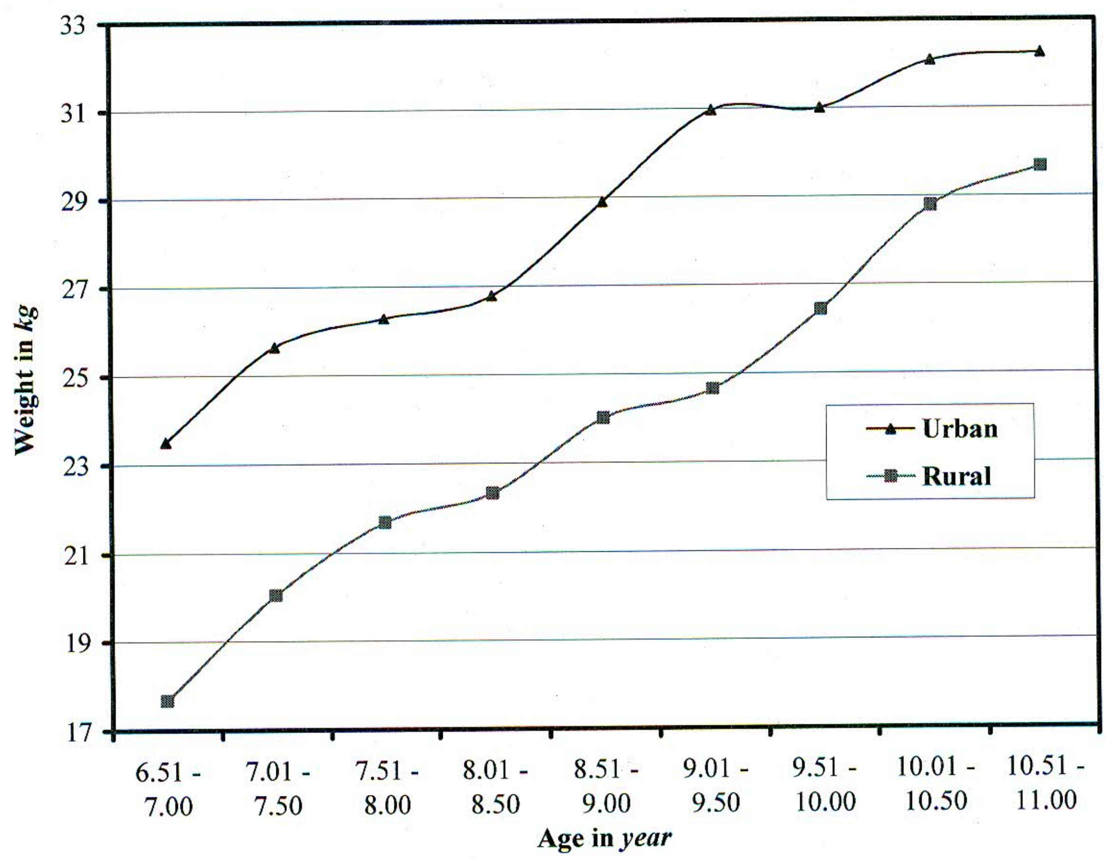


Figure 5.1.2e: Weight of urban and rural females

5.1.3: Growth of Sitting Height

The Longitudinal data on sitting height of Bangladeshi primary school going children from 6 to 11 years of age was collected individually and their age specific mean value for males and females are calculated and shown in figure 5.1.3a. This figure highlighted that at age intervals 6.51 – 7.00 and 9.51-10.00 on average sitting height of females is greater than males but for other age intervals mean sitting height of females are less than males. The maximum sex difference in mean sitting height is observed to be 0.54 cm, 66.77 cm for males and 66.23 cm for females with standard deviations 2.74cm and 3.60 cm, respectively. This implies, sitting height velocity for females are comparatively larger than males, and also sitting height of males are more consistent than females.

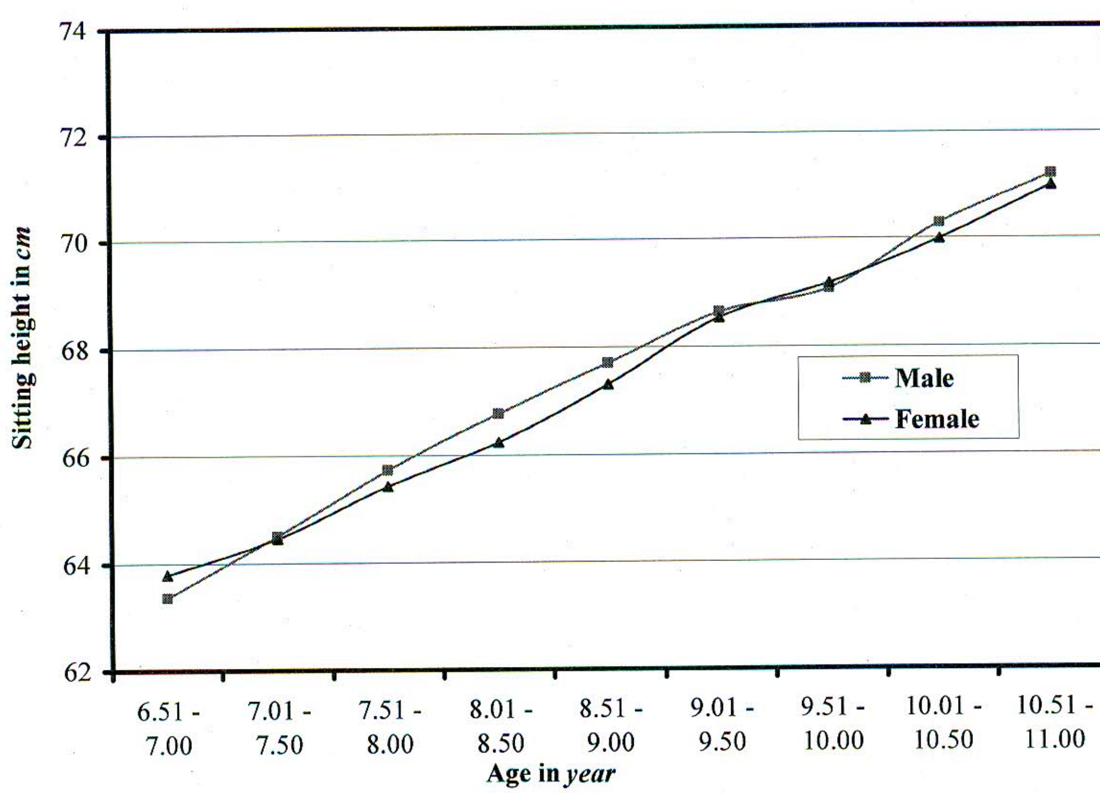


Figure 5.1.3a: Sitting height of males and females

For Urban Children

Sitting height of urban males and females are shown in figure 5.1.3b. It is found that at age intervals 6.51 – 7.00 and 10.51-11.00 sitting height of females are greater than males on average but for other age intervals mean sitting height of females are less than males. The maximum sex difference in sitting height is observed to be 1.70 cm, 71.67 cm for males and 73.38 cm for females with standard deviations 4.29 cm and 3.05 cm, respectively. This implies, mean sitting height velocity for urban males is comparatively larger than females, but male children are more consistent than females. This figure also indicated that at age intervals 6.50- 7.50, 9.01-9.50 and 9.51-10.00, sitting height of females and males are same but after the age interval 10.01-10.50 the sitting height of females exceed males. There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the cause.

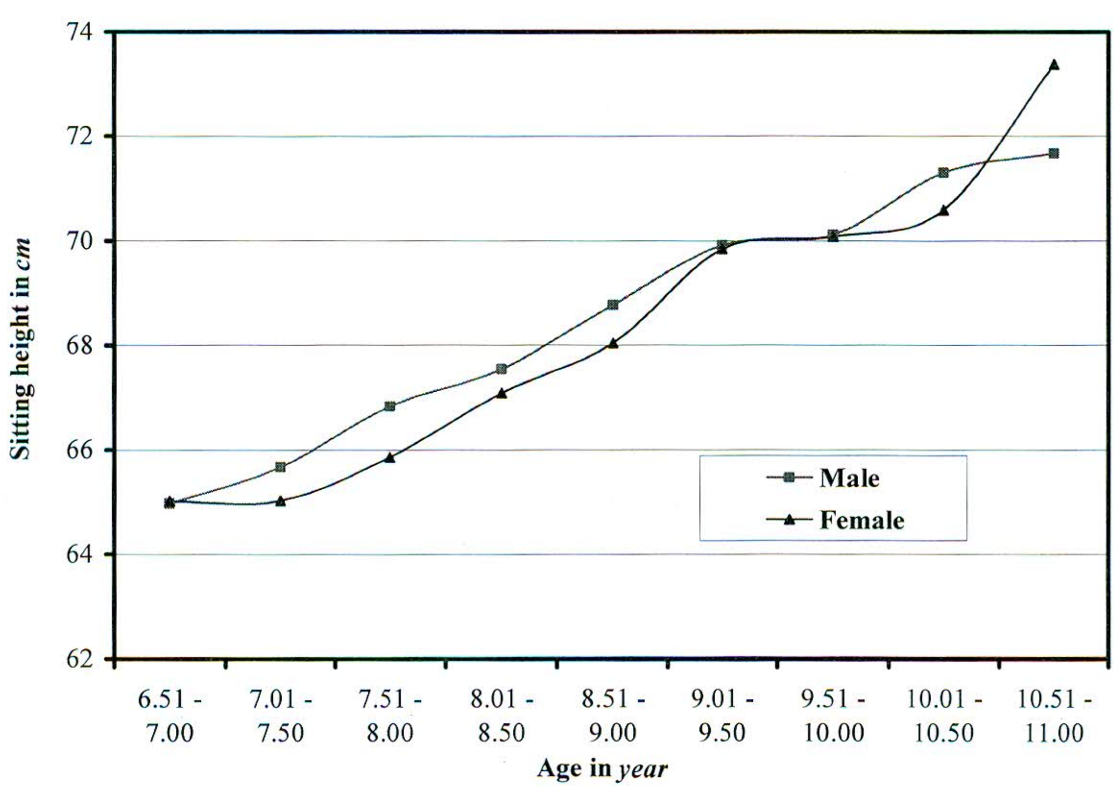


Figure 5.1.3b: Sitting height of urban males and females

For Rural Children

The age specific data on sitting height of rural males and females are shown in figure 5.1.3c. This figure shows that at age intervals 6.51 – 7.00 and 7.01 – 8.00 mean sitting height of females are greater than males but for other age intervals mean sitting height of males are greater than females. The maximum sex difference in mean sitting height is observed to be 0.93 cm, 70.87 cm for males and 69.94 cm for females with standard deviations 3.49 cm and 3.20 cm, respectively. This implies, mean sitting height velocity for rural males is comparatively larger than females, but males are more consistent than females. This figure also indicates that the growth in sitting height of males and females in rural are closely related and their differences are not significant statistically.

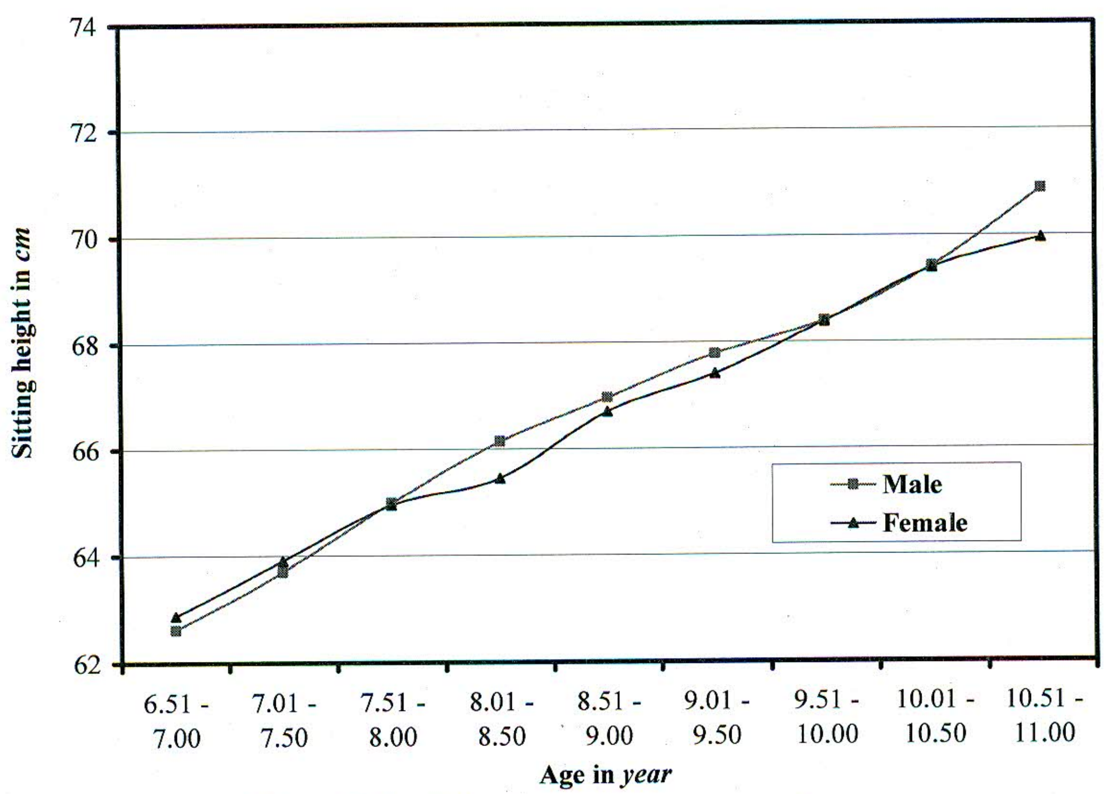


Figure 5.1.3c: Sitting height of rural males and females

Regional difference in Males

The Longitudinal data on sitting height of urban and rural are shown in figure 5.1.3d. This figure implies that at age interval 6.51–11.00 mean sitting height of urban males is greater than rural males. The maximum difference in sitting height is observed to be 2.36 cm, 64.97 cm for urban males and 62.61 cm for rural males with standard deviations 1.45 cm and 2.50 cm, respectively. This implies, growth velocity for urban males and rural males are not so different, but sitting height of rural male are more consistent than urban. This figure also indicates that males of urban are taller than rural males and there has a significant difference ($p<0.05$). There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over these causes.

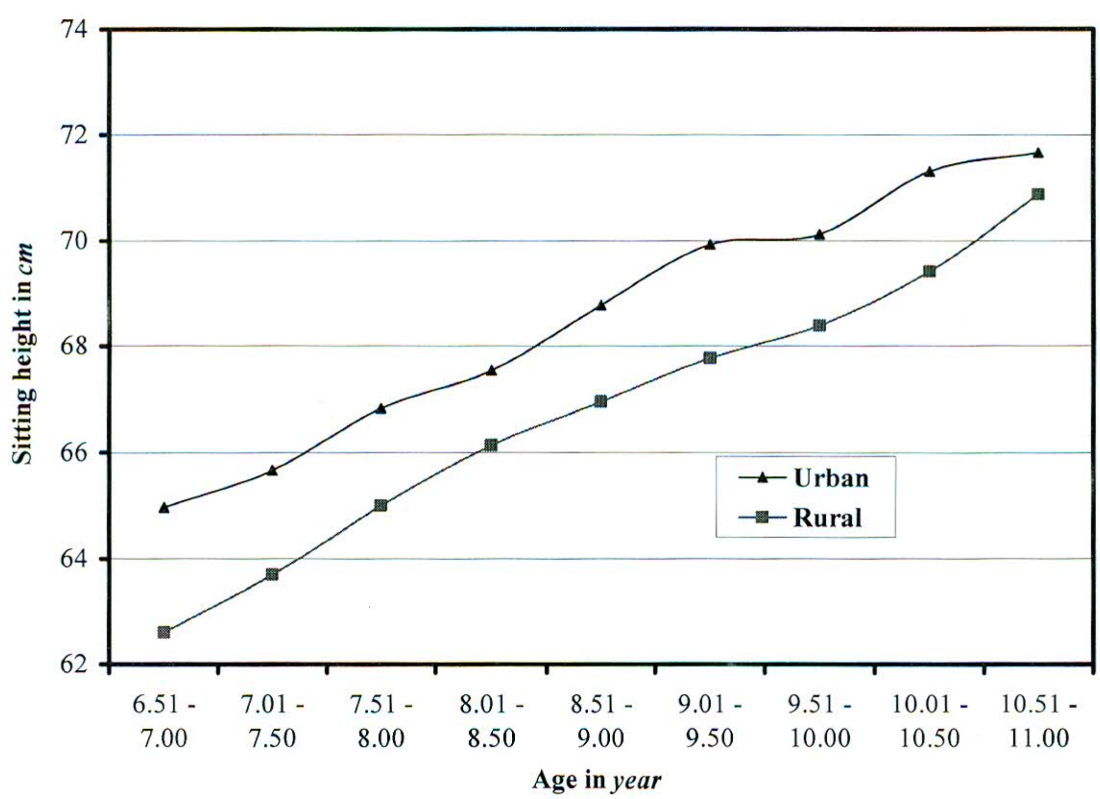


Figure 5.1.3d : Sitting height of urban and rural males

Regional difference in Females

Sitting heights of urban and rural females are shown in figure 5.1.3e. This figure shows that at age interval 6.51–11.00, sitting height of urban females is greater than rural females. The maximum difference in sitting height is observed to be 3.43 cm, 63.97 cm for urban females and 62.33 cm for rural females with standard deviations 2.22 cm and 3.06 cm, respectively. This implies growth velocity for urban females and rural females are not so different in sitting height, but rural females are more consistent than urban. This figures also shows that females of urban are taller than rural females and their difference is significant ($p<0.05$). This may be happened due to some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the issue.

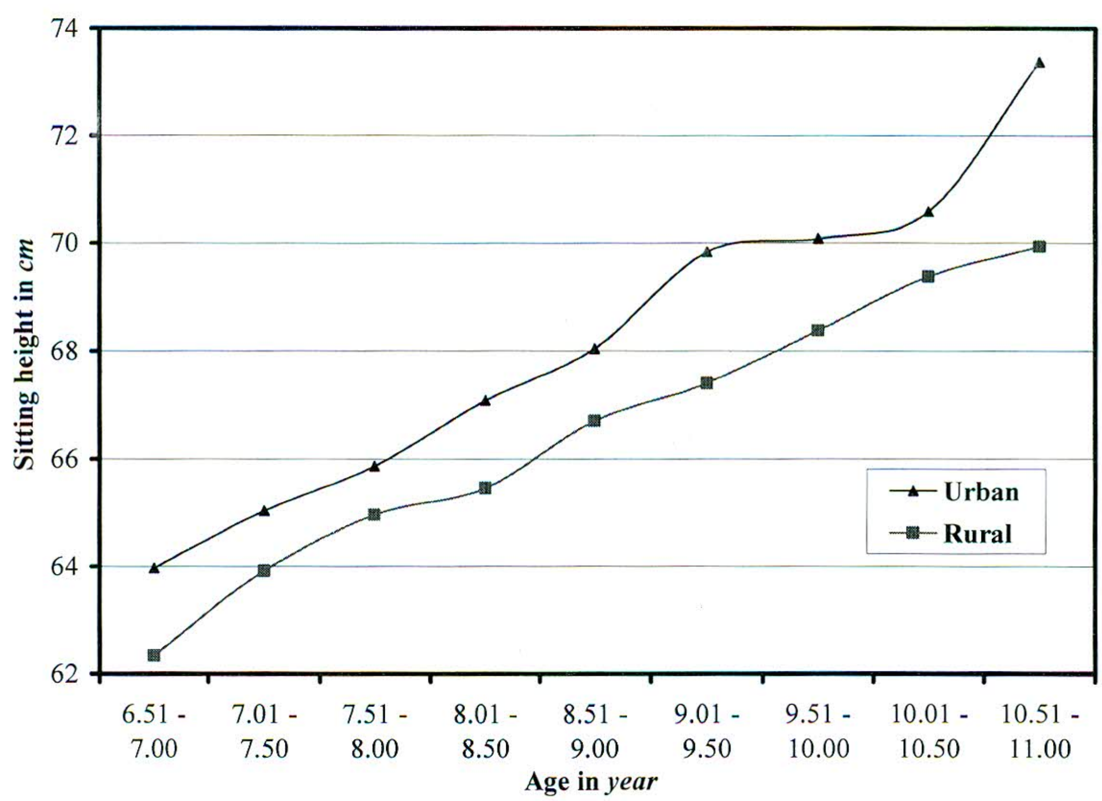


Figure 5.1.3e : Sitting height of urban and rural females

Growth Allometry of Sitting Height

Growth allometry of sitting height with respect to stature is given below:

$Sitting\ height = 1.46(Stature)^{0.789}$, for males

$Sitting\ height = 0.969(Stature)^{0.873}$, for females

$Sitting\ height = 1.318(Stature)^{0.811}$, for urban males

$Sitting\ height = 0.609(Stature)^{0.968}$, for urban females

$Sitting\ height = 1.605(Stature)^{0.768}$, for rural males

$Sitting\ height = 1.420(Stature)^{0.794}$, for rural females

The regression coefficients show changes in various growth proportions for sitting height with respect to changes in stature. The allometric coefficients (slopes) indicate that for both males and females growth of sitting height with respect to stature follows negative allometry. This implies growth rate of sitting height is smaller than that of stature. The slope difference of urban females and rural females are statistically significant ($p<0.05$).

5.1.4: Growth of Leg Length

The Longitudinal leg length of males and females are shown in figure 5.1.4a. It shows that at age interval 6.51-10.50 the leg length of males and females are closely related and there has no significant difference but after the age interval 10.01-10.50 the leg length of females exceeds males. At age interval 6.51-7.00 leg length of males and females are respectively 56.19 cm and 56.47 cm but at age interval 10.51-11.00 leg length of males and females are respectively 67.31cm and 66.11cm. This implies there has a littlie difference.

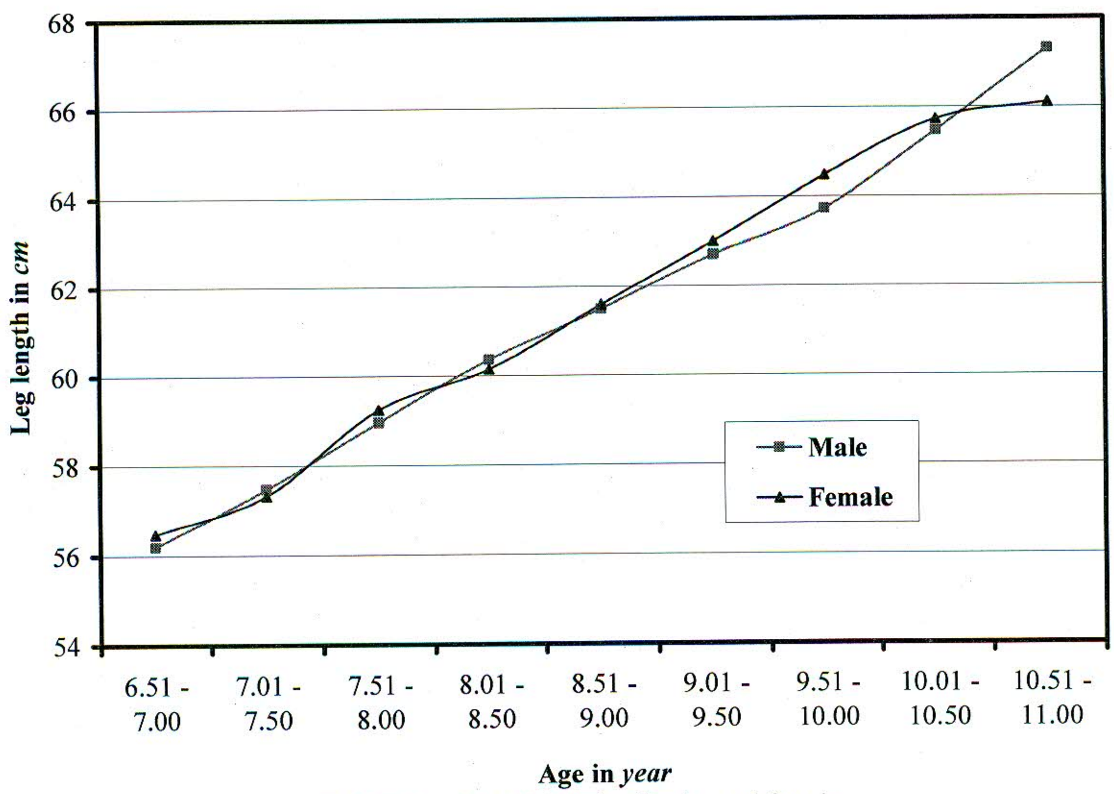


Figure 5.1.4a: Leg length of males and females

For Urban Children

Leg length of urban males and females are shown in figure 5.1.4b. This figure implies that at age interval 7.01 – 7.50 mean leg length of females are less than males but other for age intervals mean leg length of females are greater than males. The maximum sex difference in leg length is observed to be 1.28 cm, 63.95 cm for males and 65.23 cm for females with standard deviations 3.42 cm and 2.91 cm, respectively. This implies, mean leg length velocity for urban males is comparatively larger than females and also growth in leg length of males are more consistent than females. An examination of the results indicated that there has no significant difference in leg length between urban males and females.

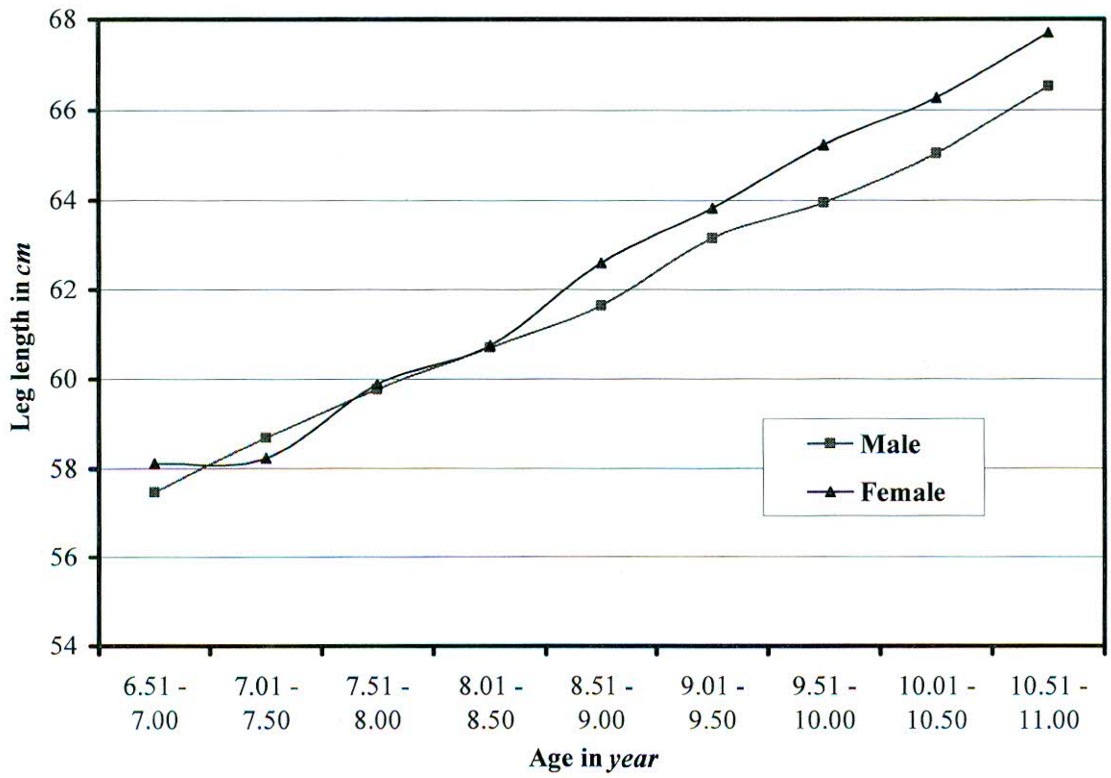


Figure 5.1.4b: Leg length of urban males and females

For Rural Children

The Longitudinal data on leg length of males and females are shown in figure 5.1.4c. This figure indicates that at age interval 6.51-10.50 leg length of rural males and females are closely related and there has no significant difference but after age interval 10.01-10.50 the leg length of males are exceed females. At age interval 6.51-7.00 leg length of males and females are 55.60 cm and 55.24 cm, respectively but at age interval 10.51-11.00 leg length of males and females are 67.87 cm and 65.40 cm, respectively. This implies an increasing diversity is present in leg length of rural males than females after age interval 10.51-11.00 but for other age intervals growth in leg length of rural males and females is more or less uniform.

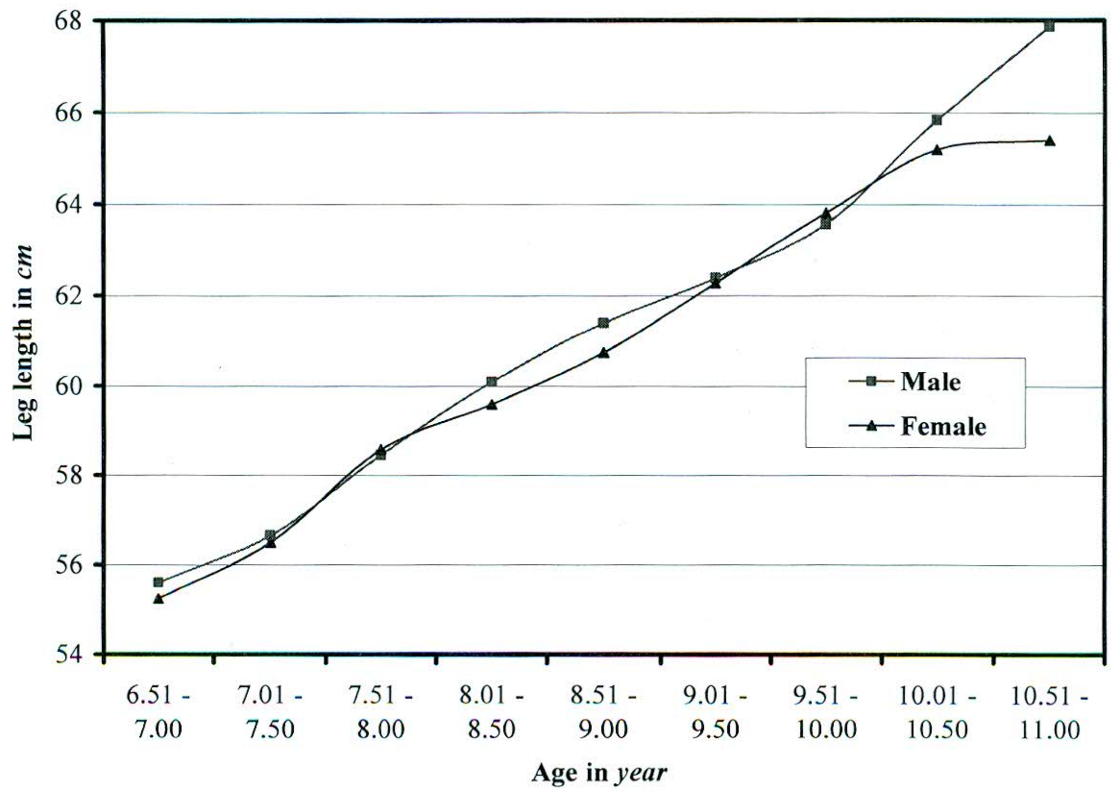


Figure 5.1.4c: Leg length of rural males and females

Regional difference in Males

Age specific leg lengths of urban and rural males are shown in figure 5.1.4d. This figure divulged that at age interval 6.51–10.00 mean leg length of urban males is greater than that of rural males but after the age interval 9.51-10.00 mean leg length of rural males is greater than urban males. The maximum difference in leg length is observed to be 2.04 cm, 58.68 cm for urban males and 56.64 cm for rural males with standard deviations 2.65 cm and 4.02 cm, respectively. This implies growth velocity for rural males are comparatively larger than urban males but growth in leg length for urban males are more consistent than rural males. Moreover there has no significant difference in leg length between rural and urban males.

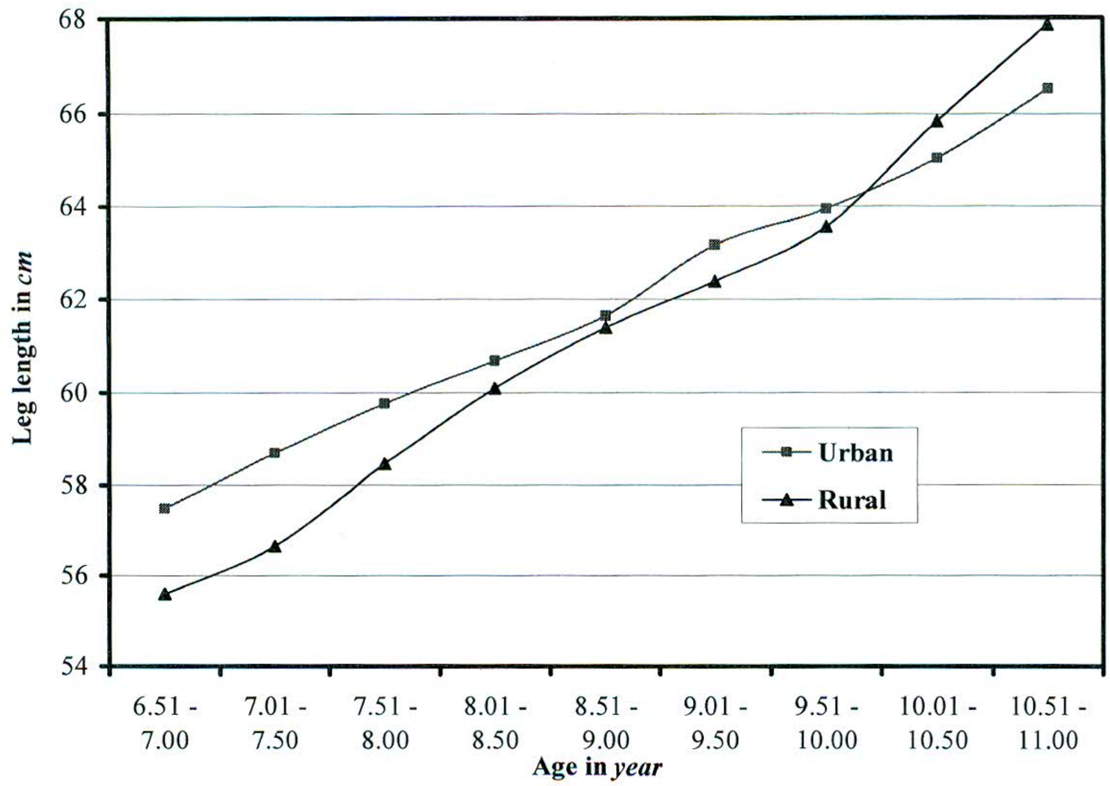


Figure 5.1.4d : Leg length of urban and rural males

Regional difference in Females

Leg lengths of urban and rural females are shown in figure 5.1.4e. It is found that at age interval 6.51–11.00, mean leg length of urban females is greater than that of rural females. The maximum difference in leg length is observed to be 3.60 cm, 57.67cm for urban females and 54.07 cm for rural females with standard deviations 4.15 cm and 4.67 cm, respectively. This implies growth velocity of urban females is more consistent than rural females. It is found that females of urban are taller than rural in leg length. There may happens due to some causes, financial or either environmental or genetically or psychological or social, need to further investigation.

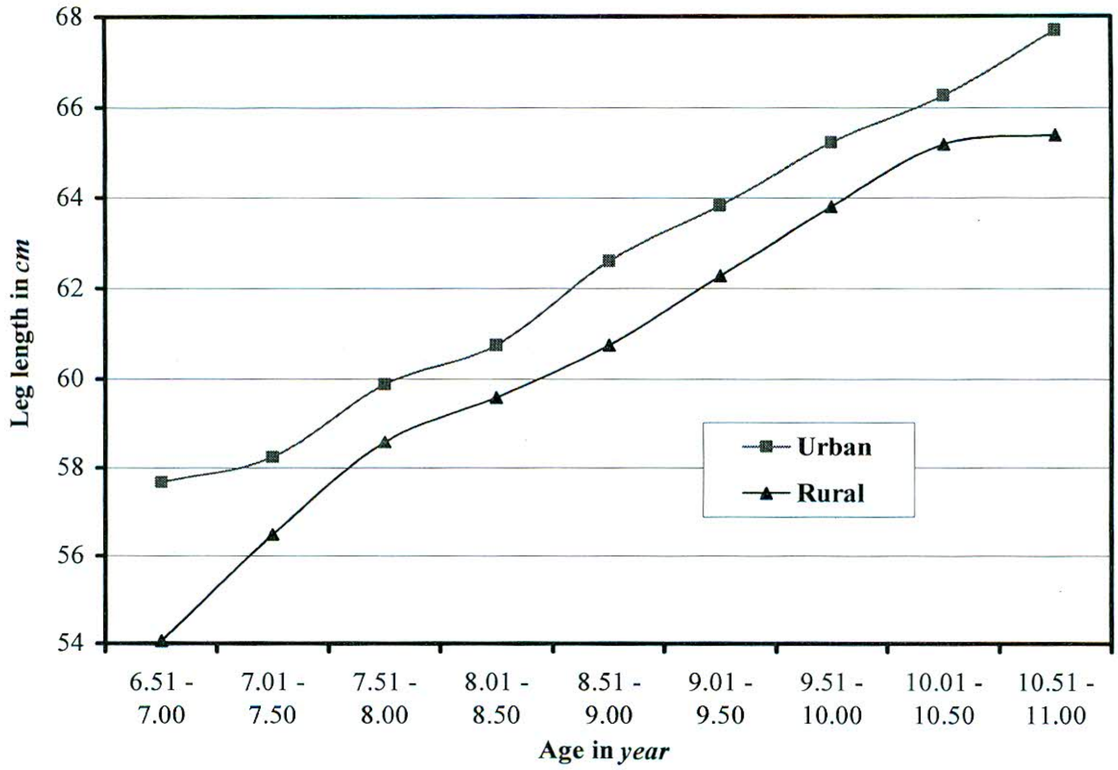


Figure 5.1.4e : Leg length of urban and rural females

Growth Allometry of Leg Length

Growth allometry of leg length with respect to stature is given below:

$Leg\ length = 0.156(Stature)^{1.230}$, for males

$Leg\ length = 0.246(Stature)^{1.137}$, for females

$Leg\ length = 0.172(Stature)^{1.208}$, for urban males

$Leg\ length = 0.405(Stature)^{1.034}$, for urban females

$Leg\ length = 0.143(Stature)^{1.249}$, for rural males

$Leg\ length = 0.163(Stature)^{1.222}$, for rural females

The allometric coefficients (slopes) indicate that for both males and females growth of leg length with respect to stature follows positive allometry. This implies growth rate of leg length is greater than that of stature. It also indicates that growth of urban females in leg length is isometry, which means growth rate of leg length is same proportion to the growth rate of stature. The slope difference between urban females and rural females is statistically significant ($p<0.05$).

5.1.5: Chest Circumference

The Longitudinal chest circumference of males and female are shown in figure 5.1.5a. This figure indicates that at age interval 6.51 – 8.50 chest circumference of males is less than females but after age interval 10.01-10.50 chest circumference of males is greater than females and for the other intervals growth in chest circumference for males and females is more or less uniform. The maximum sex difference in chest circumference is observed to be 2.05 cm, 57.08 cm for males and 59.13 cm for females with standard deviations 2.99 cm and 5.97 cm, respectively. This implies, at age interval 6.51-7.00 years, growth velocity for females are comparatively larger than males, however, growth of males in chest circumference are more consistent than females. Sex difference in chest circumference is found to be insignificant.

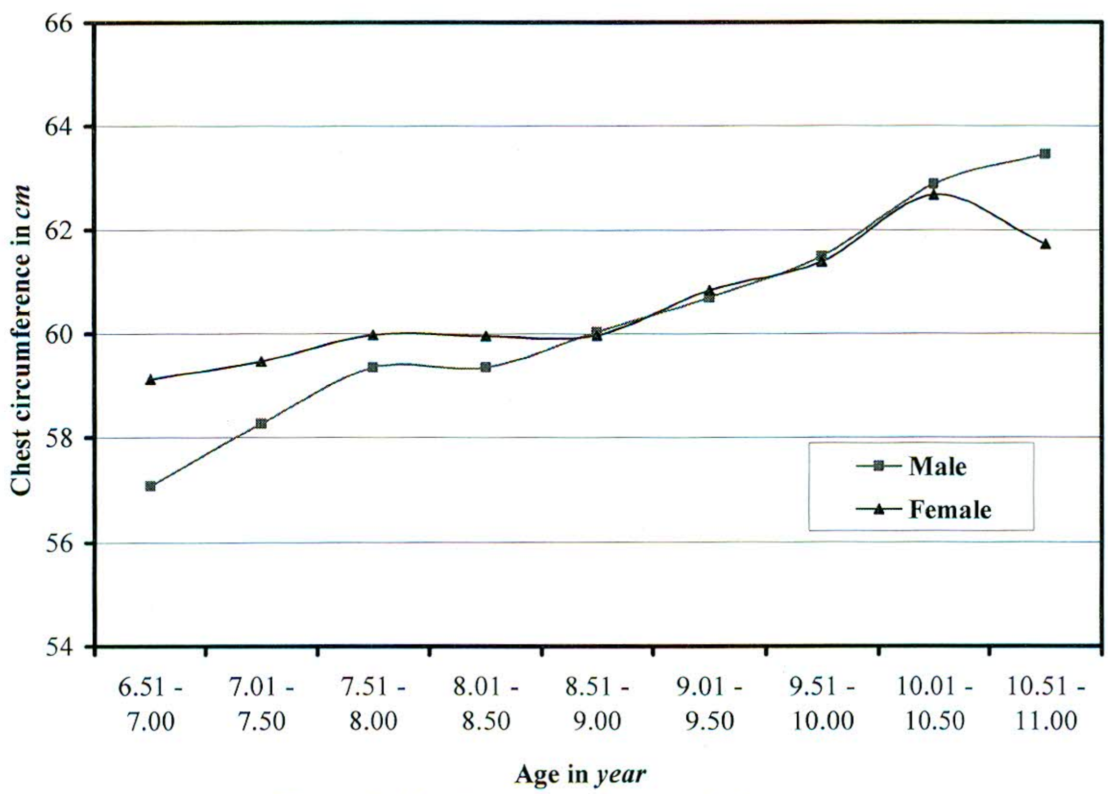


Figure 5.1.5a: Chest circumference of males and females

For Urban Children

The Longitudinal data on chest circumference of urban students are shown in figure 5.1.5b. It is found that at age interval 6.61 - 8.50 and 9.01-10.50 chest circumference of males is less than females but the age interval 8.51- 9.00 and 10.51- 11.00 chest circumference of males are greater than females. This figure also indicates that chest circumference in males is greater than females but the growth difference of urban males and females in chest circumference are not statistically significant.

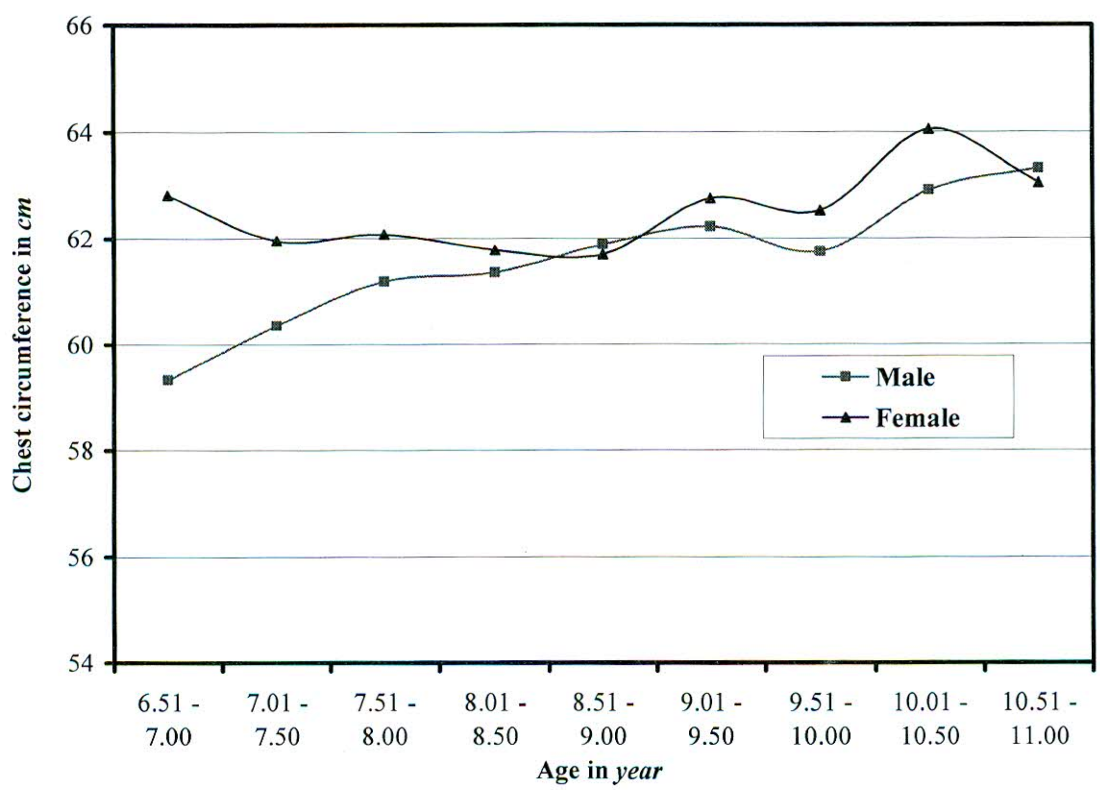


Figure 5.1.5b: Chest circumference of urban males and females

For Rural Children

Chest circumference of rural males and females are shown in figure 5.1.5c. It is evident that chest circumference in rural males and females are close to each other at age interval 6.51-9.00 years but after age 9 an increasing growth velocity is present in male's chest circumference while its growth in females are less than males. At age interval of 10.51-11.00 years, chest circumference of males is 63.56 cm and 61.13 cm for females. Although the growth difference of rural males and females in chest circumference are not statistically significant. The maximum sex difference in chest circumference is observed to be 2.43 cm, 63.56 cm for males and 61.13 cm for females with standard deviations 4.72 cm, and 3.75 cm, respectively. This implies, the growth of rural females is more consistent than males in chest circumference.

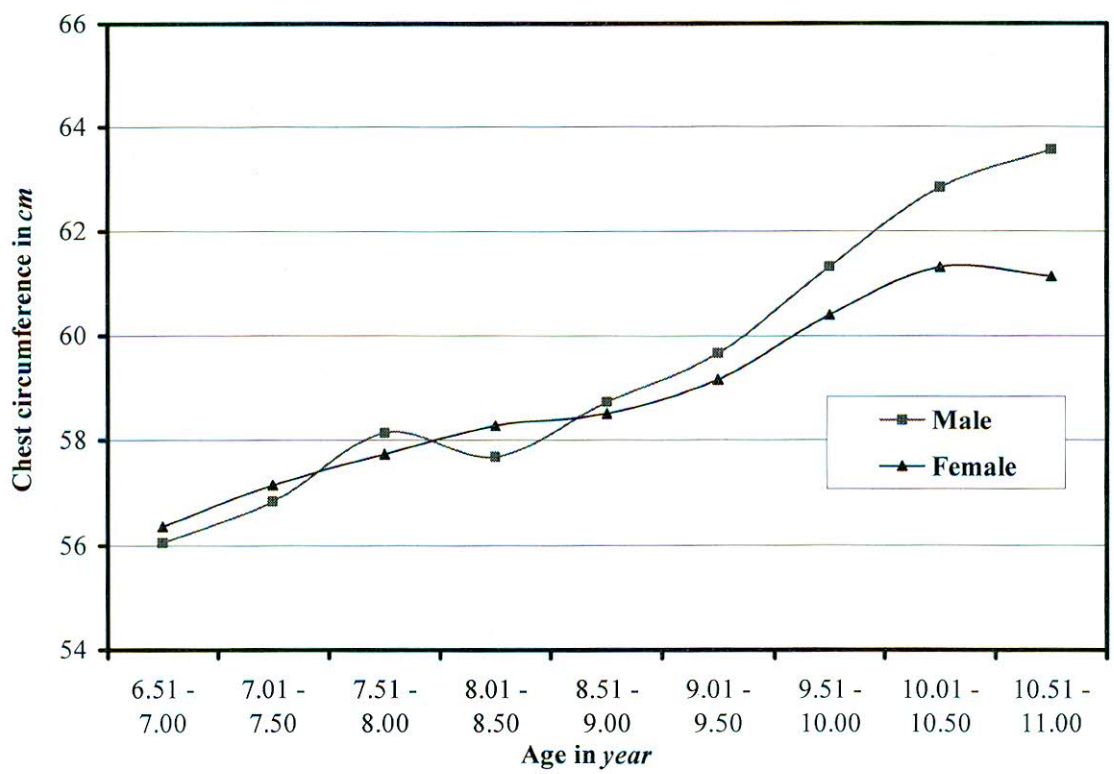


Figure 5.1.5c: Chest circumference of rural males and females

Regional difference in Males

Chest circumferences of urban and rural males are shown in figure 5.1.5d. This figure indicates that at age interval 6.51 – 9.50, chest circumference of urban males is greater than rural males and the age interval 9.51-11.00, growth in chest circumference of urban and rural males are more or less uniform. The maximum difference in chest circumference is observed to be 3.68 cm, 61.37 cm for urban males and 57.69 cm for rural males with standard deviations 4.30 cm and 2.51 cm, respectively. This implies growth velocity for urban males are comparatively larger than rural males, but growth of rural males are more consistent than urban males in chest circumference. It is mentionable that at age interval 6.51-9.50 years, regional difference of males (urban and rural males) is statistically significant ($p<0.05$). There might be some causes, need further investigation.

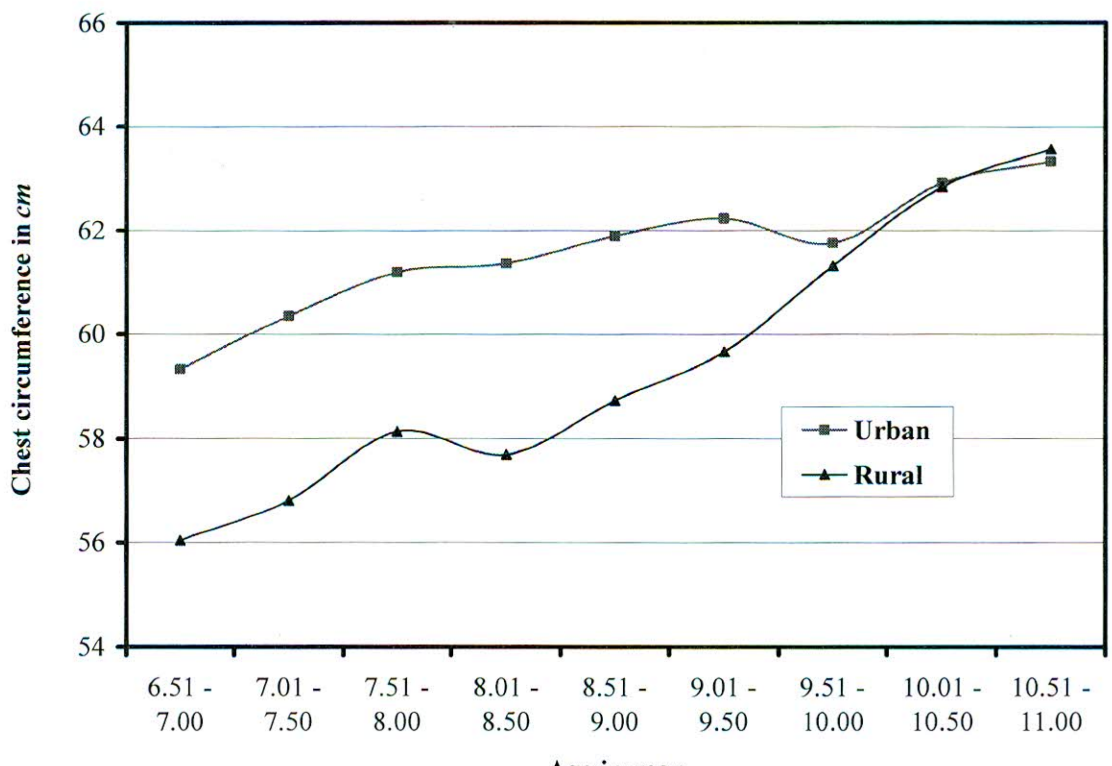


Figure 5.1.5d : Chest circumference of urban and rural males

Regional difference in Females

Age specific mean values of chest circumference of urban and rural females are shown in figure 5.1.5e. It is observed that at age interval 6.51–11.00, growth in chest circumference of urban females is greater than rural females. The maximum difference in chest circumference is observed to be 6.03 cm, 60.40 cm for urban female and 54.37 cm for rural with standard deviations 9.95 cm and 3.96 cm, respectively. This implies, growth velocity in chest circumference for urban females is greater than rural females but growth of rural females is more consistent than urban. It mentionable for regional difference among urban and rural females is statistically significant ($p<0.05$). This figure also indicates that females of urban are healthy than rural females. There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation.

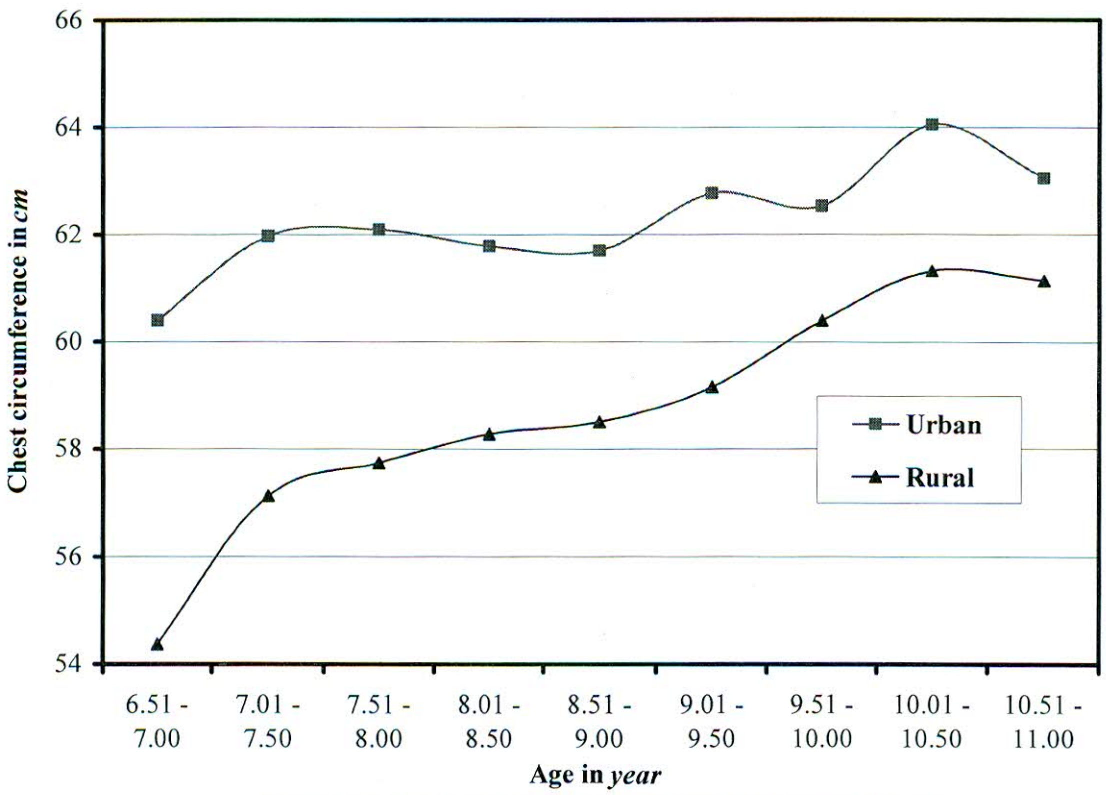


Figure 5.1.5e: Chest circumference of urban and rural females

Growth Allometry of Chest Circumference

Growth allometry of chest circumference with respect to stature is given below:

$Chest\ circumference = 1.840(Stature)^{0.719}$, for males

$Chest\ circumference = 0.989(Stature)^{0.847}$, for females

$Chest\ circumference = 1.158(Stature)^{0.816}$, for urban males

$Chest\ circumference = 0.442(Stature)^{1.016}$, for urban females

$Chest\ circumference = 2.447(Stature)^{0.658}$, for rural males

$Chest\ circumference = 2.941(Stature)^{0.618}$, for rural females

The allometric coefficients indicate that for both males and females growth of chest circumference with respect to stature follows negative allometry. This implies growth rate of chest circumference is less than growth rate of stature. It also indicates that growth of urban females in chest circumference is isometry, which means growth rate of chest circumference and stature are same proportion.

5.1.6: Growth of Head Length

Longitudinal head length of males and females are shown in figure 5.1.6a. This figure indicates that for all age intervals, head length of males is greater than females. The difference of them is 4.34 mm at age interval 6.51-7.00 where 166.53 mm for males and 162.19 mm for females with standard deviations 6.85 mm and 7.87 mm, respectively. The difference of male's and female's head length at age interval 10.51-11.00 is 3.19 mm, 172.18 mm for males and 168.99 mm for females with standard deviations are 6.69 mm & 6.03 mm, respectively. This implies growth of males in head length is more consistent than females. It is found that sex difference in head length at age interval 7.51-8.50 is statistically significant ($p<0.05$).

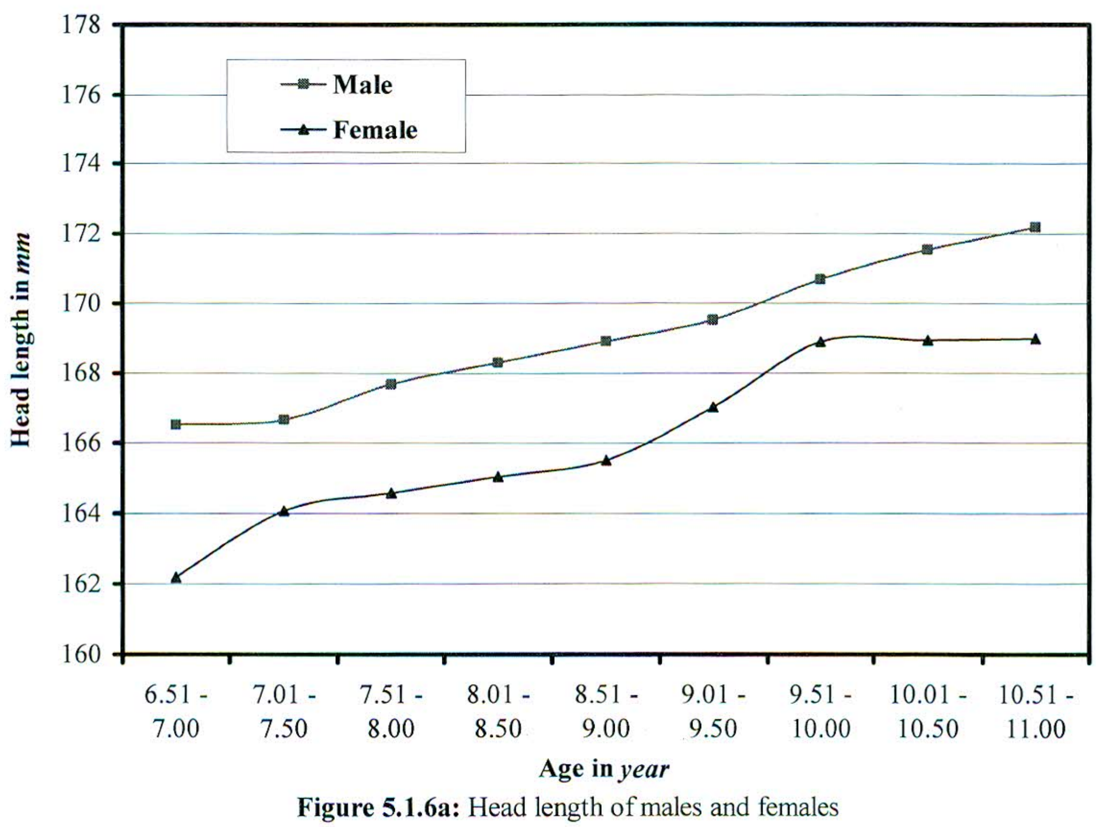


Figure 5.1.6a: Head length of males and females

For Urban Children

Age specific mean values of head length of urban males and females are shown in figure 5.1.6b. It clear that for all age intervals head length of urban males is greater than females. The sex difference is 5.57 mm at age interval 6.51-7.00 where 169.45 mm for males and 163.89 mm for females with standard deviations are 5.73 mm & 6.13 mm, respectively. The difference of urban male's and female's head length at age interval 10.51-11.00 is 6.21 mm, 176.71 mm for males and 170.50 mm for females with standard deviations are 7.36 mm and 0.58 mm respectively. These results suggested that growth velocity of urban males in head length is greater than females and the sex differences in head length are statistically significant ($p<0.05$).

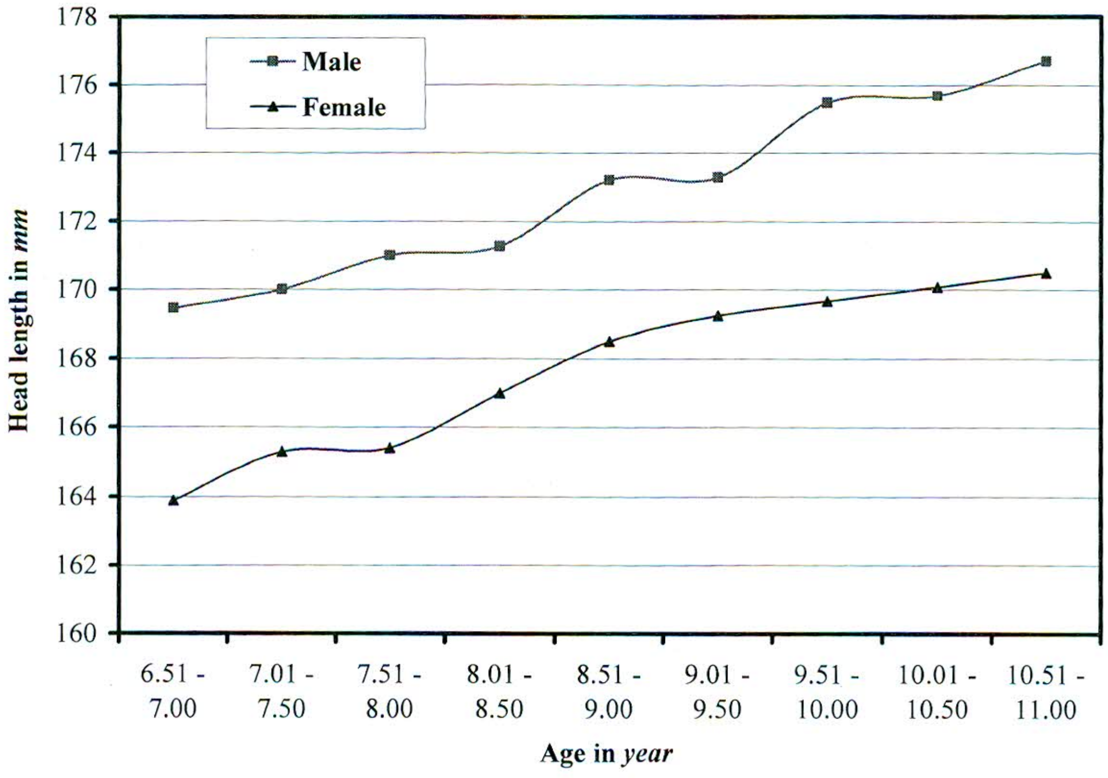


Figure 5.1.6b: Head length of urban males and females

For Rural Children

Head length of rural males and females are shown in figure 5.1.6c on average. This figure indicates that for all age intervals head length of rural males is greater than females. The difference of rural male's and female's head length at age interval 6.51-7.00 is 3.54 mm, 164.46 mm for males and 160.92 mm for females with standard deviations 6.49 mm and 9.00 mm, respectively. The sex difference at age interval 10.51-11.00 is 3.65 mm where 169.10 mm for males and 165.35 mm for females with standard deviations 4.59 mm and 6.30 mm, respectively. These results suggested that growth velocity of rural females in head length is greater than males but growth of head length of males are more consistent than females. It is also found that the differences are statistically insignificant.

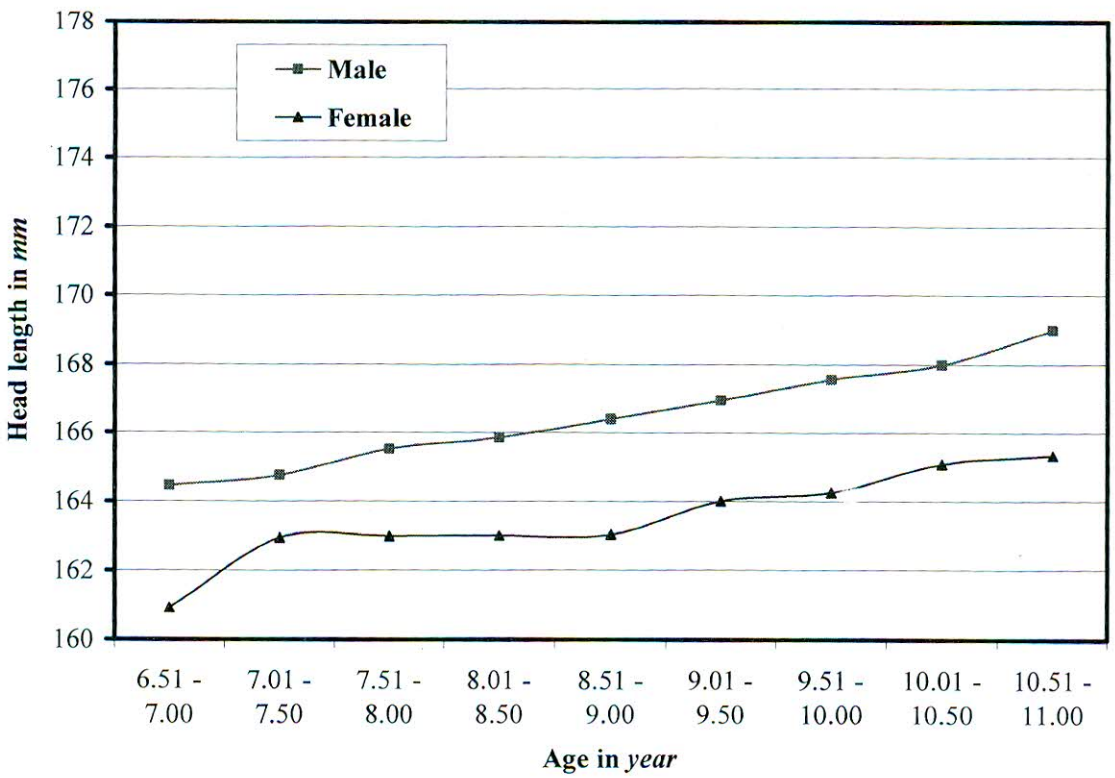


Figure 5.1.6c: Head length of rural males and females

Regional difference in Males

Head lengths of urban and rural males are shown in figure 5.1.6d. This figure shows that for all age interval head length of urban males is greater than rural males. The maximum difference in mean head length is observed to be 7.90 mm, 175.47 mm for urban males and 167.57 mm for rural males with standard deviations 6.69 mm and 5.65 mm, respectively. This implies, growth variation for urban males is comparatively larger than rural males, but growth in head length of rural males are more consistent than urban males. The results also indicate that the regional differences in head length of males are statistically significant ($p<0.05$).

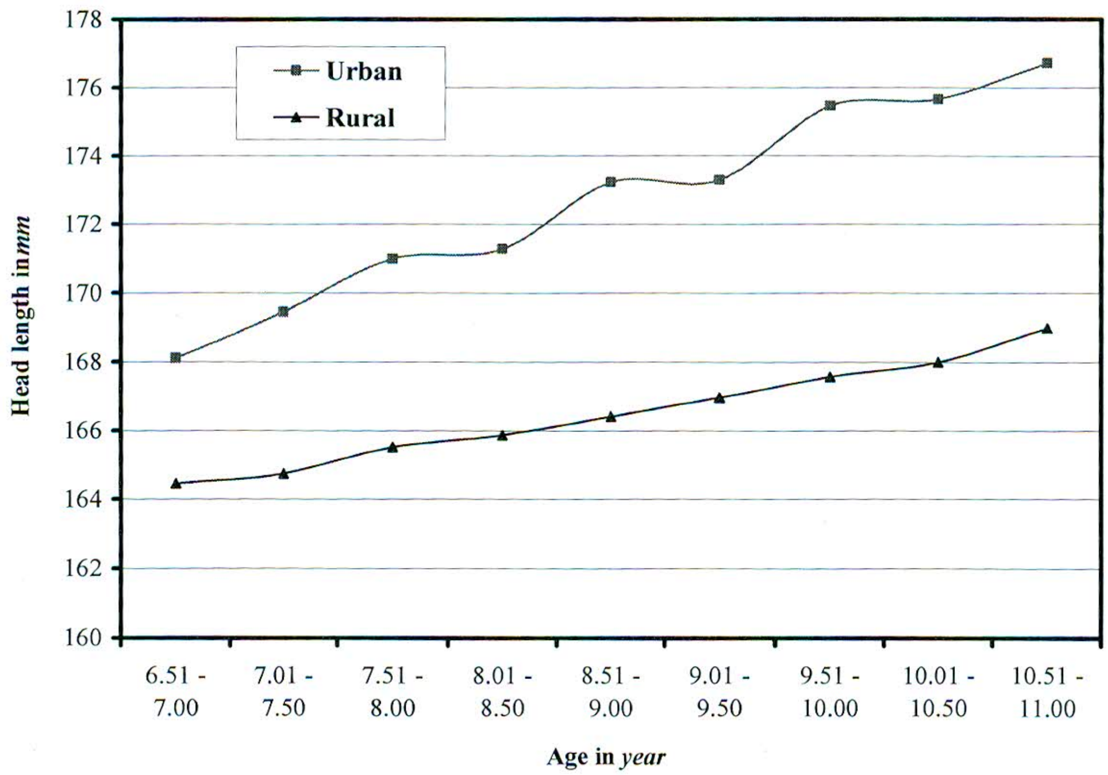


Figure 5.1.6d: Head length of urban and rural males

Regional difference in Females

Head lengths of urban and rural females are shown in figure 5.1.6e. It is found that for all age interval head length of urban females is greater than rural females. The maximum regional difference in head length is observed to be 5.46 mm, 168.50 mm for urban females and 163.04 mm for rural females with standard deviations 6.87 mm and 7.03 mm, respectively. This implies growth variation within rural females is comparatively larger than urban females, but growth in head length of urban females are more consistent than rural females. This results also indicate that the regional differences in head length of females are statistically significant ($p<0.05$).

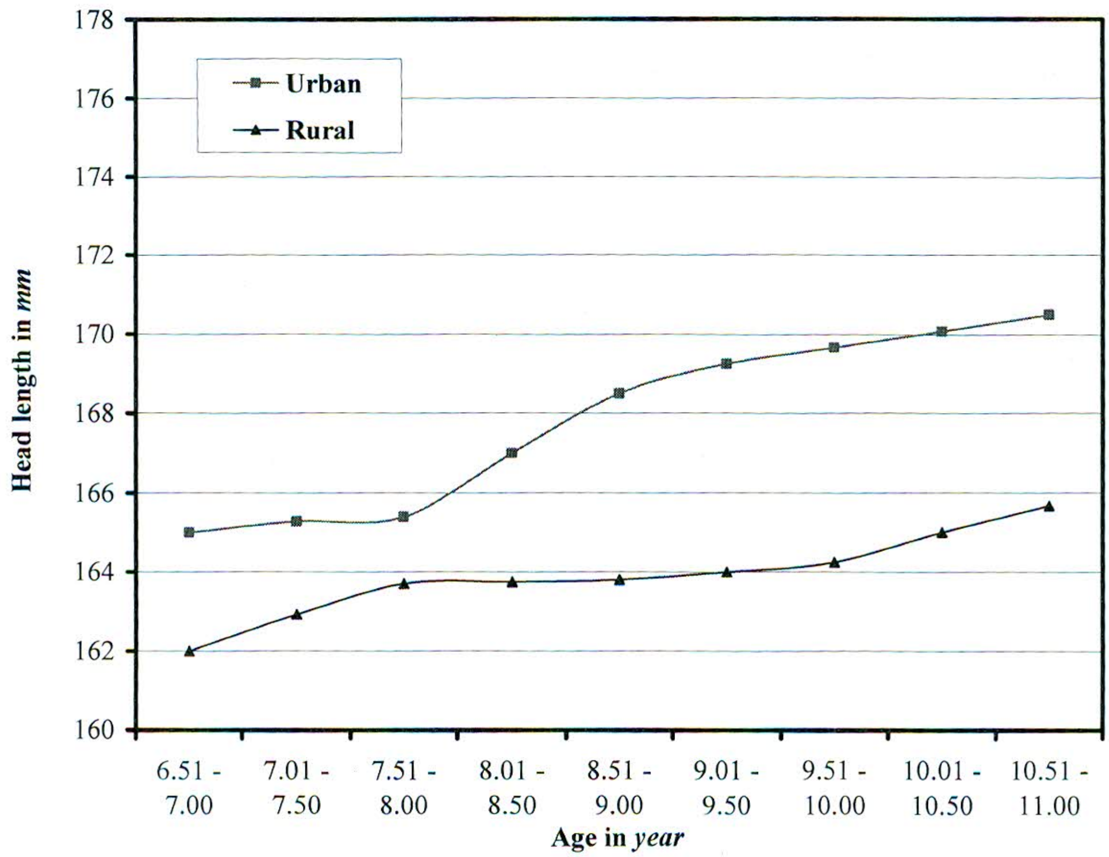


Figure 5.1.6e: Head length of urban and rural females

Growth Allometry of Head length

Growth allometry of head length with respect to stature is given below:

$Head\ length = 48.105(Stature)^{0.258}$, for males

$Head\ length = 33.686(Stature)^{0.328}$, for females

$Head\ length = 36.009(Stature)^{0.322}$, for urban males

$Head\ length = 30.543(Stature)^{0.350}$, for urban females

$Head\ length = 67.277(Stature)^{0.186}$, for rural males

$Head\ length = 45.436(Stature)^{0.264}$, for rural females

From above fitted allometric growth models, it is clear that for both males and females growth of head length with respect to stature follow negative allometry. This implies growth rate of head length is less than that of stature. This results also indicate that regional slope difference in females is statistically significant ($p<0.05$).

5.1.7: Growth of Head Breadth

Head breadth of males and females are shown in figure 5.1.7a. The figure indicates that for all age intervals, head breadth of males is greater than females. It is found that sex difference is 2.82 mm at age interval 6.51-7.00 where 141.11 mm for males and 138.29 mm for females with standard deviations 5.31 mm and 6.16 mm, respectively. The difference of male's and female's head breadth at age interval 10.51-11.00 is 4.61 mm, 147.53 mm for males and 142.92 mm for females with standard deviations are 5.56 mm and 5.28 mm respectively and the difference of this interval is maximum between 6 to 11 years of age. The results also indicate that the sex difference in head breadth at age interval 8.01-11.00 is statistically significant ($p<0.05$).

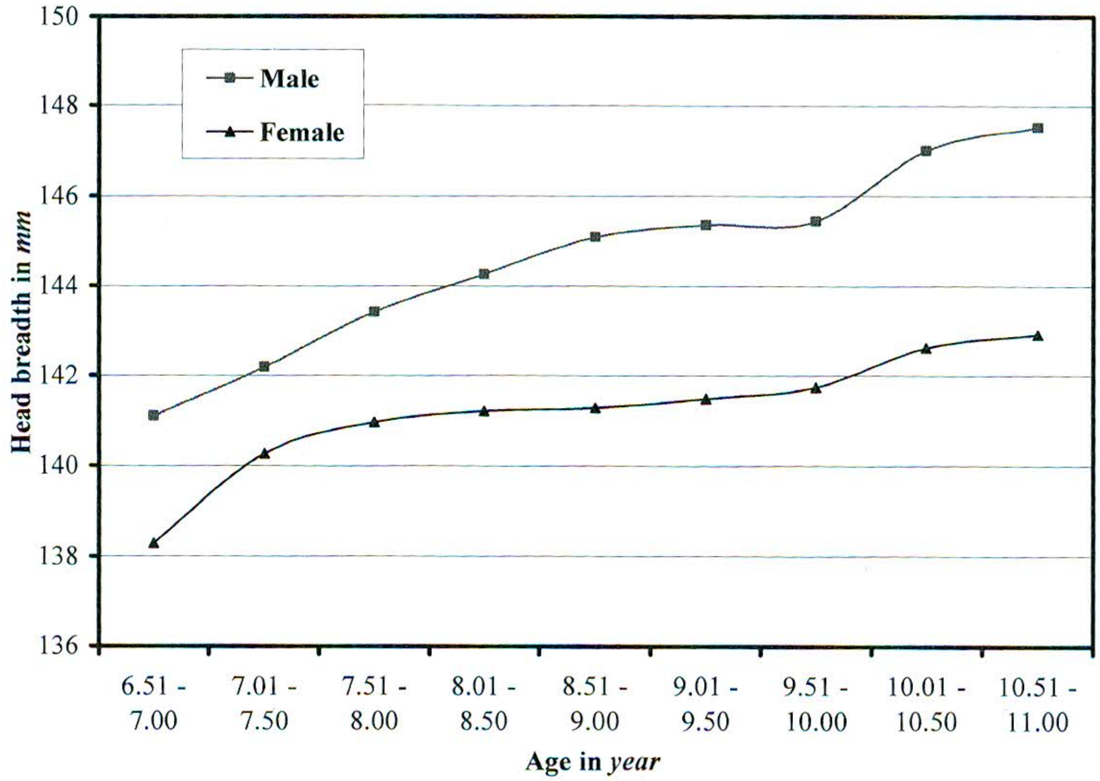


Figure 5.1.7a: Head breadth of males and females

For Urban Children

Age specific mean values of head breadth of urban males and females are shown in figure 5.1.7b. It shows that for all age interval head breadth of urban males is greater than females. At age interval 6.51-7.00 the difference of urban male's and female's head breadth is 3.40 mm where 144.18 mm for males and 140.78 mm for females with standard deviations are 3.76 mm and 7.40 mm, respectively and the difference at age interval 10.51-11.00 is 6.05 mm, 149.00 mm for males and 142.95 mm for females with standard deviations 6.83 mm and 6.48 mm, respectively. It also found that the sex differences of urban in head breadth are statistically significant ($p<0.05$).

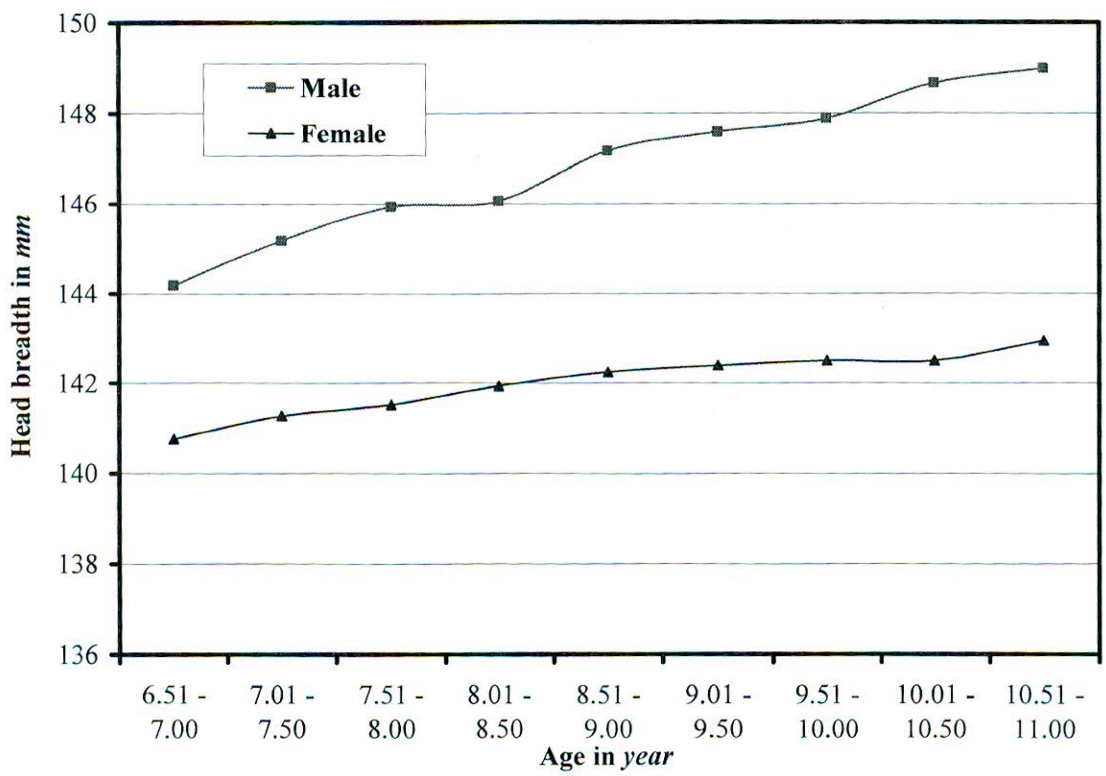


Figure 5.1.7b: Head breadth of urban males and females

For Rural Children

The longitudinal data on head breadth of rural males and females are shown in figure 5.1.7c on average. This figure indicates during study period, head breadth of rural males is greater than females. At age interval 6.51-7.00 the sex difference is 2.81 mm where 139.23 mm for males and 136.42 mm for females with standard deviations 4.94 mm and 4.50 mm, respectively. The difference of rural male's and female's head breadth at age interval 10.51-11.00 is 3.50 mm, 146.50 mm for males and 143.00 mm for females with standard deviations 4.58 mm and 3.84 mm, respectively. These results indicate that growth velocity of rural males in head breadth is greater than females but growth of rural females are consistent than rural males and the sex difference in rural at age interval 8.51-10.00 is statistically significant ($p<0.05$).

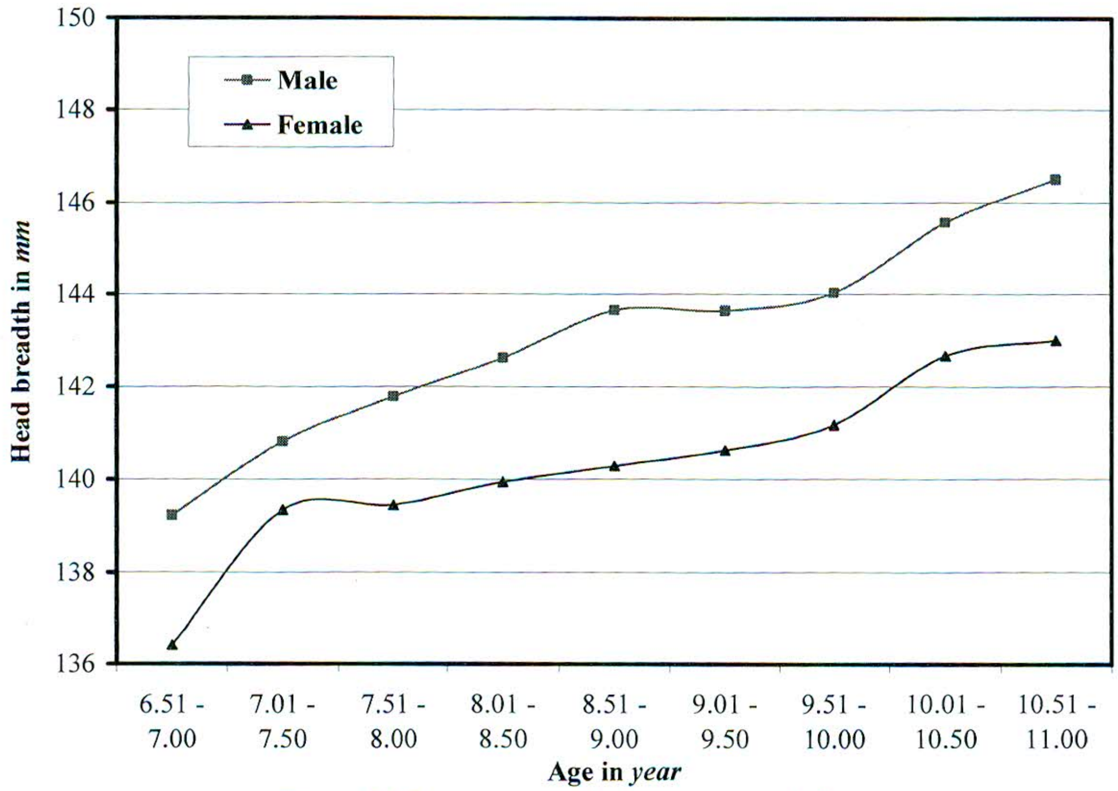


Figure 5.1.7c: Head breadth of rural males and females

Regional difference in Males

Head breadth of urban and rural males is as follows in figure 5.1.7d. It is found that for all age intervals head breadth of urban males is greater than rural males. The maximum difference in mean head breadth is observed to be 5.94 mm at age interval 6.51-7.00 where 145.17 mm for urban males and 139.23 mm for rural males with standard deviation 3.76 mm and 4.94 mm respectively. This implies, growth variation for rural males is comparatively larger than urban males, but growth in head breadth of urban males are more consistent than rural males. This also indicates that at age intervals 6.51-8.50 and 9.01-10.51, the regional difference in head breadths of males are statistically significant ($p<0.05$).

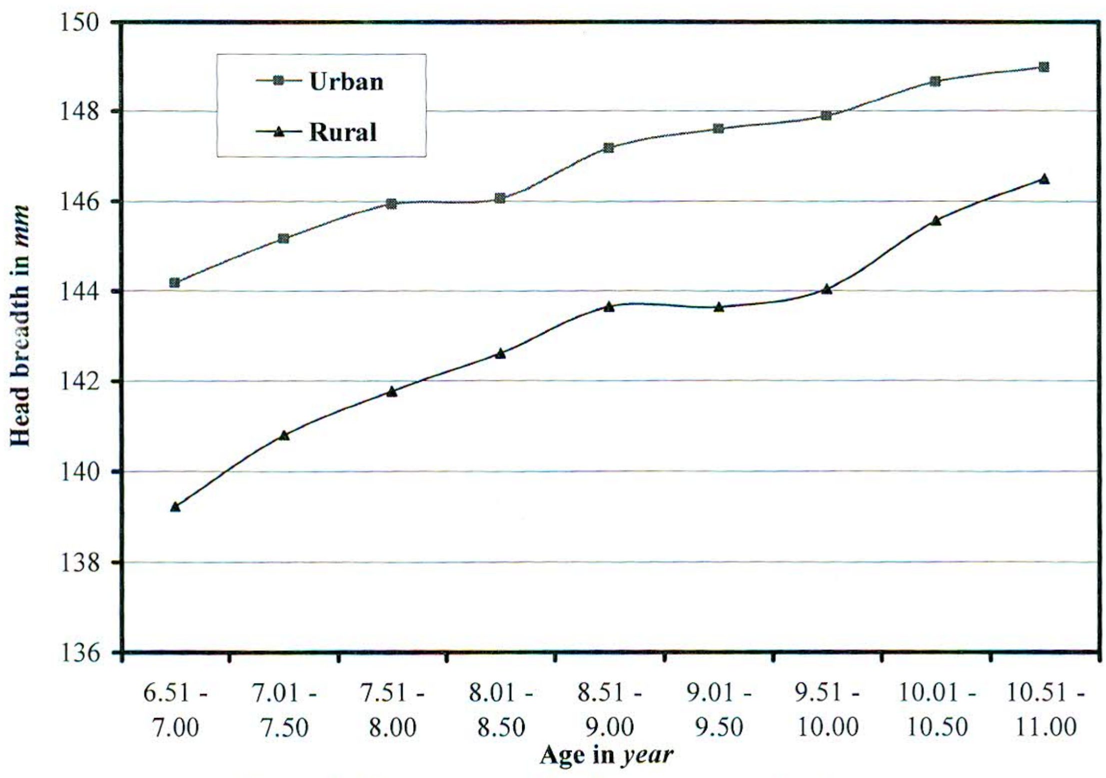


Figure 5.1.7d: Head breadth of urban and rural males

Regional difference in Females

Head breadths of urban and rural females are shown in figure 5.1.7e on average. It is evident that at age interval 6.51-10.00, head breadth of urban females is greater than rural females but after age interval 9.51-10.00, an increasing diversity is present for rural females. The maximum difference in head breadth is observed to be 4.36 mm at age interval 6.51-7.00 where 140.78 mm for urban females and 136.42 mm for rural females with standard deviations 7.40 mm and 4.50 mm, respectively, this implies, at this point growth variation for urban females is comparatively larger than rural females, but growth in head breadth of rural females are more consistent than urban females. The figures indicate that there is no mentionable growth in head breadth of rural males during study period because from age interval 7.01-10.50 head breadth lies between 141.29 mm to 142.50 mm for urban females while at age interval 6.51-10.00 head breadth lies between 136.42 mm to 141.17 mm for rural females. It is also found that the regional difference in head breadth is statistically not significant.

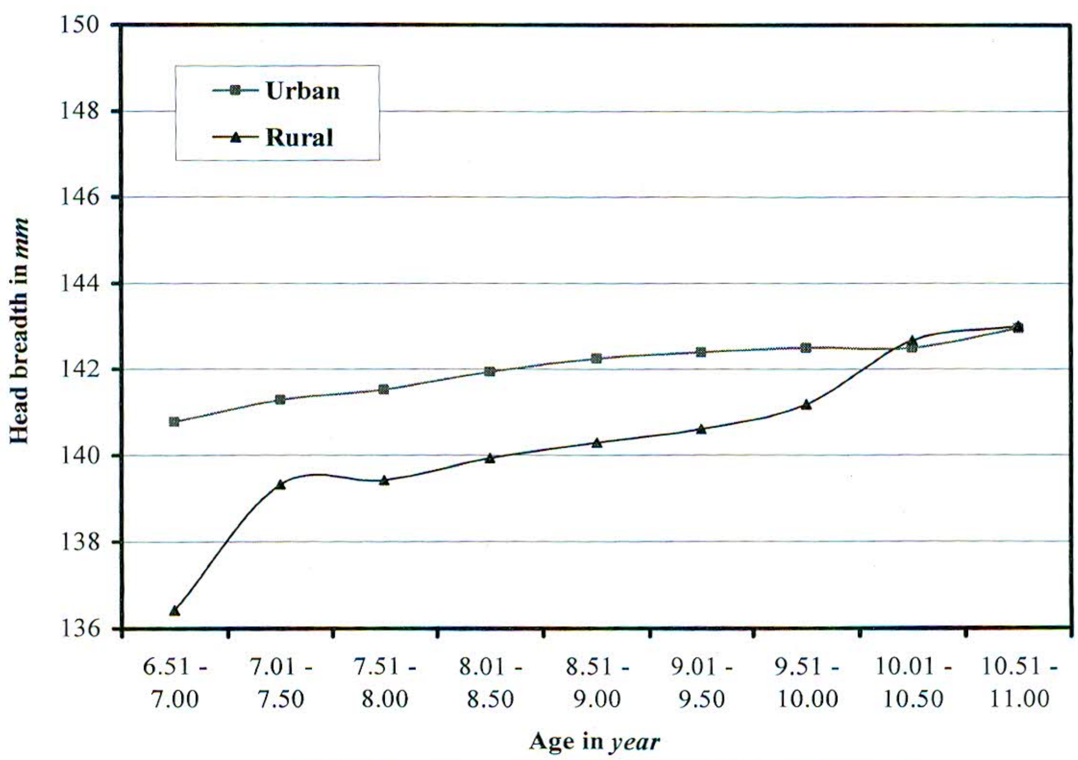


Figure 5.1.7e: Head breadth of urban and rural females

Growth Allometry of Head Breadth

Growth allometry of head breadth with respect to stature is given below:

$Head\ breadth = 33.340(Stature)^{0.302}$, for males

$Head\ breadth = 54.082(Stature)^{0.197}$, for females

$Head\ breadth = 22.329(Stature)^{0.387}$, for urban males

$Head\ breadth = 50.564(Stature)^{0.212}$, for urban females

$Head\ breadth = 44.745(Stature)^{0.239}$, for rural males

$Head\ breadth = 60.540(Stature)^{0.173}$, for rural females

The fitted allometric growth models indicate that for both males and females growth in head breadth with respect to stature follow negative allometry. This implies growth rate of head length is less than growth rate of stature. These results also indicate that sex difference and regional slope difference in males and females are statistically significant ($p<0.05$).

5.1.8: Growth of Head Circumference

Age specific mean values of head circumference of males and females are shown in figure 5.1.8a. It evident that head circumference of males is greater than females. The sex difference at age interval 10.51-11.00 is 0.77 cm where 51.27 cm for males and 50.50 mm for females with standard deviations 1.73 cm and 1.31 cm, respectively. The difference of male's and female's head circumference at age interval 6.51-7.00 is 0.89 cm, 49.06 cm for males and 48.18 cm for females with standard deviations are 1.43 cm and 2.21 cm, respectively. These results suggested that growth velocity of males in head circumference is greater than females and the difference among them at age interval 8.01-8.50 is statistically significant ($p<0.05$) but difference of other intervals is not significant.

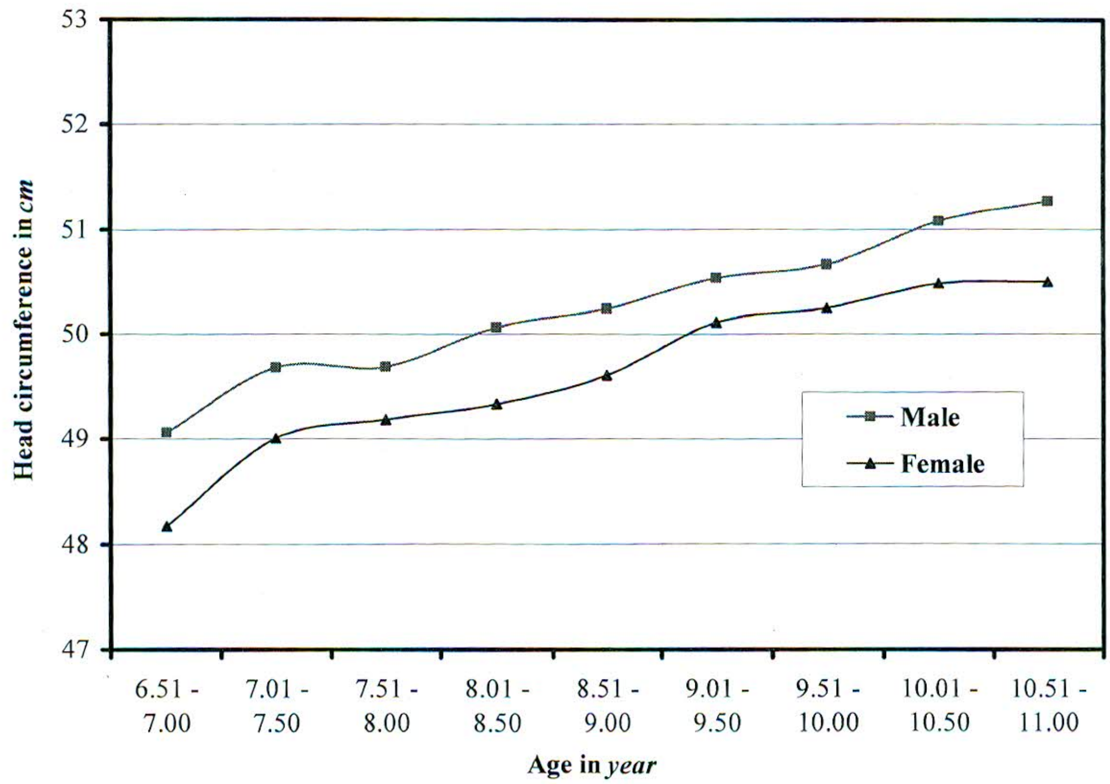


Figure 5.1.8a: Head circumference of males and females

For Urban Children

The Longitudinal data on head circumference of urban males and females are shown in figure 5.1.8b. It is found that during study period mean head circumference of males are greater than females at each age intervals and their growth are more or less uniform in head circumference but the sex difference in head circumference in urban is statistically significant ($p<0.05$) at age intervals 7.51-8.50 and 9.51-10.00 years. This figure indicates that the maximum sex difference in head circumference is observed to be 1.22 cm at age interval 7.51-8.00 where 50.75 cm for urban males and 49.53 cm for females with standard deviations 1.23 cm and 2.12 cm respectively, this implies, at this point growth variation for urban females is comparatively larger than males, but growth in head circumference of males are more consistent than urban females.

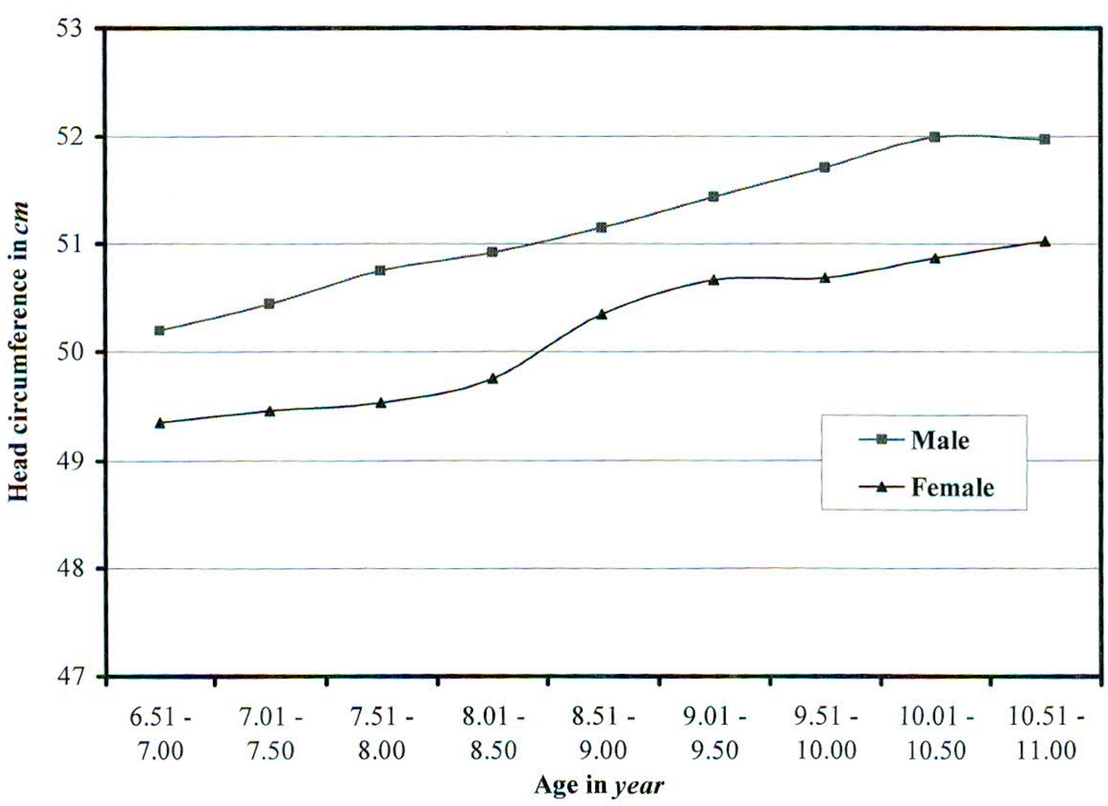


Figure 5.1.8b: Head circumference of urban males and females

For Rural Children

Head circumference of rural males and females are shown individually in figure 5.1.8c. It is evident that growth pattern of rural males and females in head circumference are same but head circumferences of rural males are greater than rural females. It is found that sex difference in rural is statistically insignificant during study period. This figure indicates that at age interval 6.51-7.00 sex difference is 1.14 cm where 48.54 cm for rural males and 47.40 for rural females with standard deviations 1.37 cm and 1.55 cm, respectively. On the other hand at age interval 10.51-11.00 difference in head circumference between rural males and females is 0.63 cm where 50.78 cm for males and 50.15 cm for females with standard deviations 1.55 cm and 1.37cm, respectively. It is clear that rural males are more consistent than females in head circumference.

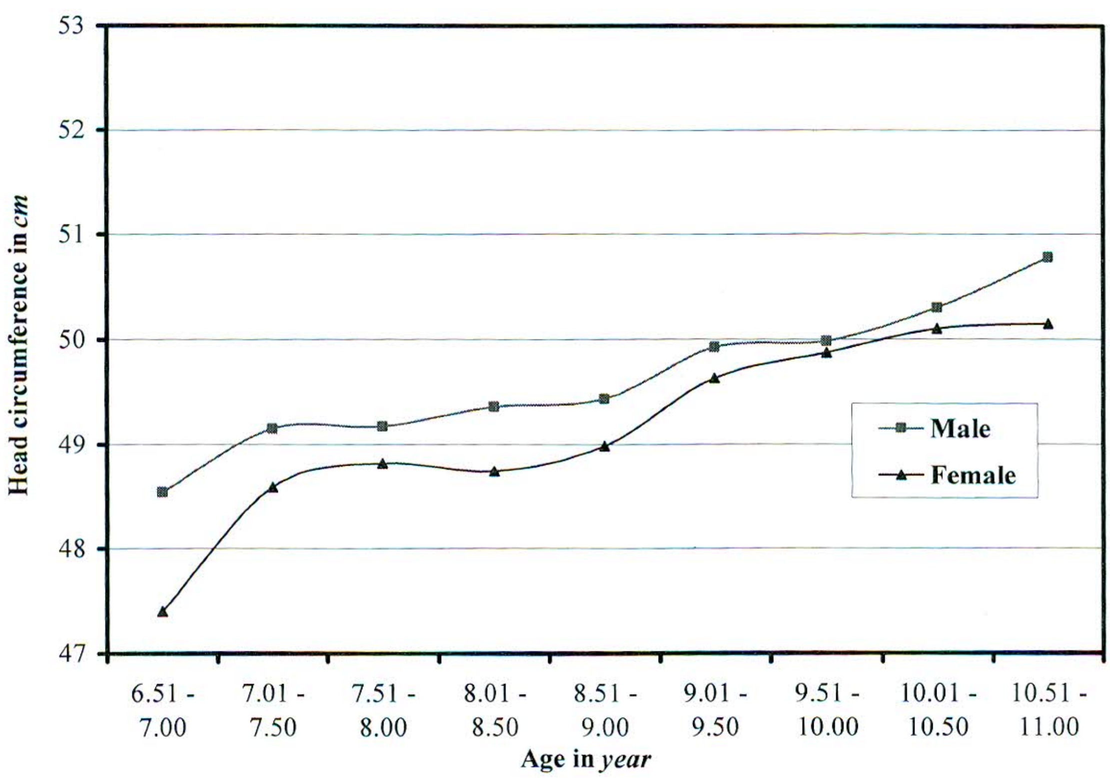


Figure 5.1.8c: Head circumference of rural males and females

Regional difference in Males

Age specific head circumferences of urban and rural males are shown in figure 5.1.8d. This figure shows for all age intervals head circumference of urban males is greater than rural males. The maximum regional difference in mean head circumference is observed to be 1.73 cm at age interval 9.51-10.00 where 51.71 cm for urban males and 49.98 cm for rural males with standard deviations 1.32 cm and 1.28 cm, respectively. This implies at this point variation of head circumference for rural males is comparatively larger than urban males, but growth in head circumference of rural males are more consistent than urban males where overall during study period, head circumference of urban males are more consistent than rural males. It is also found that the regional differences in head circumference of males are statistically significant ($p<0.05$).

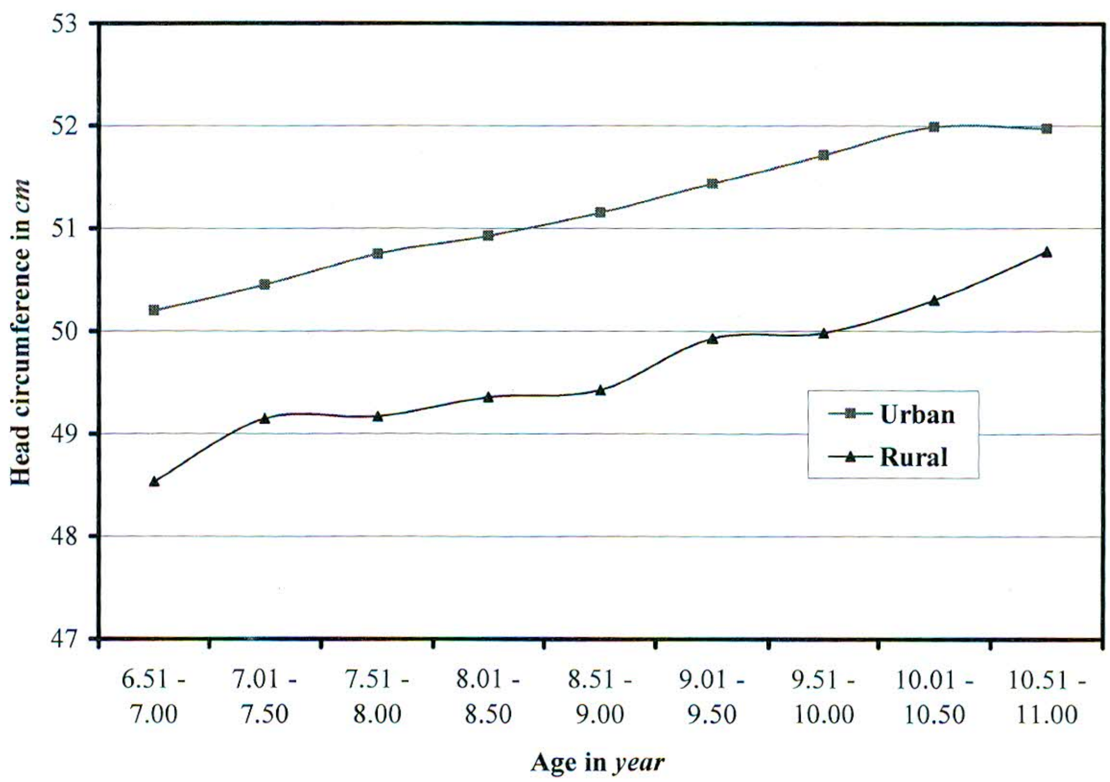


Figure 5.1.8d : Head circumference of urban and rural males

Regional difference in Females

Head circumferences of urban and rural females are shown in figure 5.1.8e. It is observed that during study period (at age interval 6.51–11.00) head circumference of urban females is greater than rural females. The maximum regional difference in head circumference is observed to be 1.95 cm, 49.35 cm for urban females and 47.40 cm for rural females with standard deviations 2.19 cm and 1.55 cm, respectively. This implies, at this age interval growth velocity in head circumference for urban females is greater than rural females but growth of rural females is more consistent than urban females. It mentionable, at age intervals 6.51-7.00 and 8.51-9.00 regional differences in head circumference of females are statistically significant ($p<0.05$).

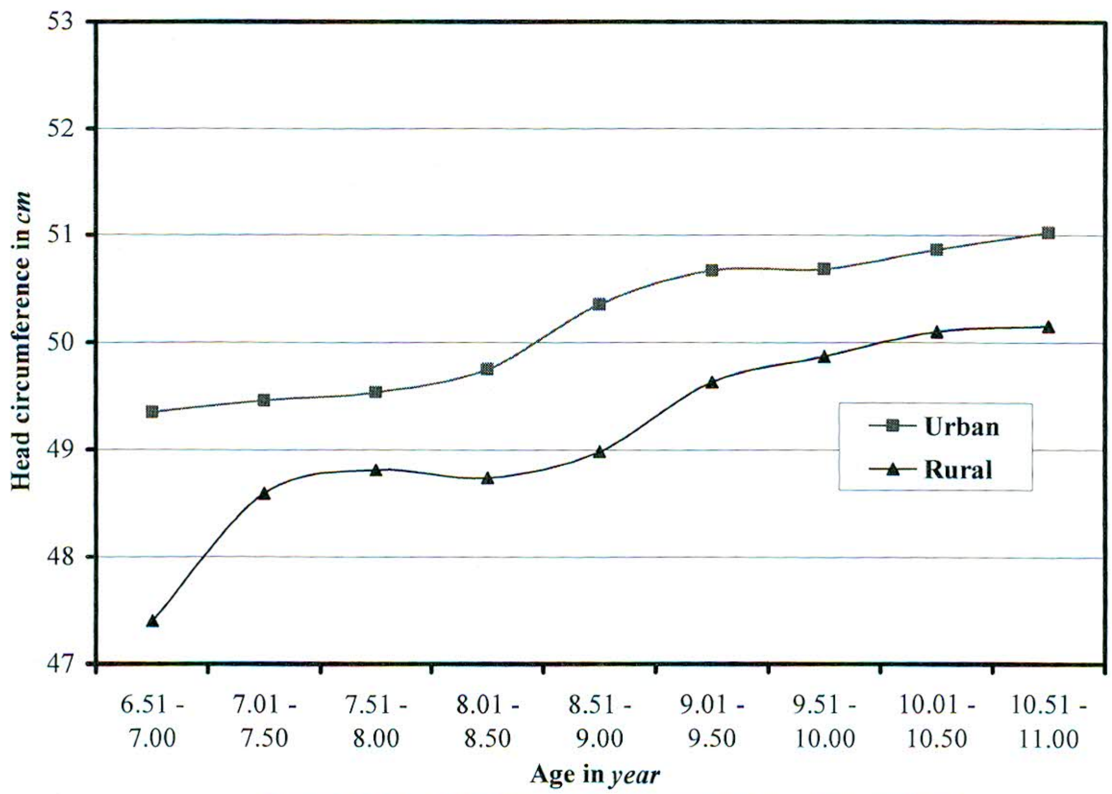


Figure 5.1.8e: Head circumference of urban and rural females

Growth Allometry of Head Circumference

Growth allometry of head circumference with respect to stature is given below:

$Head\ circumference = 12.719(Stature)^{0.282}$, for males

$Head\ circumference = 9.664(Stature)^{0.337}$, for females

$Head\ circumference = 11.539(Stature)^{0.306}$, for urban males

$Head\ circumference = 10.616(Stature)^{0.319}$, for urban females

$Head\ circumference = 15.691(Stature)^{0.237}$, for rural males

$Head\ circumference = 10.719(Stature)^{0.314}$, for rural females

The allometric coefficients indicate that for both males and females growth of head circumference with respect to stature follow negative allometry. This implies growth rate of head circumference is less than growth rate of stature. The slope difference between urban males and rural males is statistically significant ($p<0.05$).

5.1.9: Elbow-Wrist Length

The Longitudinal data on elbow-wrist length (left and right) of males and females are shown in figure 5.1.9a for right elbow-wrist length and figure 5.2.9b for left elbow-wrist length. These figures indicate that within the age interval 6-11 years, growth of right elbow-wrist length and left elbow-wrist length is more or less uniform for both males and females. It is also found that growth of males is greater than females in right and left elbow-wrist length for all age intervals. The maximum sex difference in right elbow-wrist length is 0.77 cm at age interval 10.51-11.00 where 21.25 cm for males and 20.48 cm for females with SD 1.48 cm and 1.41 cm, respectively, the maximum sex difference in left elbow-wrist length is 0.77 cm at age interval 10.51-11.00 where 21.28 cm for males and 20.52 cm for females with SD 1.46 cm and 1.38 cm, respectively. This implies at this age interval growth velocity for male children are comparatively larger than females but growth of females in left and right elbow-wrist length are more consistent than males. It is mentionable that except this interval, growth of males in left and right elbow-wrist length is more consistent than females. It is found that there has no difference between left and right elbow-wrist length (figures 5.1.9c and 5.1.9d). The sex difference in Elbow-Wrist length is found but it is statistically insignificant.

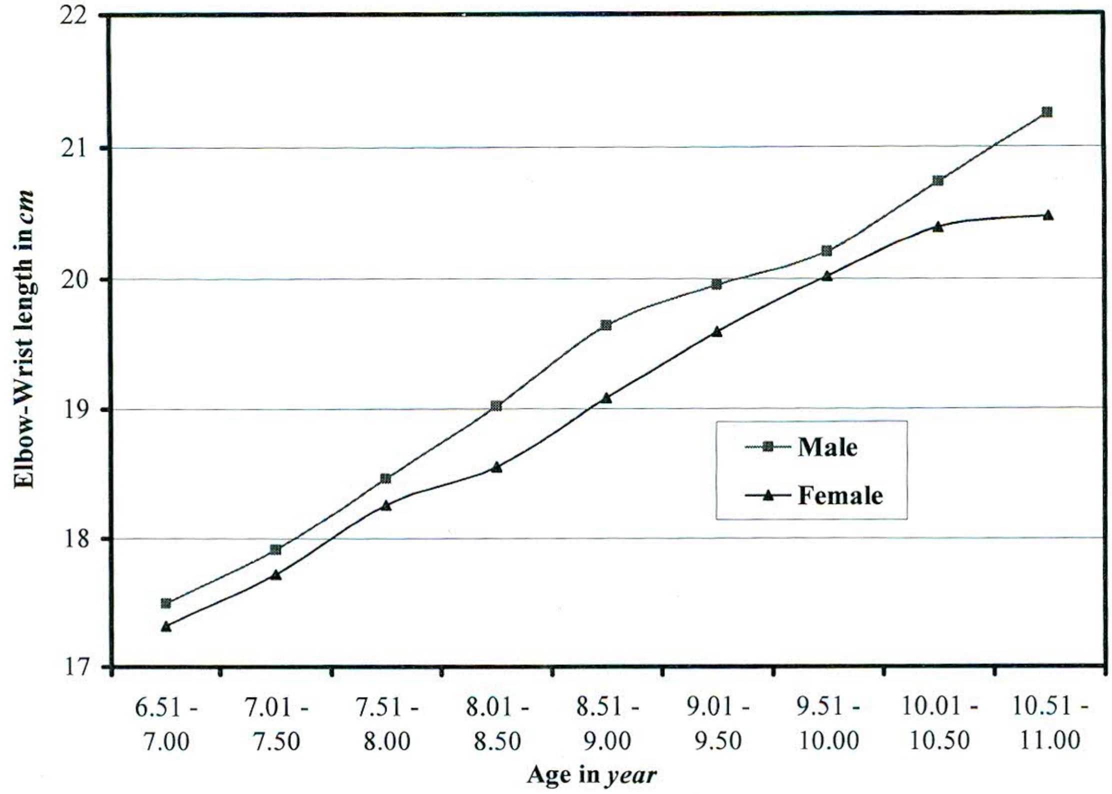


Figure 5.1.9a: Elbow-wrist length (right) of males and females

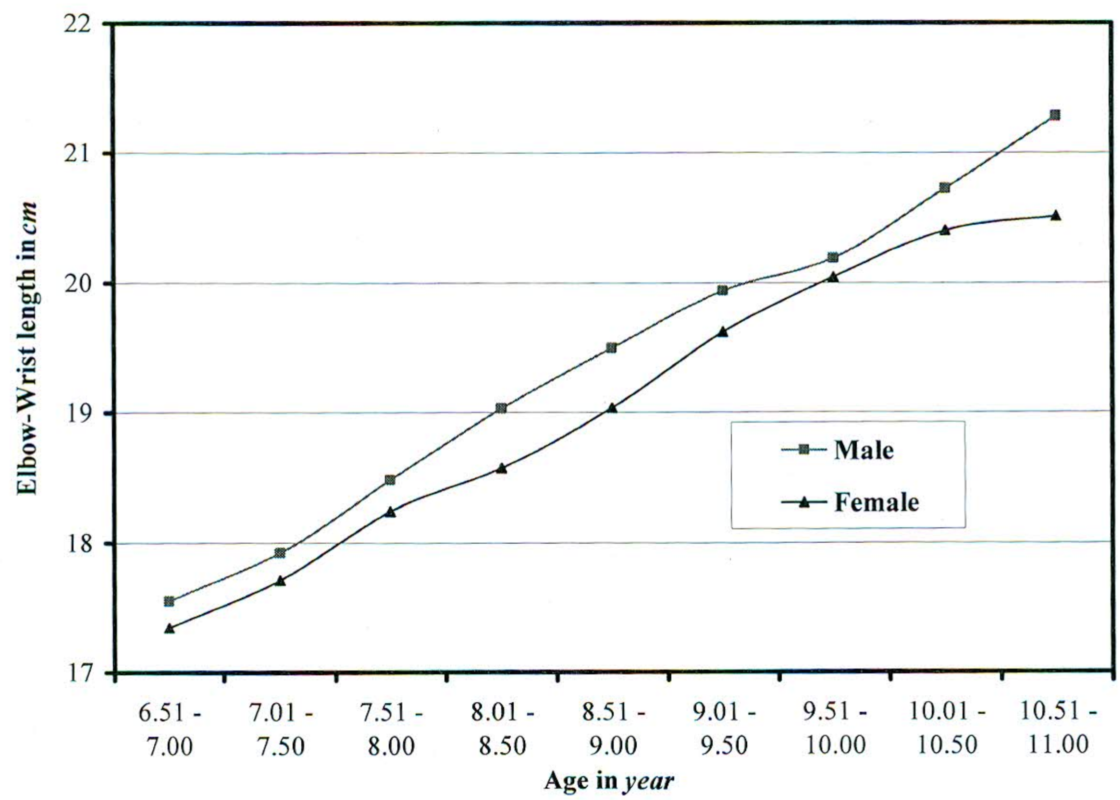


Figure 5.1.9b: Elbow-wrist length (left) of males and females

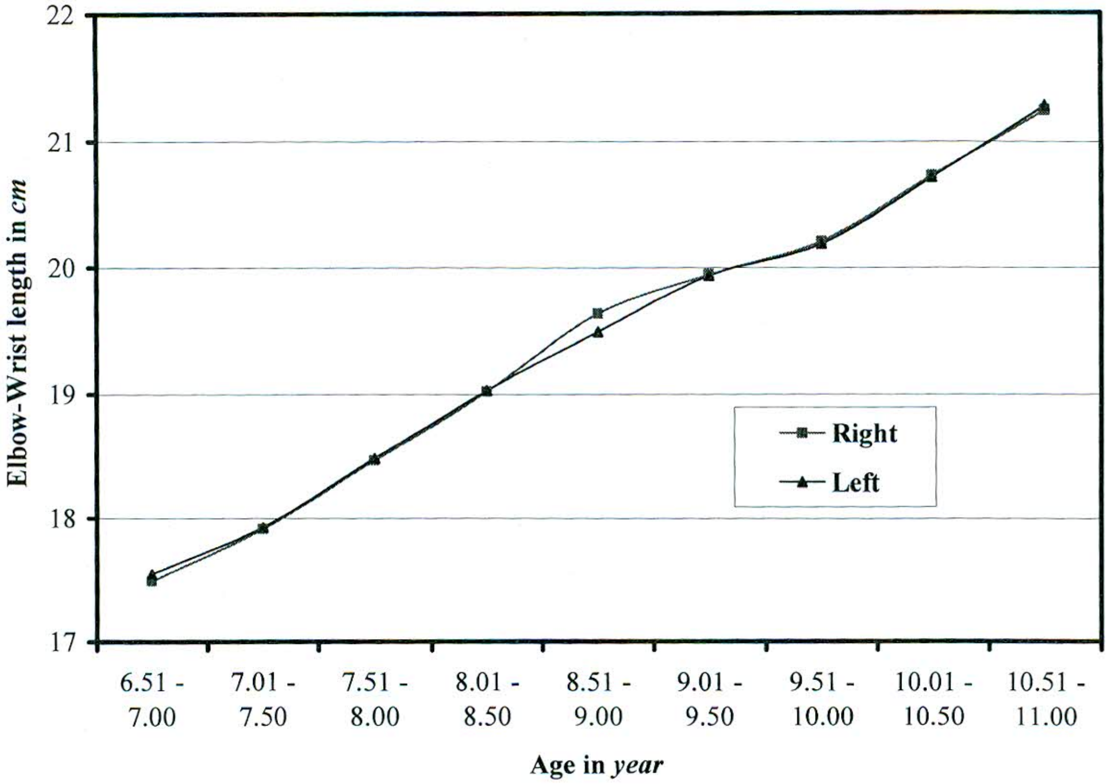


Figure 5.1.9c : Rigth and left elbow-wrist length of males

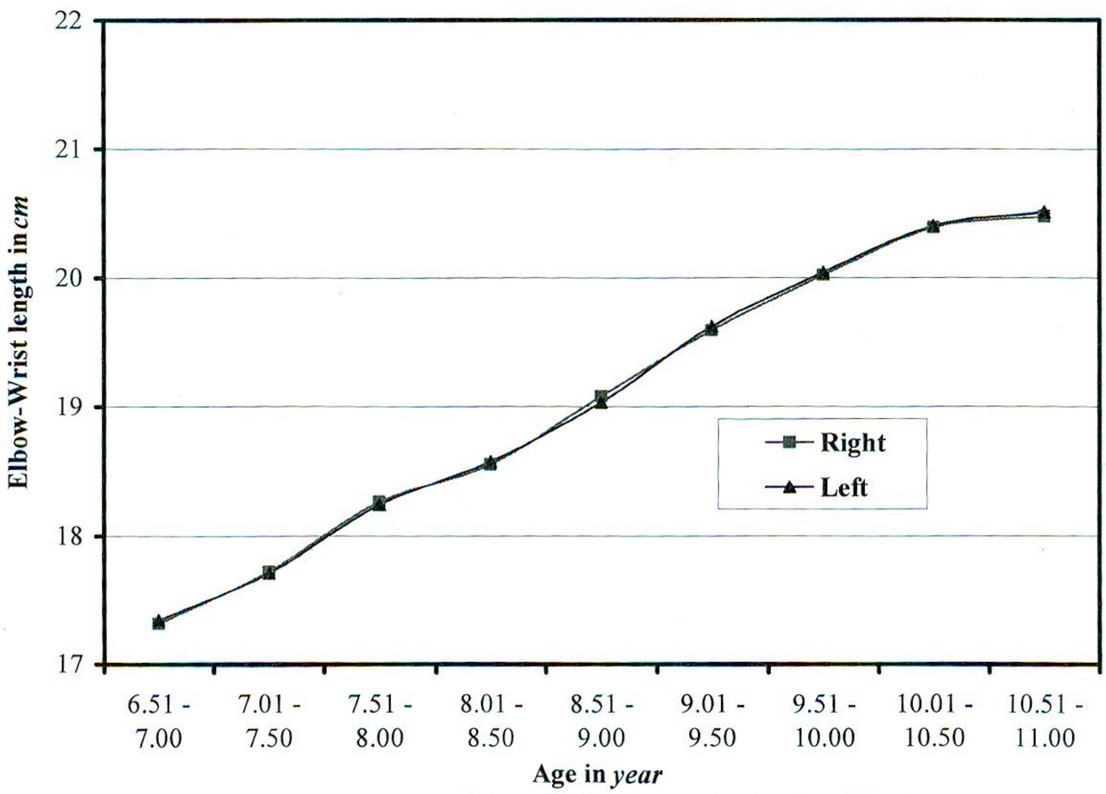


Figure 5.1.9d: Right and left elbow-wrist length of females

Growth Allometry of Elbow-Wrist Length

Growth allometry of elbow-wrist length with respect to stature is given below:

Right elbow-wrist length = 0.030(Stature)$^{1.330}$, for males

Right elbow-wrist length = 0.035(Stature)$^{1.294}$, for females

Left elbow-wrist length = 0.033(Stature)$^{1.312}$, for males

Left elbow-wrist length = 0.034(Stature)$^{1.303}$, for females

Right elbow-wrist length = 0.042(Stature)$^{1.264}$, for urban males

Right elbow-wrist length = 0.028(Stature)$^{1.339}$, for urban females

Left elbow-wrist length = 0.040(Stature)$^{1.273}$, for urban males

Left elbow-wrist length = 0.025(Stature)$^{1.366}$, for urban females

Right elbow-wrist length = 0.026(Stature)$^{1.358}$, for rural males

Right elbow-wrist length = 0.045(Stature)$^{1.246}$, for rural females

Left elbow-wrist length = 0.030(Stature)$^{1.329}$, for rural males

Left elbow-wrist length = 0.044(Stature)$^{1.248}$, for rural females

The allometric coefficients indicate that for both males and females growth of elbow-wrist length (right and left) with respect to stature is positively allometric. This implies growth rate of elbow-wrist lengths is greater than growth rate of stature. The slope difference between urban males and rural males is statistically significant ($p<0.05$). The results also indicates that the slope difference of urban females and rural females is statistically significant ($p<0.05$) which means growth of urban males and females in elbow-wrist length are greater than rural males and females.

5.1.10: Growth of Upper Arm Length

Age specific data on upper arm length (left and right) of males and females are shown in figure 5.1.10a for right upper arm length and figure 5.2.10b for left upper arm length.. These figures indicate that within the age interval 6.51-11.00, growth of right upper arm length and left upper arm length is more or less uniform for both males and females. It is also found that during study period, growth of males and females in right and left upper arm length is closely related. The maximum sex difference in right upper arm length is 0.44 cm at age interval 10.51-11.00 where 25.21 cm for males and 24.77 cm for females with SD 1.63 cm and 1.26 cm, respectively, the maximum sex difference in left upper arm length is 0.44 cm at age interval 10.51-11.00 where 25.22 cm for males and 24.78 cm for females with SD 1.61 cm and 1.29 cm, respectively. This implies at this age interval growth velocity for males are comparatively larger than females but growth of females in left and right upper arm length are more consistent than males. It is mentionable that not only this interval but also other age intervals, growth of females in left and right upper arm length is more consistent than males. It is evident that there has no difference between left and right upper arm length (figures 5.1.11c and 5.1.11d). These figures indicate that increment of left and right upper arm length is closely related for both males and females. The maximum difference among left and right upper arm length is 0.07 cm for males and 0.05 cm for females. Though the sex difference in upper arm length is found but it is statistically not significant.

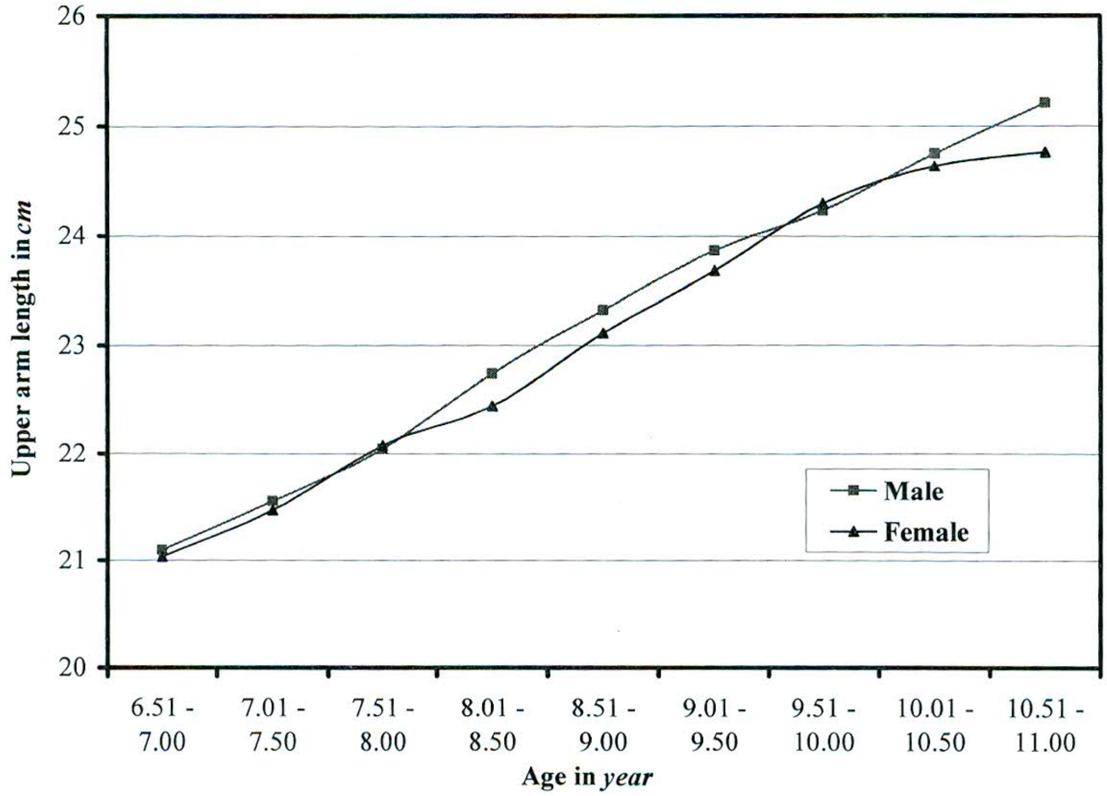


Figure 5.1.10a: Upper arm length (right) of males and females

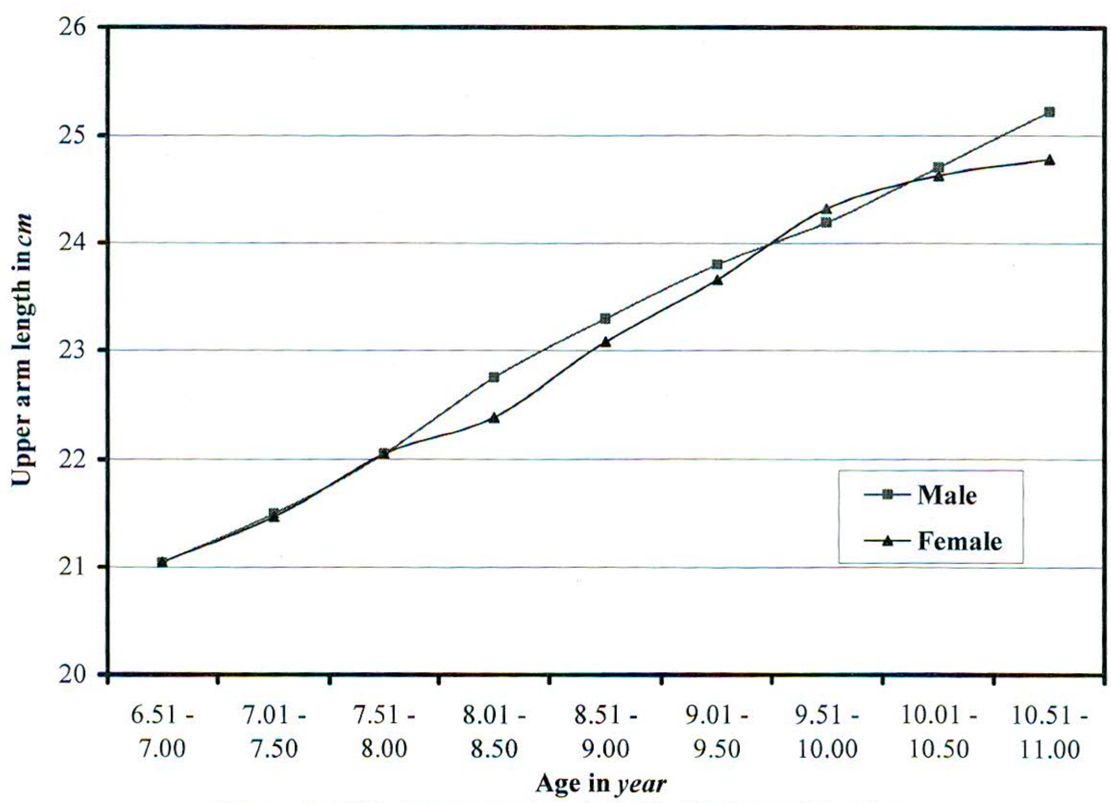


Figure 5.1.10b: Upper arm length (left) of males and females

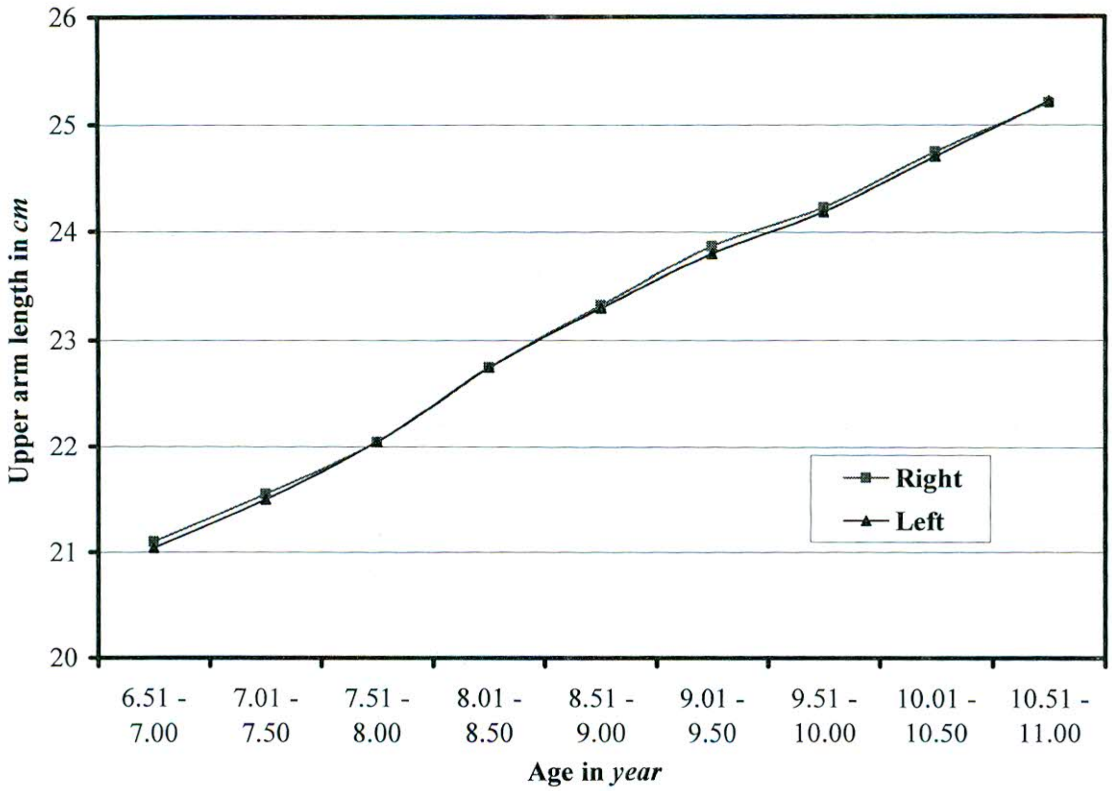


Figure 5.1.10c : Rigth and left upper arm length of males

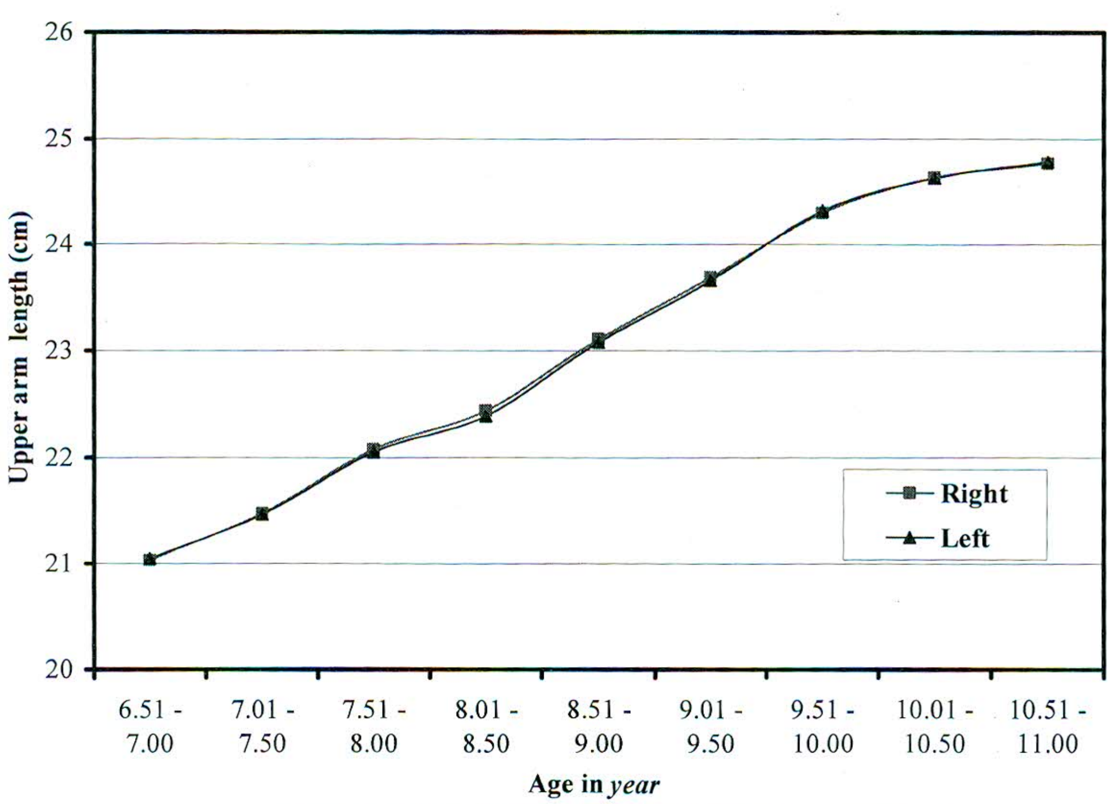


Figure 5.1.10d: Right and left upper arm length of females

Growth Allometry of Upper Arm Length

Growth allometry of upper arm length with respect to stature is given below:

Right upper arm length $= 0.058(Stature)^{1.233}$, for males

Right upper arm length $= 0.093(Stature)^{1.135}$, for females

Left upper arm length $= 0.059(Stature)^{1.231}$, for males

Left upper arm length $= 0.088(Stature)^{1.145}$, for females

Right upper arm length $= 0.074(Stature)^{1.184}$, for urban males

Right upper arm length $= 0.135(Stature)^{1.059}$, for urban females

Left upper arm length $= 0.070(Stature)^{1.194}$, for urban males

Left upper arm length $= 0.129(Stature)^{1.068}$, for urban females

Right upper arm length $= 0.053(Stature)^{1.251}$, for rural males

Right upper arm length $= 0.071(Stature)^{1.189}$, for rural females

Left upper arm length $= 0.055(Stature)^{1.243}$, for rural males

Left upper arm length $= 0.068(Stature)^{1.200}$, for rural females

Above allometric coefficients indicate that for both males and females' growth of upper arm length (right and left) with respect to stature is positively allometric but growth of urban females in upper arm length (right and left) is isometry with respect to stature. This implies growth rate of upper arm lengths of urban females is same proportion with stature but growth rate of upper arm lengths of urban males, rural males and females is greater than growth rate of stature. The results also indicate that the slope of males for both urban and rural is greater than females, which means upper arm length of males is greater than females.

5.1.11: Tibia Length

The Longitudinal data on tibia length (left and right) of males and female are shown in figure 5.1.11a for right tibia length and figure 5.2.11b for left tibia length. At age interval 6.51-7.00 years, tibia length (right) of males are found 25.85 cm on an average with SD 2.15 cm, while 25.81 cm and 1.71 cm in order for females, tibia length (left) of males are found 25.77 cm on an average with SD 2.23 cm, while 25.87 cm and 1.96 cm in order for females . This implies at this point tibia lengths (right) are not different for males and females but tibia length (left) of females is slight higher than males. These figures also indicate, from age interval 6.51-7.00 to 10.01-10.50 years, tibia length (right and left) of females is higher in few than males but after age interval 10.01-10.50, an increasing tendency is present for males. At the age of 11 years, males superseded females by 0.49 cm in right tibia length and 0.55 cm in left tibia length, where right and left tibia length of females are 30.36 cm and 30.32 cm, right and left tibia length of males are 30.85 cm and 30.87 cm, respectively. It is found that there has slight difference between male's and female's growth in left and right tibia length (figures 5.1.11c and 5.1.11d). These figures indicate that increment of left and right tibia length is closely related for both males and females. The maximum difference among left and right tibia length is 0.25 cm for males and 0.08 cm for females but the sex difference in tibia length and the difference of left and right tibia length for both males and females are statistically not significant.

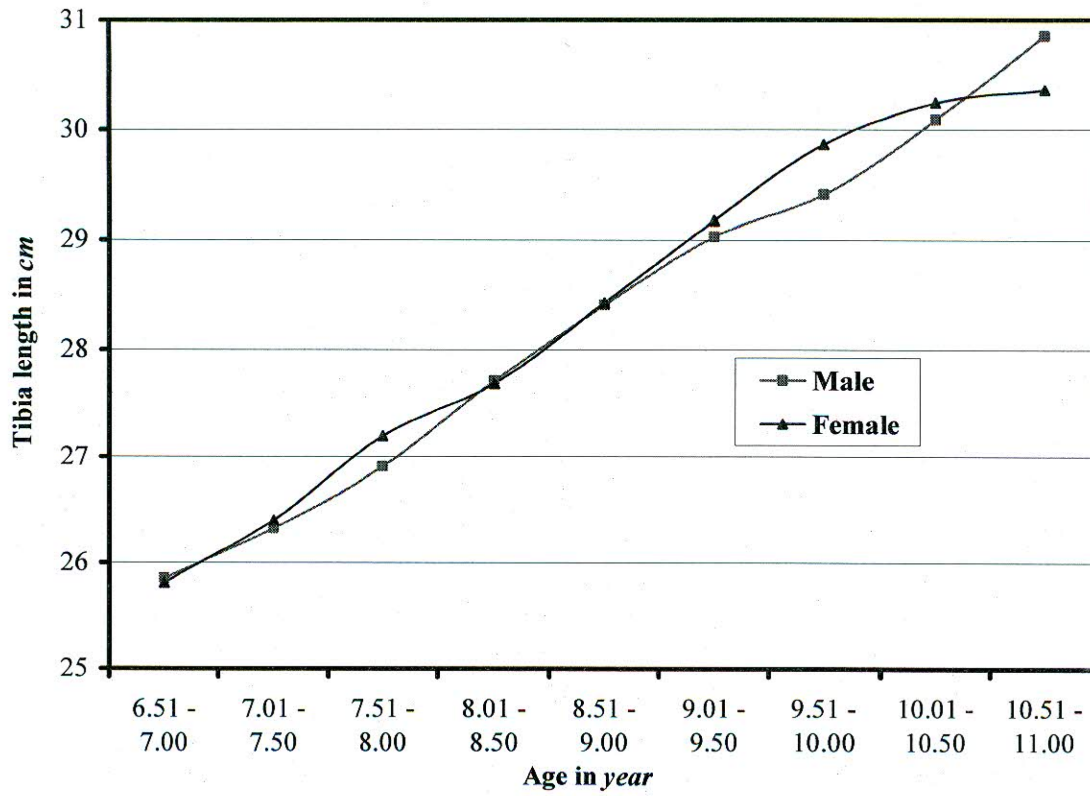


Figure 5.1.11a: Tibia length (right) of males and females

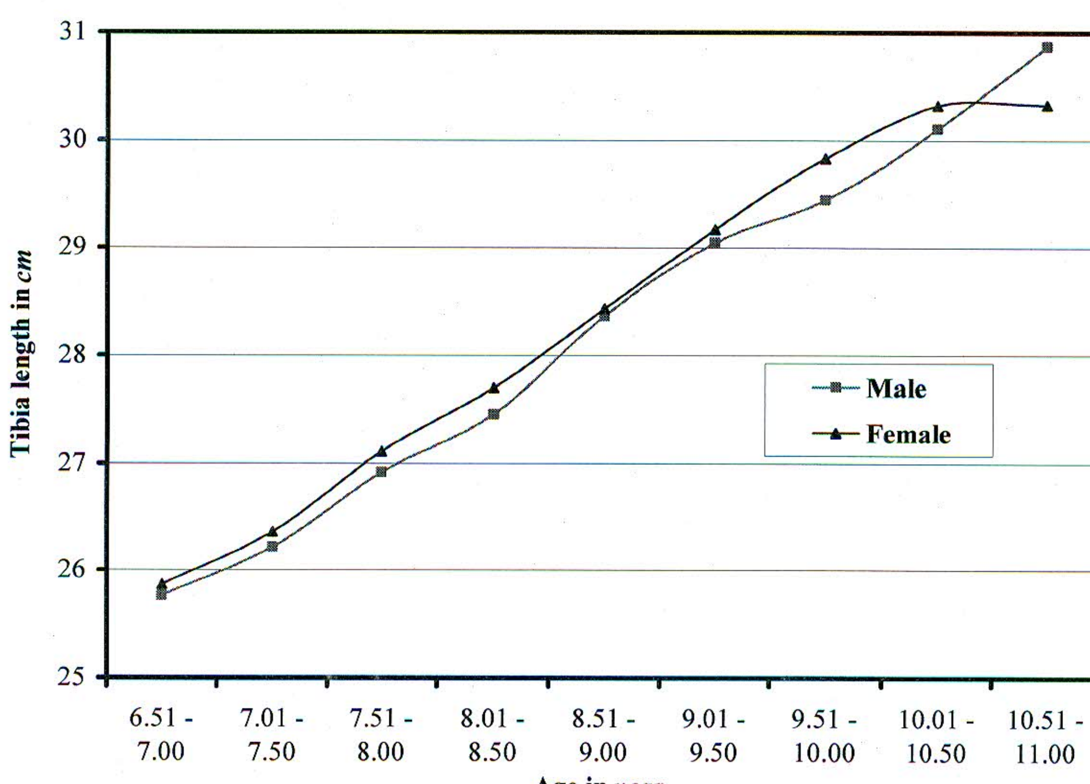


Figure 5.1.11b: Tibia length (left) of males and females

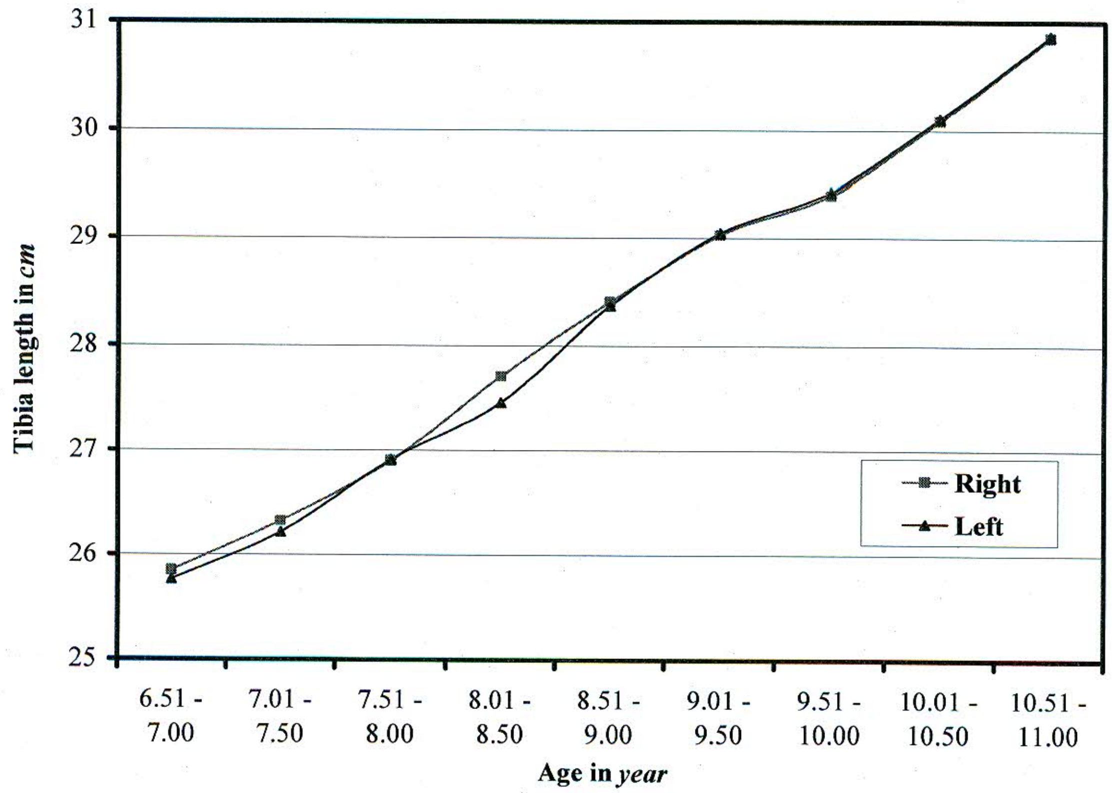


Figure 5.1.11c : Rigth and left tibia length of males

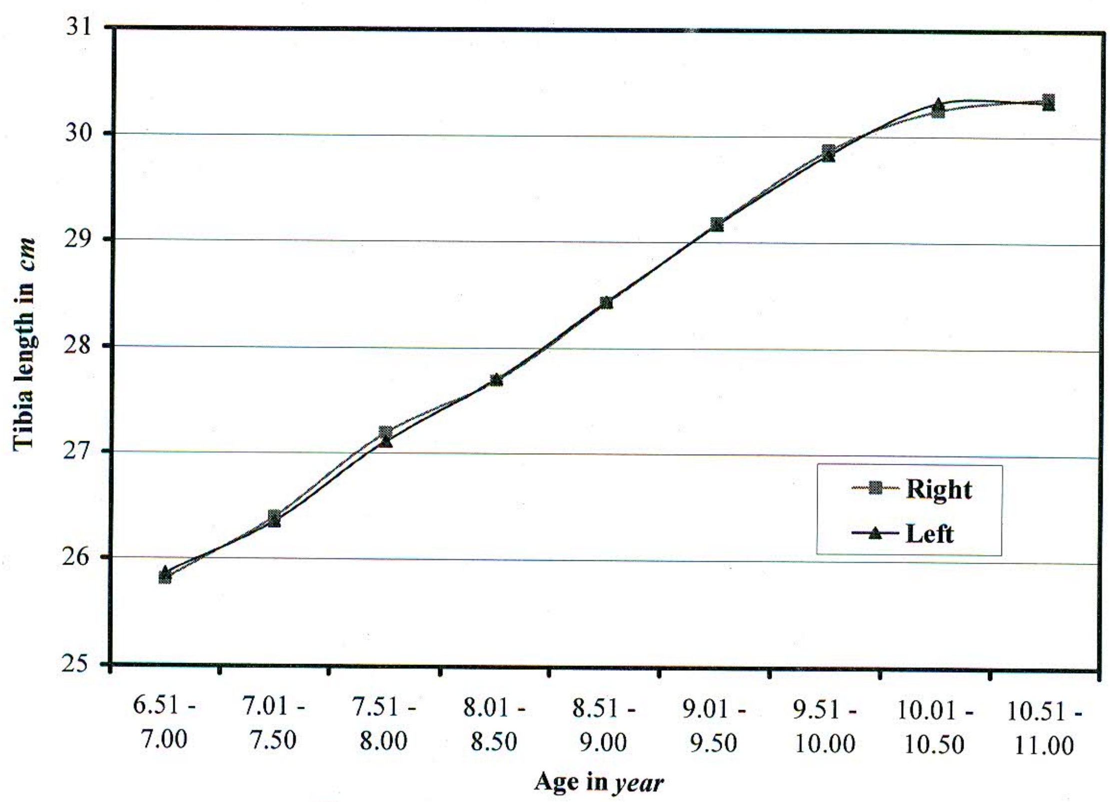


Figure 5.1.11d: Right and left tibia length of females

Growth Allometry of Tibia Length

Growth allometry of tibia length with respect to stature is given below:

$Right\ tibia\ length = 0.066(Stature)^{1.247}$, for males

$Right\ tibia\ length = 0.086(Stature)^{1.193}$, for females

$Left\ tibia\ length = 0.056(Stature)^{1.282}$, for males

$Left\ tibia\ length = 0.080(Stature)^{1.208}$, for females

$Right\ tibia\ length = 0.064(Stature)^{1.252}$, for urban males

$Right\ tibia\ length = 0.088(Stature)^{1.189}$, for urban females

$Left\ tibia\ length = 0.049(Stature)^{1.308}$, for urban males

$Left\ tibia\ length = 0.091(Stature)^{1.182}$, for urban females

$Right\ tibia\ length = 0.066(Stature)^{1.248}$, for rural males

$Right\ tibia\ length = 0.084(Stature)^{1.197}$, for rural females

$Left\ tibia\ length = 0.057(Stature)^{1.277}$, for rural males

$Left\ tibia\ length = 0.077(Stature)^{1.233}$, for rural females

It is found that for both males and females' growth of tibia length (right and left) with respect to stature is positively allometric. This implies growth rate of tibia lengths of males is greater than growth rate of their stature. The results also indicate that the slope of males for both urban and rural is greater than females, which means tibia length of males is greater than females.

5.1.12: Upper Arm Circumference

Age specific upper arm circumference (left & right) of males and females are shown in figure 5.1.12a for right upper arm circumference and figure 5.1.12b for left upper arm circumference. It is found that at age interval 6.51–10.50, right and left upper arm circumference of females is greater than males but after age interval 10.51-11.00, a decreasing diversity is present for females in right and left upper arm circumference. There might be some causes, either environmental or financial or genetically or psychological or social, demand further investigation over the issue. The maximum difference in right upper arm circumference is observed to be 1.08 cm, 15.86 cm for males and 16.94 cm for females with standard deviations 1.34 cm and 2.57 cm, respectively. The maximum sex difference in left upper arm circumference is observed to be 1.24 cm, 15.68 cm for males and 16.92 cm for females with standard deviations 1.24 cm and 2.70 cm, respectively. This implies growth velocity for females are comparatively larger than males, but growth of males are more consistent than females in left and right upper arm circumference. It is mentionable that sex difference in left and right upper arm circumference is found but it is statistically insignificant. It is observed that increment of right upper arm circumference is slight higher than left for both males and females (figures 5.1.12c and 5.1.12d) but the differences among left and right upper arm circumference is not statistically significant.

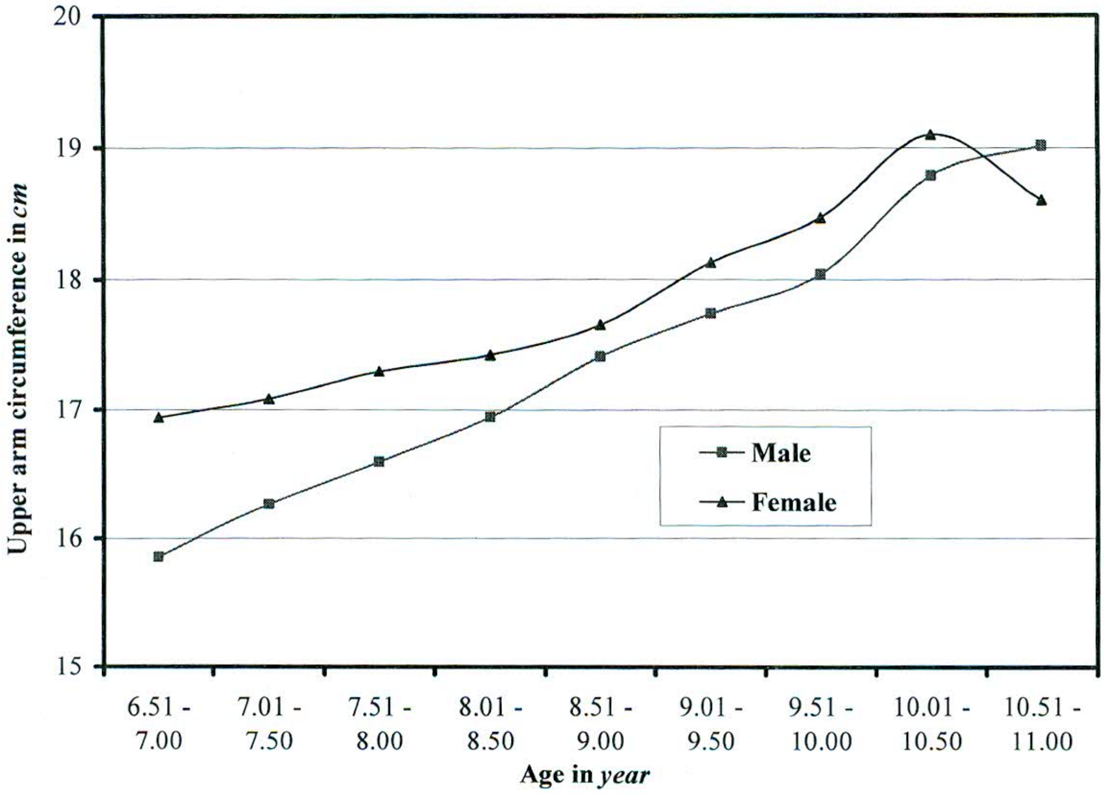


Figure 5.1.12a: Upper arm circumference (right) of males and females

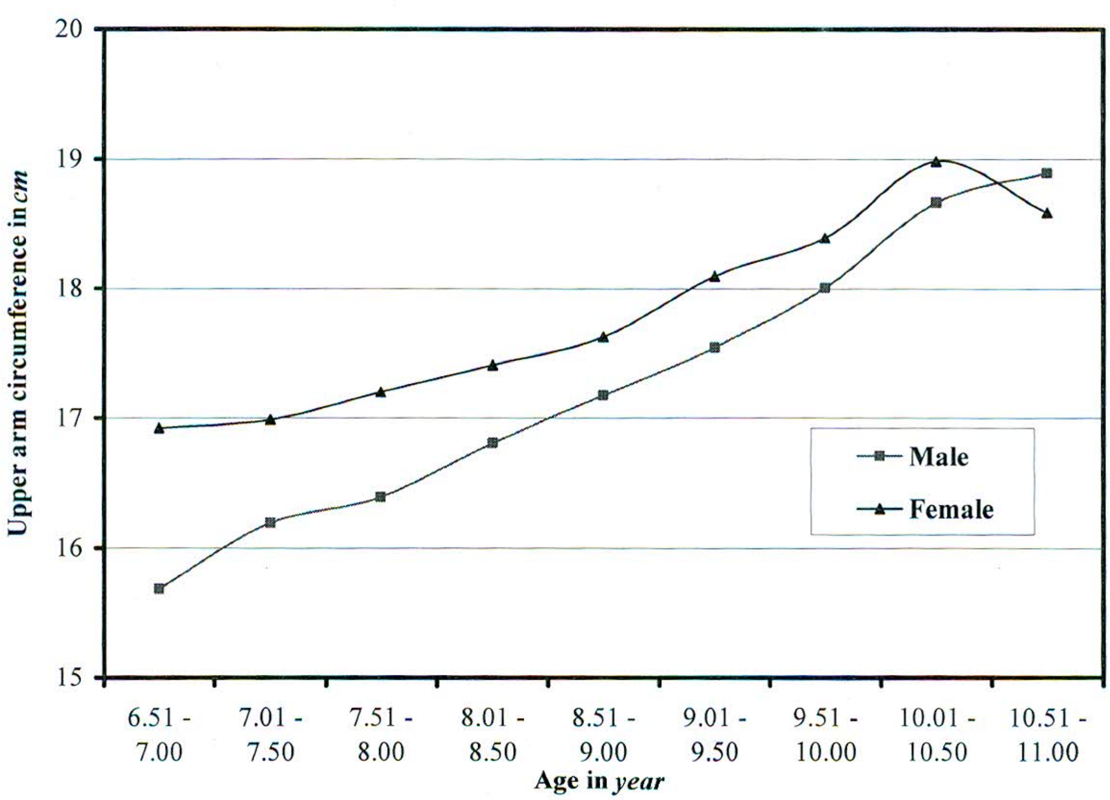


Figure 5.1.12b: Uupper arm circumference (left) of males and females

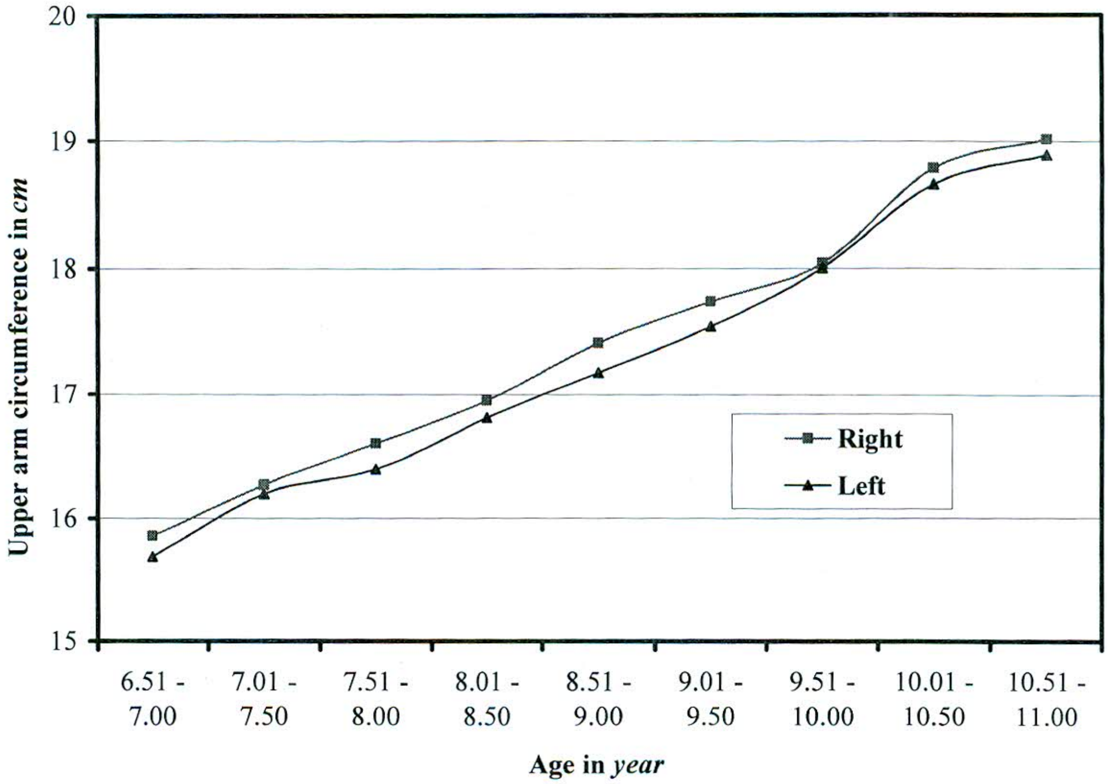


Figure 5.1.12c : Rigth and left upper arm circumference of males

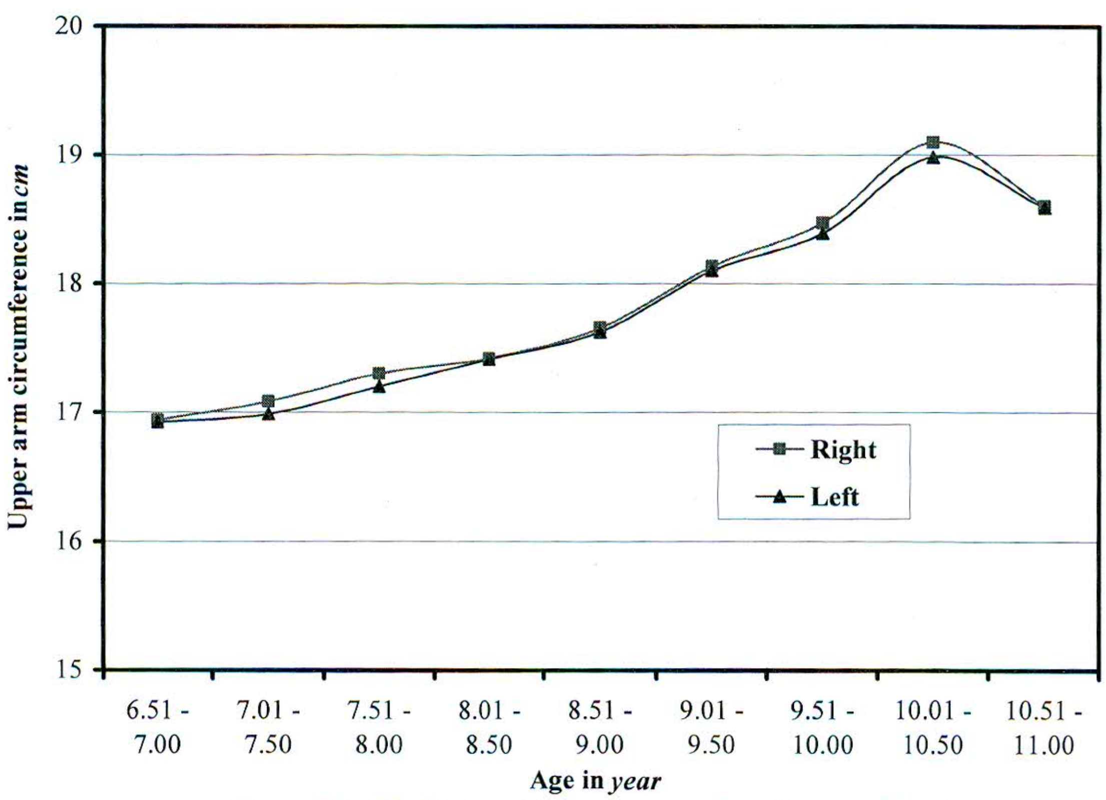


Figure 5.1.12d: Right and left upper arm circumference of females

Growth Allometry of Upper Arm Circumference

Growth allometry of upper arm circumference with respect to stature is given below:

Right upper arm circumference = 0.035(Stature)$^{1.275}$, for males

Right upper arm circumference = 0.0470(Stature)$^{1.223}$, for females

Left upper arm circumference = 0.038(Stature)$^{1.262}$, for males

Left upper arm circumference = 0.044(Stature)$^{1.236}$, for females

Right upper arm circumference = 0.007(Stature)$^{1.630}$, for urban males

Right upper arm circumference = 0.026(Stature)$^{1.353}$, for urban females

Left upper arm circumference = 0.007(Stature)$^{1.611}$, for urban males

Left upper arm circumference = 0.028(Stature)$^{1.334}$, for urban females

Right upper arm circumference = 0.090(Stature)$^{1.079}$, for rural males

Right upper arm circumference = 0.171(Stature)$^{0.949}$, for rural females

Left upper arm circumference = 0.095(Stature)$^{1.065}$, for rural males

Left upper arm circumference = 0.147(Stature)$^{0.980}$, for rural females

Above allometric coefficients indicate that for overall males and females' growth of upper arm circumference (right and left) with respect to stature is positively allometric but growth of rural males in upper arm circumference (right and left) is isometry with respect to stature and growth of rural females is negative allometry. This implies growth rate of upper arm circumferences of rural males is same proportion with stature but growth rate of upper arm circumferences of rural females is less than growth rate of their stature. The results also indicate that the slope of males for both urban and rural is greater than females, which means upper arm circumference of males is greater than females.

5.2: Longitudinal Growth Study with Percentile Chart

Seven percentile values 5th, 10th, 25th, 50th, 75th, 90th and 95th for stature, weight, sitting height, leg length, chest circumference, head length, head breadth and head circumference of Bangladeshi school going males and females from 6-12 years of age were calculated using the software SPSS and percentile charts are constructed. Each percentile value was smoothed by a cubic spline function. Actually, the percentile curves of stature, sitting height, leg length, head length and head circumference are originally rather smooth with little fluctuations.

5.2.1: Growth of Stature

Growth percentile chart of stature is shown in figure 5.2.1a for males and 5.2.1b for females. These figures indicate that within the age of 7-11 years, growth in stature is more or less uniform for both males and females but an increasing diversity is observed in the growth of stature of males for age below 7 years and after 11 years, and for females of age below 7 years. At the age of 7 years stature of male's lies between 111.00 cm to 129.65 cm, at age of 11 years stature lies between 127.46 cm and 152.56 cm and at age of 12 years stature lies between 130.40 cm and 153.40 cm. At the age of 7 years stature of females' lies between 109.88 cm and 130.30 cm and at age of 11 years stature lies between 126.27 cm and 147.40 cm that range in height of males at 7 years, 11 years and 12 years are different but range in height of females at 7 years and 11 years are not different. The 50th percentile curve shows at age 7 years, mean height of males is 120.80 cm and that of females is 120.50 cm and at age 11 years, it is 138.00 cm for males, 138.38 cm for females, they are so close but minimum height of males and females at age 7years is 111.00 cm and 109.88 cm, respectively. On the other hand maximum height of males and females at age 11 years is 152.56 cm and 147.40 cm. So males are taller than females and growth of males is greater than females.

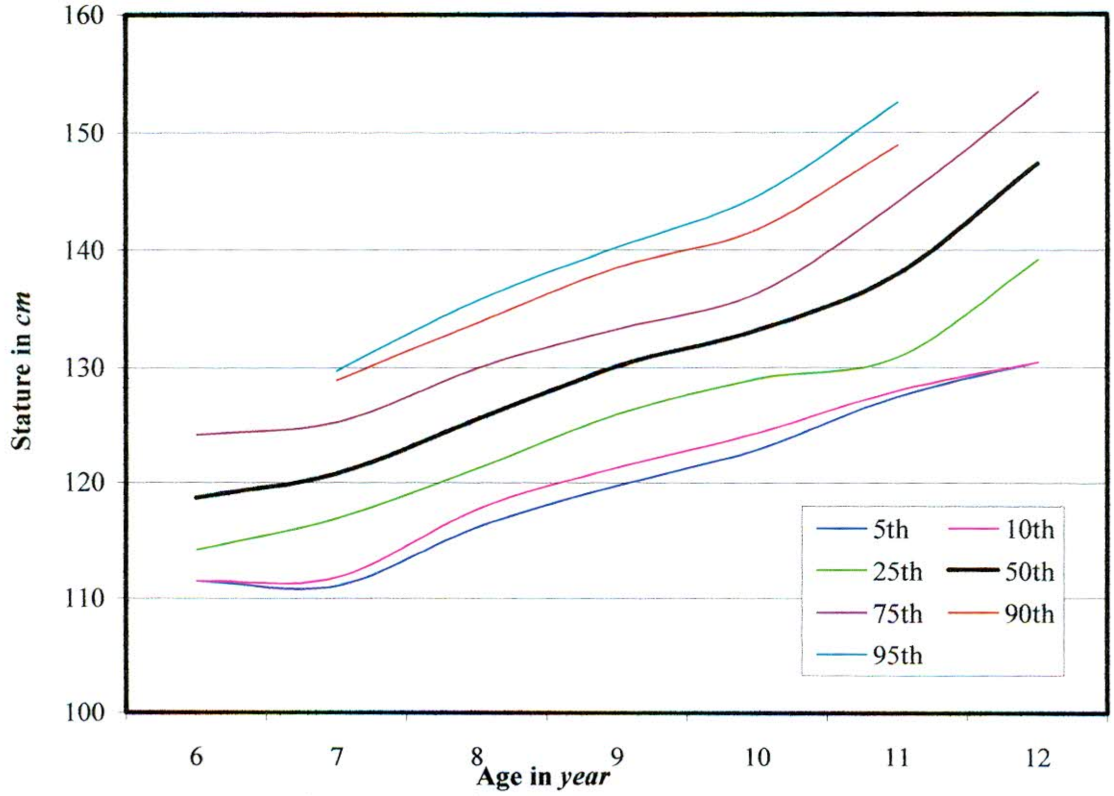


Figure 5.2.1a : Stature percentile chart of males

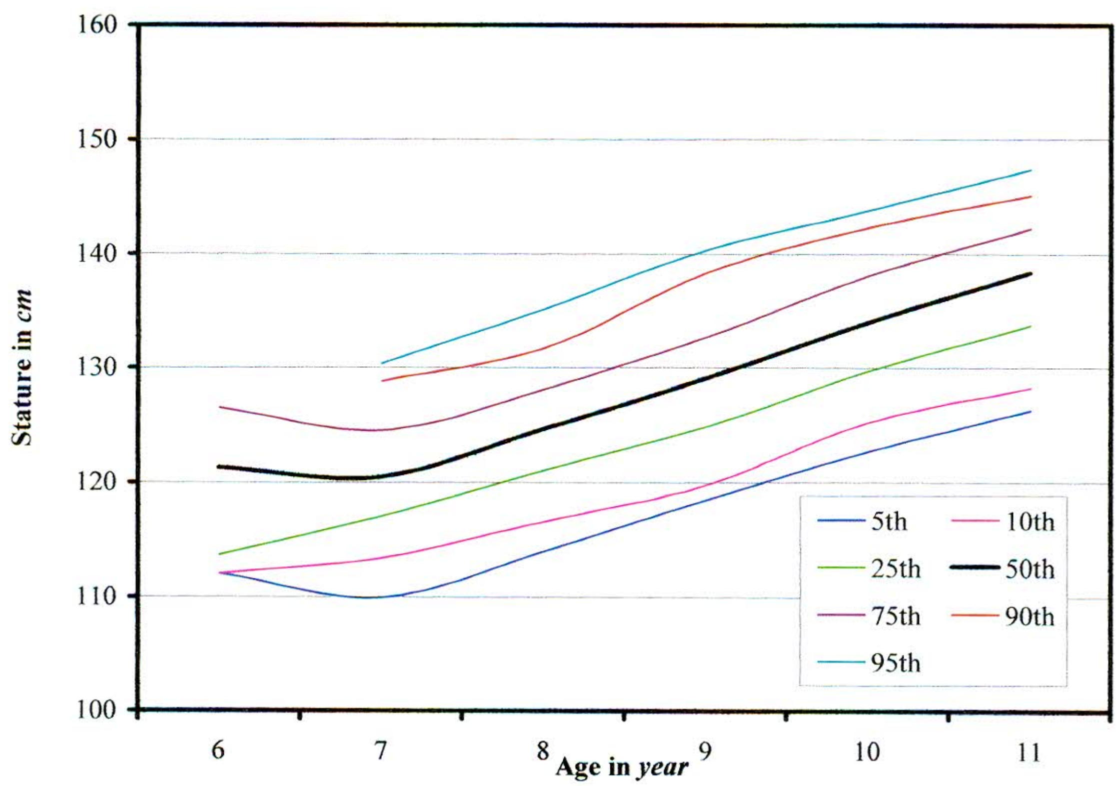


Figure 5.2.1b: Stature percentile chart of females

5.2.2: Growth of Weight

Percentile chart of weight of males and females is shown in figure 5.2.2a for males and 5.2.2b for females. These figures indicate that within the age of 7-10 years, growth in weight is more or less uniform for both males and females but an increasing diversity is observed in the growth of stature of males for age of below 7 years and after 10 years, and for females of age below 7 years. At the age of 7 years, weight of male lies between 15.125 kg and 27.625 kg, at age of 10 years weight lies between 20.70 kg and 39.80 kg and at age of 12 years weight lies between 27 kg and 43.125 kg. At the age of 7 years weight of females lies between 16 kg and 34.75 kg and at age 10 years, weight lies between 20.73 kg and 41.55 kg, this implies range of weight of males at 7 years, 10 years and 12 years are different but range of weight of females at 7 years and 10 years are not different. These figures indicate that weight of females is smoother than males. The 50th percentile curve shows at age 7 years, weight of males is 20.60 kg and female is 20 kg and at age 11 years, males is 26.5 kg and females is 30 kg, their are so different but minimum weight of males and females at age 7 years is 15.25 kg and 16 kg, respectively. On the other hand maximum weight of males and females at age 11 years is 46.85 kg and 44.45 kg, respectively. So weight of males is greater than females at age of 11 years which means growth of males in weight is greater than females for a few.

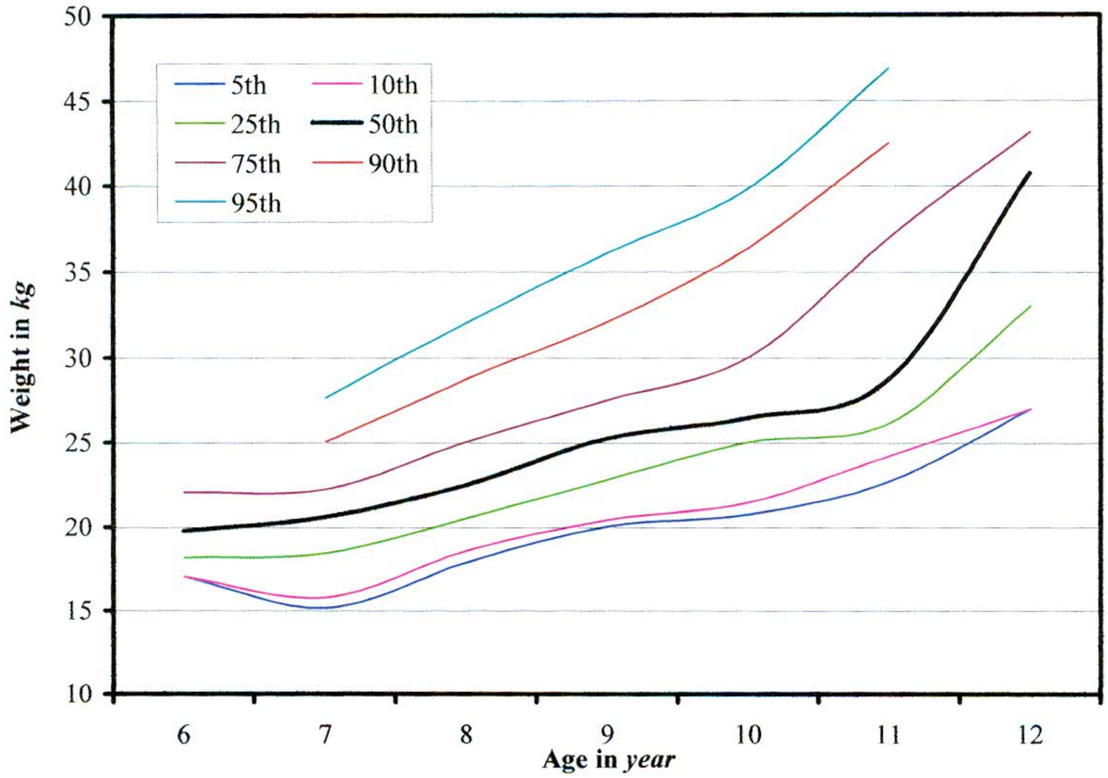


Figure 5.2.2a: Weight percentile chart of males

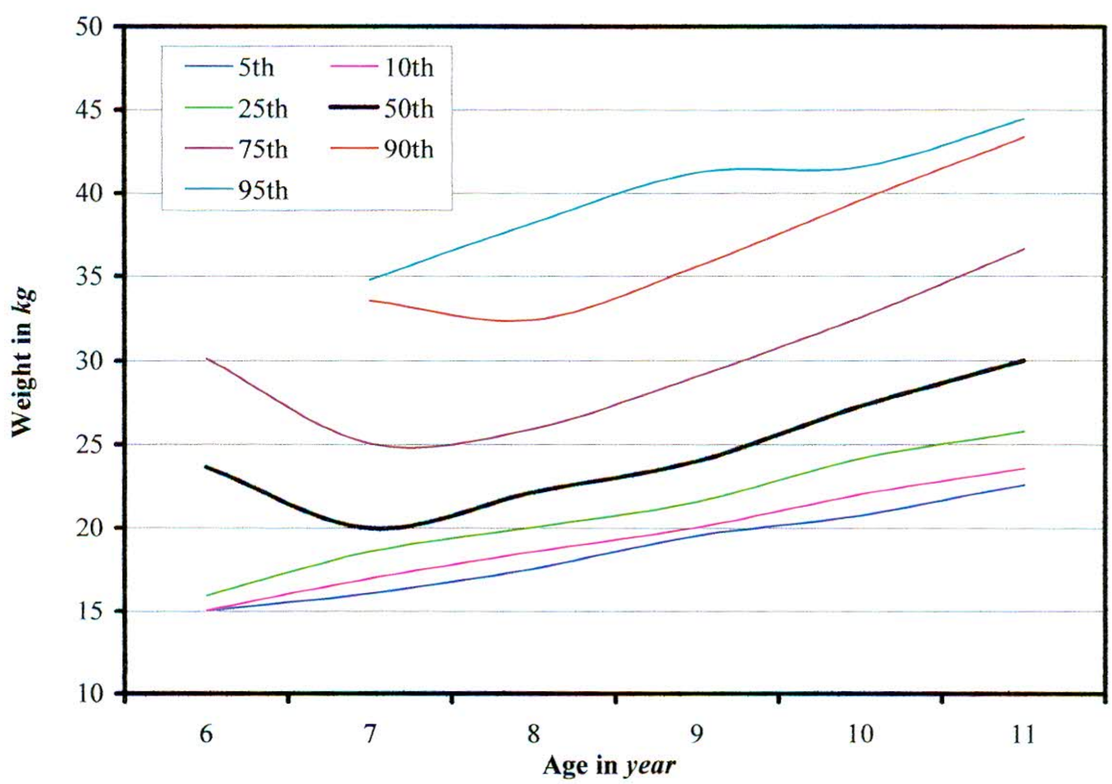


Figure 5.2.2b: Weight percentile chart of females

5.2.3: Growth of Sitting Height

Growth percentile chart of sitting height of males and females are shown in figure 5.2.3a and the figure 5.2.3b, respectively. An observation of the figures indicate that within the age of 7-10 years, growth of sitting height of males and females is more or less uniform but an increasing diversity is observed in the growth of sitting height of males for age of below 7 years and after 10 years, and for females of age below 7 years. It is found that after 10 years of age growth rate of sitting height in 50^{th} and 75^{th} percentile for males is higher than 6-10 years of age. On the other hand age of 7-11 years, growth of females in sitting height is so smooth. At the age of 7 years, sitting height of males lies between 60.00 cm and 68.00 cm, at age of 10 years it lies between 65.00 cm and 74.00 cm, and at age of 12 years sitting height lies between 67.30 cm and 79.15 cm. At the age of 7 years sitting height of female's lies between 58.50 cm and 69.88 cm, and at age of 10 years, it lies between 63.84 cm and 76.93 cm which means range of males sitting height at 7 years and 10 years are not so different but at age of 12 years are different. It is also found that range of female's sitting height between at 7 years and 10 years has a littlie difference. After that growth of females in sitting height is smoother than males. After 7 years of age for both males and females the 25^{th}, 50^{th} and 75^{th} percentile curve is growing up smooth. It is mentionable that 5^{th} and 10^{th} percentile curve are coincided at 6 years of age for both males and females again 11 years for females, 12 years for males.

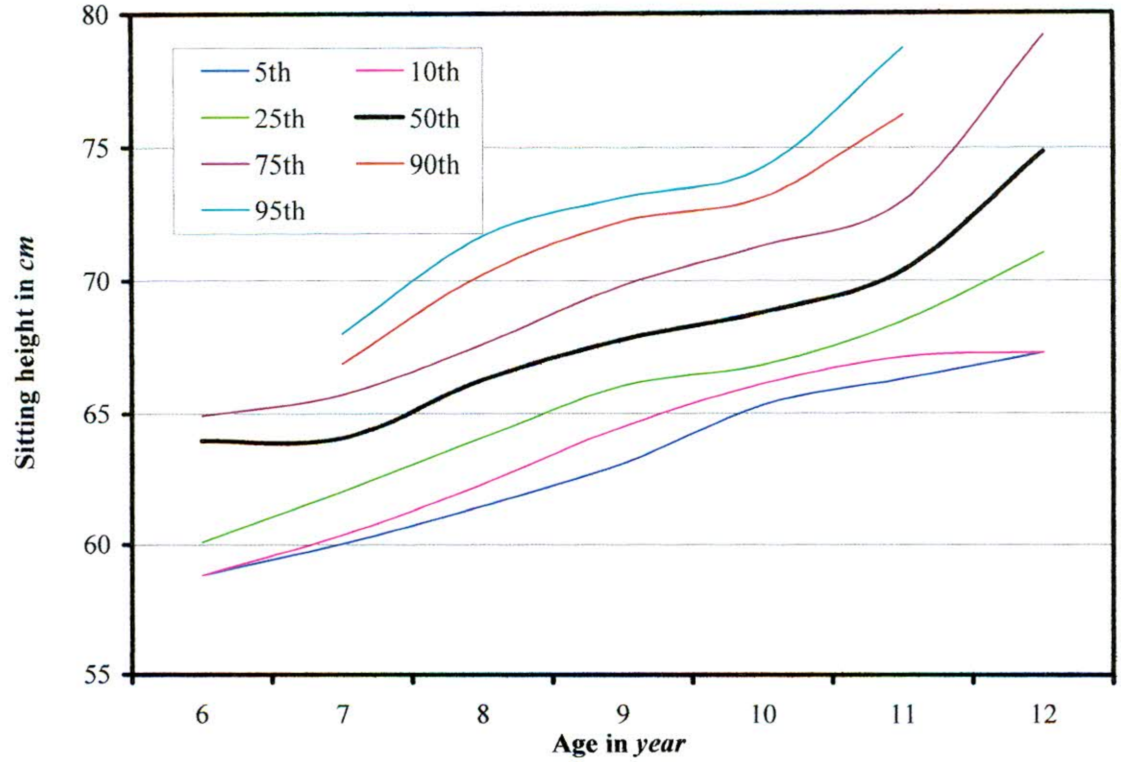


Figure 5.2.3a : Sitting height percentile chart of males

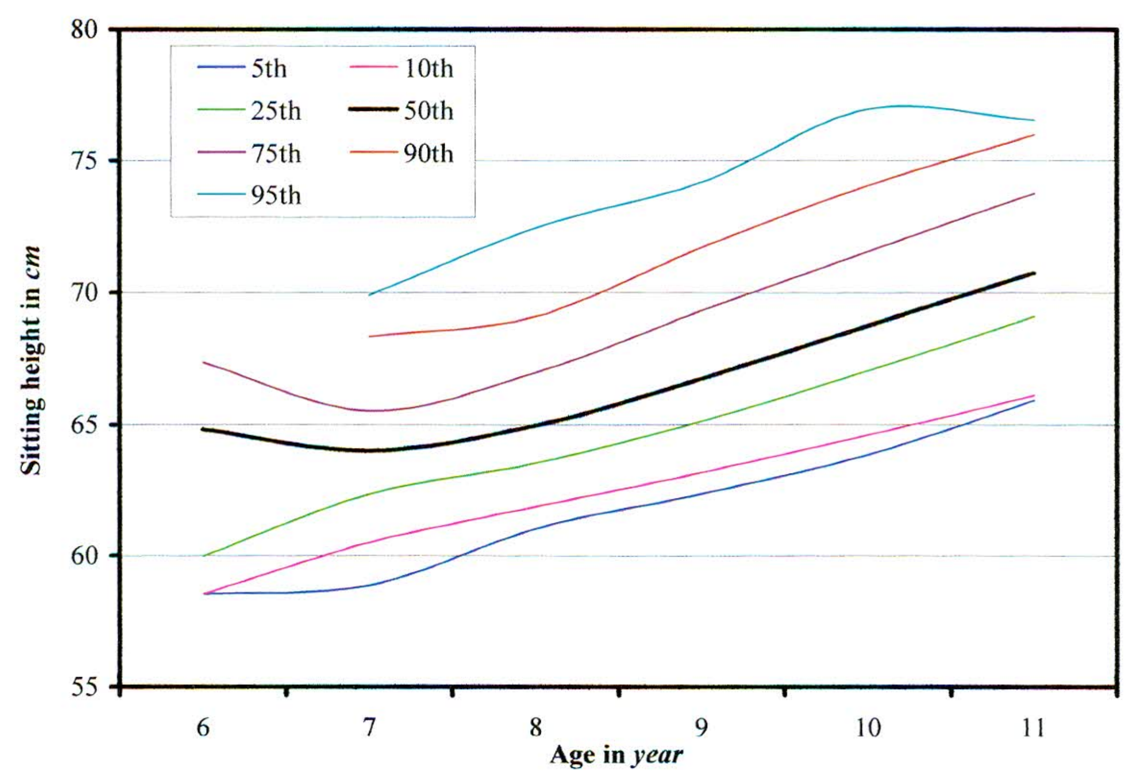


Figure 5.2.3b: Sitting height percentile chart of females

5.2.4: Growth of Leg Length

Growth chart of leg length of males and females are shown in figures 5.2.4a and 5.2.4b, respectively. These figures indicate that within the age of 7-11 years, growth of leg length of both males and females is more or less uniform but an increasing diversity is observed in the growth of leg length of males for age below 7 years and after 11 years, and for females of age below 7 years. It is evident that after 11 years of age, growth rate in leg length for males is higher than 6-11 years of age. On the other hand age of 7-11 years the growth of females in leg length is so smooth but below 7 years of age the growth of females is decreasing order in 5^{th}, 10^{th} and 75^{th} percentile but 25^{th} and 50^{th} percentile curve is growing up smoothly from 6 to 11 years of age. 25^{th}, 50^{th} and 75^{th} percentile curves are increased in parallel from 7 to 12 years of age for males. It is mentionable that 5^{th} and 10^{th} percentile curve are coincided at 6 years of age for both males and females again 12 years for males. At the age of 6 years, leg length of male's lies between 51.60 cm and 59.20 cm, at age of 11 years it lies between 59.98 cm and 75.45 cm, and at age of 12 years leg length lies between 63.10 cm and 75.05 cm. At the age 6 years leg length of females lies between 53.50 cm and 60.45 cm, and at age 11 years, it lies between 60.17 cm and 72.03 cm which means range of male's leg length at 6 years and 11 years are different. These figures also indicate range of females sitting height between 7 years and 10 years are also different from males. After all the growth of males and females in leg length is smooth from 7-11 years of age but minimum leg length of males and females at age 7 years is 50.40 cm and 50.30 cm, respectively. On the other hand maximum leg length of males and females at age 11 years is 75.45 cm and 72.03 cm. So growth of males in leg length is greater than females.

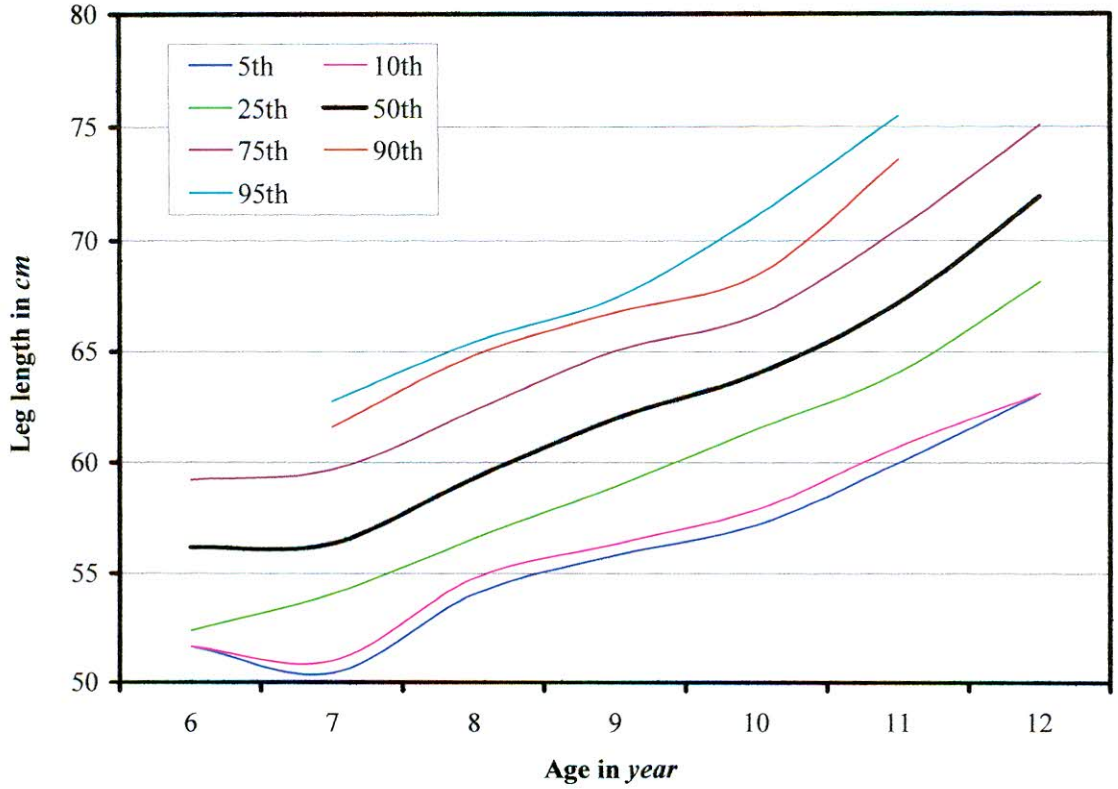


Figure 5.2.4a: Leg length percentile chart of males

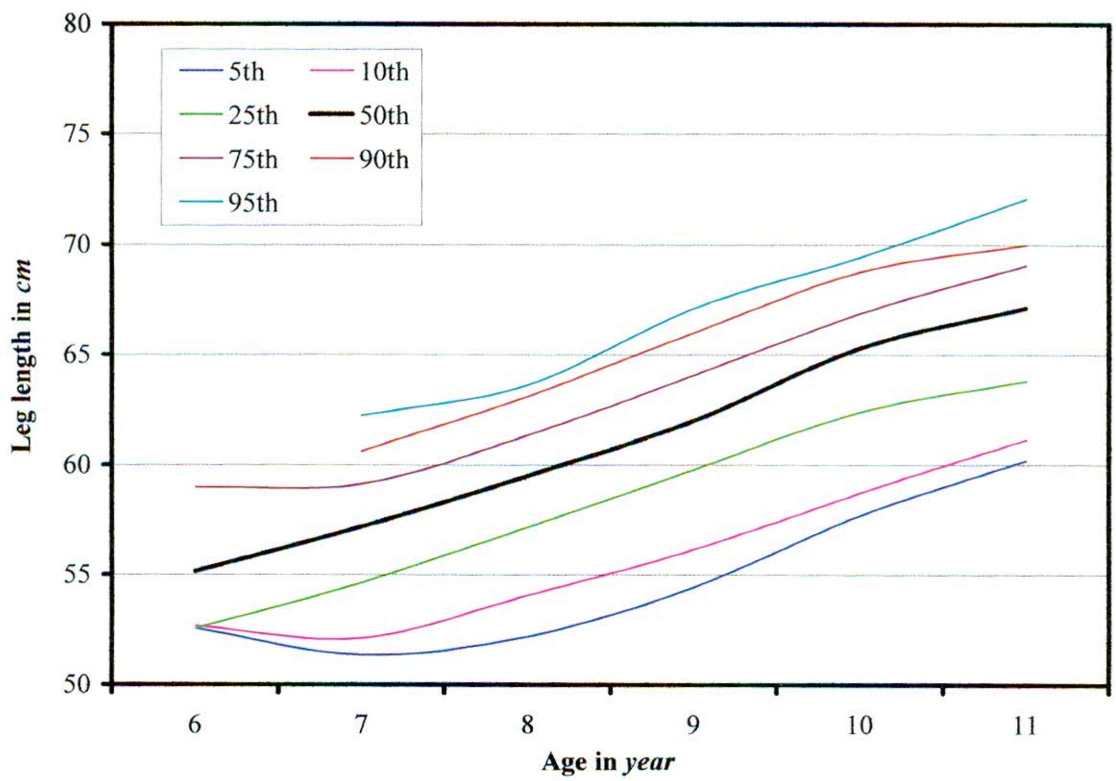


Figure 5.2.4b: Leg length percentile chart of females

5.2.5: Chest Circumference

Growth chart of chest circumference of males and females are shown in figures 5.2.5a and 5.2.5b, respectively. At age 6 years it is observed for 50th percentile about 57.65 cm with the maximum of 60.125 cm and minimum of 52.5 cm for males. The corresponding values for females are 55.60 cm, 66.80 cm and 54.13 cm. At the age of 11 years, it is observed for 50th percentile about 66.17 cm while the maximum 73.04 cm and minimum of 55.68 cm for males. The corresponding values for females are 62.15 cm, 76.23 cm and 54.57 cm, respectively. It is found that growth of females is similar for 5th, 10th, 25th, 50th, 75th and 95th percentile but the 75th and 90th percentile for females is different than other percentile values. At age of 6 years 75th percentile for females is 66.08 cm, at age 7 years these value is 61.50 cm, at age 7 years it is 62.35 cm and at age of 10 years that value is 65.83 cm. There might be some causes, either genetically or social or psychological or environmental, demand further investigation over this issue. At the lower 50th percentiles, a drift of decrease in growth is measured for males during the age of 10-11 years, but after the age of 11 years the growth in chest circumference is highly increasing than 6-11 years of age. The overall growth in chest circumference is observed to be faster for males than females.

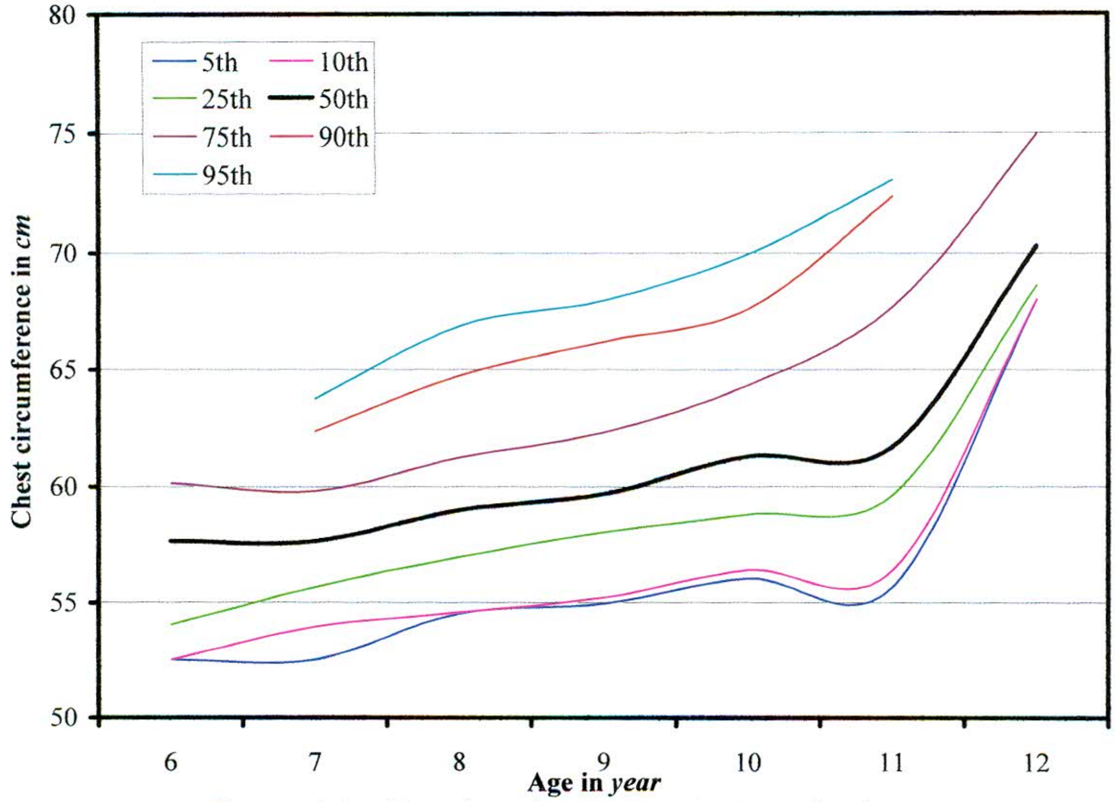


Figure 5.2.5a: Chest circumference percentile chart of males

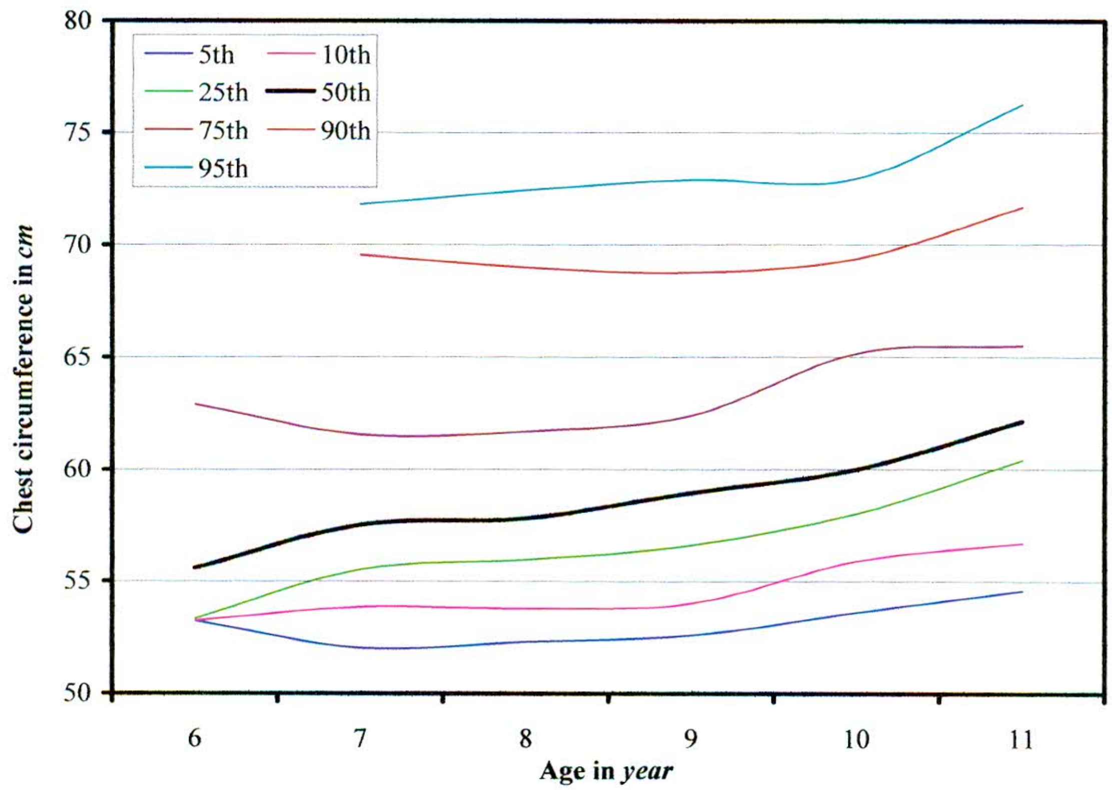


Figure 5.2.5b: Chest circumference percentile chart of females

5.2.6: Head Circumference

Head circumference percentile chart of males and females are shown in figures 5.2.6a and 5.2.6b, respectively. At age 6 years it is observed for 50^{th} percentile about 48.85 cm with the maximum of 49.65 cm and minimum of 48.00 cm for males. The corresponding values for females are 49.05 cm, 50.38 cm, and 45.0 cm. At the age of 11 years, it is observed for 50^{th} percentile about 51.05cm while the maximum of 54.905 cm and minimum of 48.45 cm for males. The corresponding values for females are 50.53 cm, 52.76 cm and 47.93 cm, respectively. These figures indicate that growth of females is similar for 5^{th}, 10^{th}, and similar for 50^{th} and 75^{th} percentile but the 25^{th} and 90^{th} percentile for females is different than other percentile values. At age 6 years and after 11 years the difference between 5^{th} and 75^{th} percentile for males is about 1.50 cm and 1.42 cm, for females these differences are 5.38 cm and 4.88 cm, respectively. The maximum difference among percentile curves for males is 6.00 cm and for females is 7.00 cm. It is also mentionable that growth of head circumference is a little amount for males and females during study period where growth of males is closely related than females.

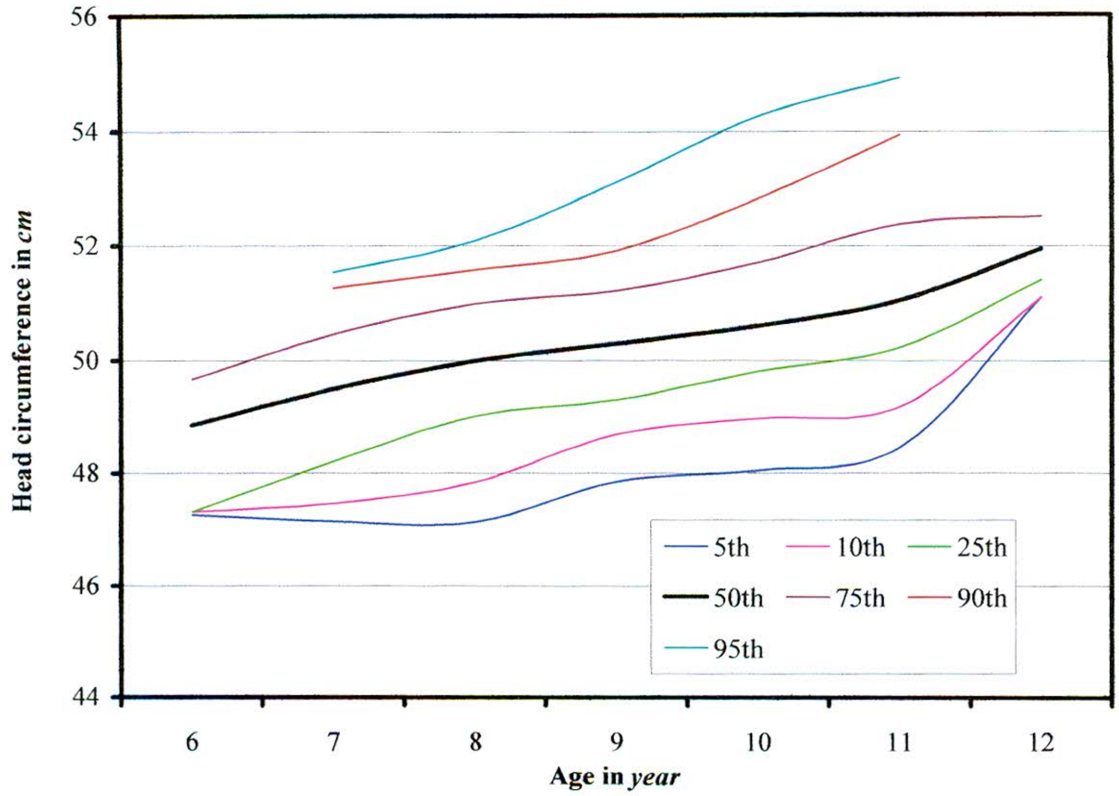


Figure 5.2.6a: Head circumference percentile chart of males

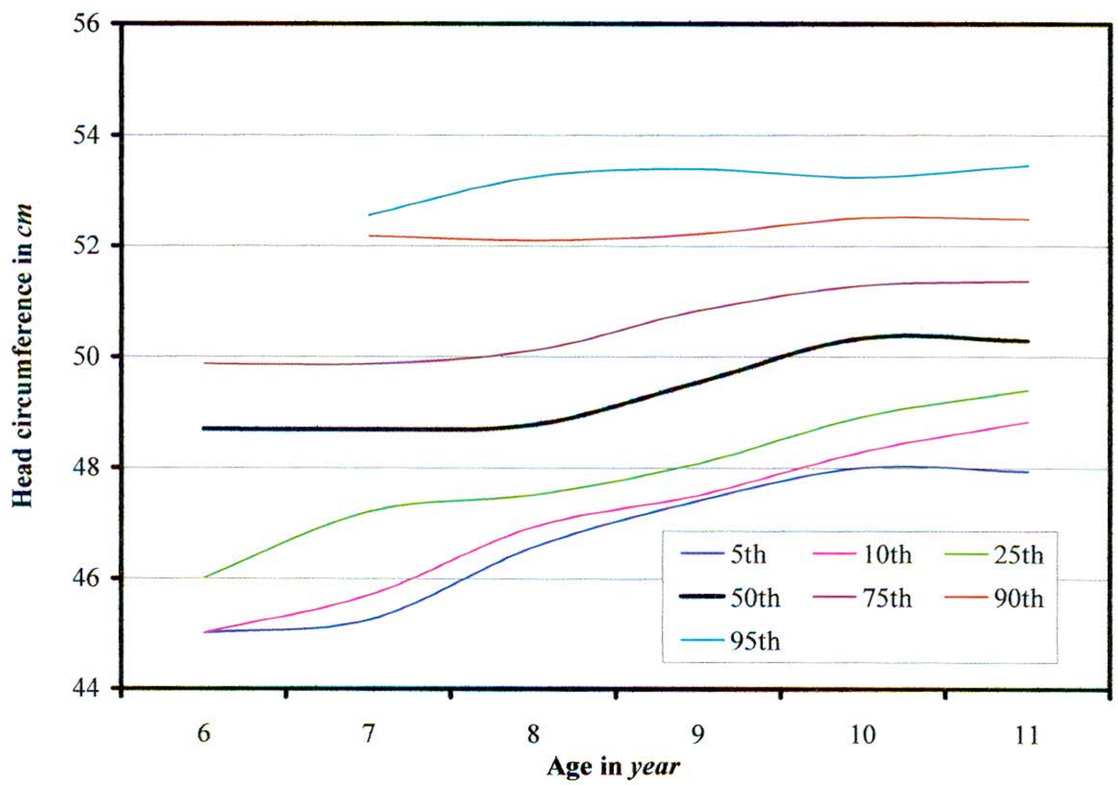


Figure 5.2.6b: Head circumference percentile chart of females

Chapter Six

Concluding Remarks

Chapter- Six

Concluding Remarks

6.1: Major Findings

Mean stature velocity for male children are comparatively larger than females, and also stature of males are more consistent than females. It is found that at age interval 7.01 - 8.00 and 9.51 – 10.00, on average, rural females are taller than rural males but for other age intervals rural males are taller than females. The maximum sex difference in stature is observed to be 3.40 cm, 138.74 cm for males and 135.34 cm for females with standard deviations 7.82 cm and 6.33 cm, respectively. This implies, mean stature velocity for males is comparatively larger than females, and also stature of male are more consistent than females in rural. Mean stature velocity for rural males is comparatively larger than that of urban males, and also statures of urban males are more consistent than rural males. The urban females are taller than rural females and their difference is significant ($p<0.05$). The urban males and females are heavier than rural males and females, and their differences is statistically significant ($p<0.05$).

Sitting height velocity for females are comparatively larger than males, and also sitting height of males are more consistent than females. Average sitting height velocity for rural males is comparatively larger than females, but males are more consistent than females. Also, the growth in sitting height of males and females in rural are closely related and their differences are not significant. The urban children are taller in sitting height than rural children and their difference is significant ($p<0.05$).

Growth of leg length of males and females has a littlie difference. Average leg length velocity for urban males is comparatively larger than females and also growth in leg length of urban males are more consistent than urban females and there was no significant difference between urban males and females. Leg length of rural males and females are closely related and there has no significant difference but an increasing diversity is present in leg length of rural males than females after age interval 10.51-11.00. The maximum regional difference in leg length is observed to be 2.04 cm, 58.68 cm for urban males and 56.64 cm for rural males with standard deviations 2.65 cm and 4.02 cm, respectively implying growth velocity for rural males are comparatively larger than urban males but growth in leg length for urban males are more consistent than rural males. Moreover there has no significant difference in leg length between rural and urban males. The maximum regional difference of females in leg length is observed to be 3.60 cm, 57.67cm for urban females and 54.07 cm for rural females. It is found that females of urban are taller than rural in leg length.

After age of 10 years, chest circumference of males is greater than females. and for the other intervals growth in chest circumference for males and females is more or less uniform and growth of males in chest circumference are more consistent than females. Sex difference in chest circumference is found to be insignificant. The chest circumference of urban males is greater than urban females but the growth difference of urban males and females in chest circumference are not significant. The chest circumference of rural males and females close to each other at age interval 6.51-9.00 years but after age 9 an increasing growth velocity is present in males while its growth in females are less than males but the growth of rural females is more consistent than rural males. The maximum regional difference of males in chest circumference is observed to be 3.68 cm and the maximum regional difference of females in chest circumference is observed to be 6.03 cm. The growth of rural females is more consistent than urban and regional differences of males and females are statistically significant ($p<0.05$).

Head length of males is greater than that of females and growth of males is more consistent than females. Average head length of urban males is greater than urban females and the sex differences in head length of urban is statistically significant ($p<0.05$). Average head length of rural males is greater than females and growth velocity of rural females in head length is greater than males but the sex differences in rural is insignificant. Regional difference for males and females in head length are statistically significant ($p<0.05$).

Average head breadth of males is greater than females. The sex differences of urban in head breadth are statistically significant ($p<0.05$). Average head breadth of rural males is greater than females but growth of rural females are consistent than rural males. Average head breadth of urban males is greater than rural males. Growth variation for rural males is comparatively larger than urban males, but growth in head breadth of urban males are more consistent than rural males. At age interval 6.51-10.00, average head breadth of urban females is greater than rural females but after age interval 9.51-10.00, an increasing diversity is found in rural females and the regional difference in head breadth of males and females are statistically significant ($p<0.05$).

Average head circumference of males is greater than that of females. Average head circumference of urban males is greater than urban females at each age intervals. The sex difference in head circumference for urban children is statistically significant ($p<0.05$). Growth pattern of rural males and females in head circumference are same but head circumferences of rural males are greater than rural females. The sex difference in rural is not significant. Regional differences in head circumference for males are statistically significant ($p<0.05$). Head circumferences for urban females are greater than rural females but growth of rural females is more consistent than urban females.

Growth of elbow-wrist length (right and left) is more or less uniform for both males and females. Elbow-wrist length (right and left) of males is greater than females for all age intervals and there has no significant difference between left and right elbow-wrist length. The sex difference in elbow-wrist length is found but it is not significant.

Growth of right upper arm length and left upper arm length is more or less uniform and closely related for both males and females. The maximum difference between left and right upper arm length is 0.07 cm for males and 0.05 cm for females. However the sex difference in upper arm length is found but not significant.

Tibia lengths (right) are not different for males and females but tibia length (left) of females is slight higher than males. There has slight sex difference but not significant in growth of left and right tibia length.

The growth velocity for females is comparatively larger than males, but growth of males are more consistent than females in upper arm circumference (right and left). The sex difference in upper arm circumference is found but it is not significant.

Growth of stature for males with respect to sitting height is positively allometric but tending to isometry, while it is negative allometry for females. This implies growth rate of stature is greater than sitting height for males but this rate of stature is smaller than sitting height for females. It also found that growth of stature with respect to sitting height for urban males and females follow negative allometry, which means growth rate of stature is smaller than that of sitting height, but for rural males and females it shows reverse situation comparative to urban. On the other hand, it is found that growth of stature with respect to leg length follows negative allometry for both males and females, which means the growth rate of stature is smaller than that of leg length.

Growth in sitting height with respect to stature for both males and females has negative allometry implying the growth rate of sitting height is smaller than that of stature. The regional slope difference in females is statistically significant ($p<0.05$).

Growth of leg length with respect to stature follows positive allometry for both males and females implying growth rate of leg length is greater than that of stature. This relationship is isometry for urban females which means growth rate of leg length and stature are the same. The slope difference between urban females and rural females is statistically significant ($p<0.05$). Growth of urban males and females in leg length are greater than rural males and females.

Growth of chest circumference with respect to stature follows negative allometry for males and females but the growth of urban females in chest circumference is isometry, which means growth rate of chest circumference and stature are the same.

Growth in head length with respect to stature follows negative allometry for males and females and regional slope difference in females is statistically significant ($p<0.05$).

Growth of head breadth with respect to stature follows negative allometry for both males and females.

Growth of head circumference with respect to stature follows negative allometry for both males and females. Allometric coefficients of urban children are greater than rural in head circumference with respect to stature.

The allometric coefficient of elbow-wrist length (right and left) with respect to stature is greater than 1 for males and females implying growth rate of elbow-wrist lengths is greater than growth rate of stature. Growth of urban children in elbow-wrist length is greater than rural children. The slope difference between urban children and rural children are statistically significant ($p<0.05$).

Growth of upper arm length (right and left) with respect to stature is positively allometric for both males and females but growth of upper arm length (right and left) with respect to stature is isometry for urban females. The slope of males (both urban and rural) in upper arm length is greater than females, which means growth of upper arm length of males is greater than that of females.

Growth of tibia length (right and left) with respect to stature is positively allometric for both males and females. And allometric coefficient of males (both urban and rural) is greater than females, which means growth of tibia length of males is greater than that of females.

Growth of upper arm circumference (right and left) with respect to stature is positive allometry for males and females but growth of upper arm circumference (right and left) with respect to stature is isometry for rural males and it is negative allometry for rural females implying growth rate of upper arm circumference and stature are the same for rural males but in rural females it is less than that of their stature. The slope of males for both urban and rural is greater than females, which means growth of upper arm circumference of males is greater than females.

6.2: Limitations of the Study

Longitudinal study is time-consuming and laborious, and it is quite difficult to observe particular subjects at regular intervals over a long period of time without any interruption. We have started our study with 117 school going children, 55 males and 62 females. At the end of study, the sample size reduced to 89, 44 males and 45 females. During the study, we have lost about 24% of the sample due to migration of the parents. To confirm the birth date of the child, it was a problem that in rural area, most of the parents did not remember. The irregularities observed in different figures were just immediate before and after this loses in sample size. This might be due to fluctuation in sample size or some other causes. This problem might be overcome with large samples. But it was lacking of finance, perfect manpower to support this study. Longitudinal growth may be affected by some other socio-economic, physiological, environmental factors.

6.3: Scope for Further Research

There are several ways to extend our present study. It is possible to find changes in head and body dimensions in other populations by applying the same techniques. For a complete growth study, longitudinal data from birth to 18 years, at least, is necessary. This study has covered only 6-12 years of age and may be extended for further research. Impact of sample size variation, that might be a cause of fluctuations and variation in the observed growth curves may be studied with large sample. Variation among the measurements of urban and rural females may be considered for further investigation. Different growth models for predicting growth patterns may be considered. Inter-correlation between calories, protein intakes, seasonality of birth, etc that influencing the growth pattern may be taken into accounts for further research. Nutritional status, reproductive health of the mother during pregnancy, total duration of pregnancy is important issues of further research on child growth.

Bibliography

Bibliography

Alberch P. (1990): Natural selection and developmental constraints: external versus internal determinants of order in nature. In: De Rousseau CJ, editor. Primate life history and evolution. New York: Wiley-Liss. p 15–35.

Ali, M.A. (2000): Secular trends in growth of the Japanese and prediction of their adult stature. D.Sc. dissertation. Tokyo Metropolitan University, Tokyo.

Ali and Ohtsuki (2000): Estimation of the Maximum Increment age in Height and Weight during Adolescence and the Effect of World War II. American Journal of Human Biology. 12: 363-370.

Ali, M.A. and Ohtsuki, F. (2001): Prediction of adult stature for Japanese population: A stepwise regression approach. Ann. J. Hum. Biol. 13: 316-322.

Ashizawa K, Konto S, and Eto M(1994): Individual Adolescent Growth of Stature, Body weight and Chest circumference of Girls in Tokyo. Anthropol. Sci. 102(4), 421-446.

Arseniy S. Karkach (2006): Trajectories and models of individual growth. Demographic research. Volume 15, article 12, pages 347-400 published 7 november 2006. Http://www.demographic-esearch.org / volumes/ vol15/12/

Bacallao, J, Molina, J.R, Izquuierdo and Castillo MM (1992): Multivariate allometry model of Morphmetric Harmony of Four Skinfolds in the Newborn. American Journal of Human Biology 4: 258-290.

Beunen G, Oystyn M, Simons j, Renson R, and Van Gerven D (1981): Chronological age and Biological age as related to physical fitness in boys 12 to 19 years. Annals of Human Biology, vol. 8, No. 4, 321-331.

Bromage TG. (1992): The ontogeny of Pan troglodytes craniofacial architectural relationships and implications for early hominids. J Hum Evol 23:235–251.

Cameron N, Gordon-Larsen P, and Wrchota EM (1994): Longitudinal Analysis of Adolescent Growth in Height, Fatness and Fat Patterning in Rural South African Black Children. American Journal of Physical Anthropology, 93:307-321.

Champy, C. (1924): Sexualite´ et hormones. Doin, Paris.

Champy, C. (1929): La croissance dysharmonique descaracte`res sexuels accessoires. Arch. sci. phys. nat.—Zoologie 193–244.

Chiaki Tanaka, Mitsunori Murata (2004): Reference charts of body proportion for Japanese girls and boys. Annals of Human Biology. Vol. 31, No. 6, 681-689

Chinn S, Rona RJ, and Price CE (1989): The secular trend in height of Primary School children in England and Scotland 1972-1979 and 1979-1986. Journal of Human Biology. Vol. 16. No. 5, 387-395.

Cole TJ and Reode MJ (1999): Centiles of body mass index for Duch ch ildren aged 0-20 years in 1980- a baseline to assess recent trends in obesity. Annals of Human Biology, vol. 26, No. 4, pp. 303-308.

Damodar N. Gujarati (1992): Basic Econometrics, third edition, McGraw-Hill International Editions.

Daroga Singh, and FS Choudhary (1986): Theory and Analysis of Samp;e Survey Designs. Wiley Eastern Limited, New Delhi.

Dhe´re´, C. and L. Lapicque. (1898): Variation des diverses parties des centres nerveuxen fonction dupoids du corps chez le chien. Comptes rendus se´-ances soc. biol. fil., 10ese´rie, vol. 5:862–862.

Dubois, E. (1897): Sur le rapport de l' ence´phale avecla grandeur du corps chez les Mammife`res. Bull. Soc. anthropol. Paris, 4e se´rie, vol. 8:337–374.

Eveleth, P.B. and Tanner, J.M. (1976): Worldwide Variation in Human Growth. Cambridge University Press, Cambridge.

Enlow DH, Hunter WS. (1970): The growth of the face in relation to the cranial base. Eur Orthod Soc Congr Rep 44:321–335.

Enlow DH. (1968): The human face: an account of the postnatal growth and development of the craniofacial skeleton. New York: Harper and Row.

Galilei, Galileo. (1638): Discoursi e demonstrazione matematiche intorno á due nuove scienze. Leiden: Elseviers. (1950). Discourses and mathematical demonstrations concerning two new sciences: The first day, and parts of the second day, the third day and the fourth day. Chicago: Chicago University Press.

Gallo, P.G, and Mestriner, M.F (1980): Growth of Children in Somalia. Human Biology, 52(3), 547-561.

Gayon J (2000): History of the Concept of Allometry. AMER. ZOOL., 40:748–758

German RZ, and Meyers LL (1989a): The role of time and size in ontogenetic allometry: I. Review. Growth, Develop.Aging.53: 101-106.

German RZ, and Meyers LL (1989a): The role of time and size in ontogenetic allometry: II. An empiricl study of human grpwth. Growth, Develop. Aging. 53:107-115

Goldstein, H. (1979). The design and analysis of longitudinal studies: Their role in the measurements of change. Academic press, London.

Gould, S. J. (1966): Allometry and size in ontogeny and phylogeny. Biol. rev. Camb. Philos. Soc. 41:587–640.

Gould, S. J (1969): An evolutionary microcosm: Pleistocene and recent history of the land snail P.(Poecilozonites*)* in Bermuda. Bull.Mus.Comp. Zool. 138:407–532

Gould, S. J (1971): Geometric similarity in allometric growth: A contribution to the problem of scaling in the evolution of size. Am. Nat. 105:113–136.

Gould S.J (1977): Ontogeny and phylogeny. Cambridge: Harvard University Press.

Greulich WW (1976): Some Secular Changes in the Growth of American-Born and Native Japanese Children. American Journal of Physical Anthropology 45:553-568.

Guégan, J.-F., Teriokhin, A., and Thomas, F. (2000): Human fertility variation, sizerelated obstetrical performance and the evolution of sexual stature dimorphism. Proc. R. Soc. Lond. B, 267: 2529–2535.

Gupta S.C, Kapoor V.K (1983): Fundamental of Mathematical Statistics, 17th edition, Sultan Chand & Sons. 23, Daryeganj, New Delhi-110002.

Gupta S.P, Gupta M.P (2003): Business Statistics, 12th edition, Sultan Chand & Sons. 23, Daryeganj, New Delhi-110002.

Gyensis G (1997): Continuing positive growth changes in height and weight of Hungrian University Students. Annals of Human Biology, vol.24, No. 5, pp.475-479.

Henneberg GM and Louw JG (1998): Cross sectional Survey of Growth of Urban and Rural "Cape coloured" Schoolchildren: Anthropometry and Functional Tests. American Journal of Human Biology 10: 73-85.

Hill K, Kaplan H. (1999): Life history traits in humans: theory and empirical studies. Ann Rev Anthropol 28:397–430.

Hossain G (2002): Secular changes in head dimensions of Japanese adults over eight decades. D.Sc. dissertation. Tokyo Metropolitan University, Tokyo.

Huppa RD and Garlie TN (1998): Secular changes in the growth of Toronto children during the last century. Annals of Human Biology, vol.25, No. 6,553-561.

Huxley, J.S (1924*a*). The variation in the width of the abdomen in immature fiddler crabs considered in relation to its relative growth-rate. Am. Nat. 58: 468–475.

Huxley, J.S (1924*b*): Constant differential growth-ratios and their significance. Nature 114:895–896.

Huxley, J.S (1932): Problems of relative growth. Lincoln Mac Veagh—The Dial Press, New York.

Huxley, J.S (1942): Evolution: The modern synthesis. George Allen & Unwin, London.

Huxley, J. S. and G. Teissier. (1936*a*): Terminology of relative growth. Nature 137:780–781.

Huxley, J. S. and G. Teissier. (1936*b*): Terminologie et notation dans la description delacroissance relative. Comptes rendus se´ances soc. biol. fil. 121: 934–937.

Jantz RL, and Meadows L (1995): Population structure of Algonquian speakers. J. Human Biol.67: 375-386.

Jantz LM, and Jantz RL (1999): Secular change in lo9ng bone length and proportion in the United States, 1800-1970. Am. J. Phys. Anthropol. 110:57-67.

Jhonston E, Roche AF, and Susanne C (1980): Human Physical Growth and Maturation: Methodologics and Factors. New York: Plenum Press.

Kaplowitz HJ, Christine EC, Martorell R, and Rivera J (1991): Longitudinal Principle Components Analysis of Pattern and Predictors of Growth in Guatemalan Children. American Journal of Human Biology 3: 169-180.

Kasai N, Ji C-Y, and Ohsawa (1995): Secular changes in the stature, weight and age at maximum growth increments of urban Chinese girls from the 1950s to 1985. American Journal of Human Biology 7: 473-488.

Kim YS (1982): Growth status of Korean schoolchildren in Japan. Annals of Human Biology, vol. 9 No. 5, pp. 453-458.

Klingerberg C.P (1998): Heterochrony and allometry: the analysis of evolutionary change in ontogeny. Biol Rev 73:79–123.

Klingenberg, C.P (1995): Common Principal Components for Dependent Random Vectors. http://life.bio.sunysb.edu/morph/dcpc.exe.

Klingenberg, C. P. (1996). Multivariate allometry. In Advances in Morphometrics, M. Corti, A. Loy, J. P. Naylor, and D. E. Slice, eds., pp. 23-49. Plenum, New York.

Klingenberg, C.P (1996): Individual variation of ontogenies: a longitudinal study of growth and timing. Evolution 50: 2412±2428.

Klingenberg, C.P. & Zimmermann, M (1992): Static, ontogenetic, and evolutionary allometry: a multivariate comparison in nine species of water striders. Am. Nat. 140: 601±620.

Klingenberg, C.P., Neuenschwander, B.E. & Flury, B.D (1996): Ontogeny and individual variation: analysis of patterned covariance matrices with common principal components. Syst. Biol. 45: 135±150.

Koutsoyiannis, A (1977): Theory of Econometrices; English Language Book Society, Macmillan.

Parvin K (2009): Statistical study of child growth: A case study of Rajshahi City. D.Sc. dissertation, Department of Statistics, University of Rajshahi, Bangladesh.

Lapique, L (1898): Sur la relation du poids de 19 ence´phale aux poids du corps. Comptes rendus se´-ances soc. biol. fil., 10e se´rie, vol. 5:62–63.

Lapique, L (1907): Tableau ge´ne´ral des poids somatiques et ence´phaliques dans les espe`ces animales. Bull. Soc. anthropol. Paris, 5e se´rie, vol. 9:248–269.

Lapique, L (1910): Relation du poids ence´phalique a`la grandeur re´tinienne dans quelques ordres demammife`res. C. r. hebd. se´ances Acad. sci. 111: 1393–396.

Leonard WR, Robertson ML (1994): Evolutionary perspectives on human nutrition: the influence of brain and body size on diet and metabolism. Am J Hum Biol 6:77–88.

Lindgren WG and Hauspic CR(1989): Heights and weights of Swedish school children born in 1955 and 1967. Journal of Human Biology. Vol. 16, No. 5, 397-406.

Livshits G, Peter I, Vainder M, and Hauspie R (2000): Genetic analysis of growth curve of body weight, height and head circumference. Ann Hum Biol. 2000 May-Jun; 27(3): 299-312.

Madnani GMK (1994): Introduction to Econometrices, Principles and Applications, sixth edition, Rajuprimlani for Oxford & IBH publishing Co. Pvt. Ltd, 66 Janpath, New Delhi.

Malina RM (1979): secular changes in growth, maturation, and physical performance. Exercise and Sport Science Review, vol. 6, pp. 203-255.

Malina, R.M., Little, B.B., Buschang, P.H., DeMoss, J. and Selby, H.A (1985): Socioeconomic variation in the growth status of children in a subsistence agricultural community. Am. J. Physical Anthropl. 68: 385-391.

Matsuo N, Osano M, Saito M, and Tsuzaki S (1990): The head circumference growth curve for Japanese children between 0-4 years of age: comparison with Caucasian children and correlation with stature. Ann. Hum. Biol. 17: 297-303.

McGregor and Billewiez (1982): A birth-to-maturity longitudinal study of heights and weights in two West African (Gambian) villages, 1951-1975. Annals of Human Biology, vol. 9, No. 4,309-320.

Md. Ayub Ali, Kumi Ashizawa, Chiyoko Kumakura, and Ayano Kusumoto: Growth Comparison among Philippine Children: A Regression Approach. International Journal of Statistical Sciences Vol. 4, 2005, pp 1-25 © 2005 Dept. of Statistics, Univ. of Rajshahi, Bangladesh.

Mohammad K and others (1999): Weight-for-Height of children in Iran. Annals of Human Biology, 1999,vol. 26 No. 6, 537-547.

Nagamine S, and Suzuki S (1994): Anthropometry and body composition of Japanese young man and women. Human Biology, vol. 36, No. 8, 8-15.

Newell, N (1949): Phyletic increase size, an important 758 JEAN GAYON trend illustrated by fossil invertebrates. Evolution 3:103–124.

Norgan NG, Ferro-Luzzi A, and Durnin JVGA (1982): The body consumption of New Guinean adults in constrasting environments. Annals of Human Biology, vol. 9,No. 4,343-353.

Ohtsuki F, and Ito K (1980): Secular changes in head dimensions among Japanese females. Presented at XI international congress of Anatomy, August 17-23, 1980, Mexicocity, mexico.[Abstract]

Pe´zard A. (1918): Le conditionnement physiologique des caracte`res sexuels secondaires chez les oiseaux. Bull. biol. Fr. Belg. 52:1–176.

Roa and Reddy (2000): Growth pattern of the Sugalis- atribal population of Andhra Pradesh, India. Annals of Human Biology, vol. 27, No. 1, 67-81.

Rosique J and Rebato E (1995): Comparative Study of Structural Growth in Spanish Populations. American Journal of Human Biology 7:553-564.

Rovosa MJ (2000): Size and scaling in the mandible of living and extinct apes. Foli. Primatol. 71: 305-322.

Samprit Chatterjee, and Ali S. Hadi (2006): Regression Analysis by Example, 4th edition. John wiely & Sons. Inc. Publications.

Shani D, Jit I and Sanjiv (1994): Weigth of the Heart in Northwest Indian Adults. American Journal of Human Biology 6:419-423.

Shea B.T (1989): Heterochrony in human evolution. The case of neoteny reconsidered. Yrbk Phys Anthropol 32:69–101.

Shepherd RH, Sholl DA, and Vizoso A (1948): The size relationships subsisting between body length, limbs and jawa in man. J. Anat. 83: 296-303.

Shepherd, R.J (1991): Body consumtion in Biologicl Anthropology, Cambridge University Press, New York.

Sholl D (1948): The quantitative investigation of the vertebrate brain and the applicability of allometric formulae to its study. Proc. Roy. Soc. B. 135: 243-258.

Singaravelu A, and Senapathy R (2000): Quantative Methods in Business. Meenakshi Agency. 120, Pushpa Nagar, Medavakham, Chennai-601302.

Stern, D. L. and D. J. Emlen. 1999. The Developmental Basis for Allometry in Insects. Development 126:1091–1101.

Tanner JM, Whitehouse RH, Takahashi M.1966. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965, Part II. Arch Dis Child 41:613–635.

Thissen, D., Bock, D., Wainer, H., and Roche, A. (1976). Individual growth in stature: a comparison of four growth studies in the U.S.A. *Ann Hum Biol.*, 3(6):529–542.

Thompson, D'A. W. (1961). On Growth and Form. Abridged edition/edited by J. T. Bonner. Cambridge: Cambridge University Press.

Teissier, G (1931): Recherches morphologiques et physiologiques sur la croissance desinsectes. Trav.stn. biol. Roscoff, Fasc. 9:29–238.

Teissier, G (1948): La relation d'allome´trie, sa signification statistique et biologique. Biometrics 4:14–53.

Togo M and Togo T (1982): Time-series analysis of stature and body weight in five siblings. Annals of Human Biology, vol. 9. No. 5, 425-440

Tosellis S, Argnani LE, and Gualdi-Russo (2005): Growth of Chinese Italian infants in the first 2 years of life. Ann Hum. Biol. 32: 15-29.

Wales JK (1998): A brief history of the study of human growth dynamics. Annals of Human Biology, vol.25, No.2,175-184.

Wales Jk, Herber SM, Taitz LS. Height and body proportions in child abuse. Arch Dis Child 1992; 67:632–5.

White, and S. J. Gould (1965): Interpretation of the coefficient in the allometric equation. Am. Nat. 99: 5–18.

Appendix

Questionnaire

ALLOMETRIC MODEL STUDY OF INTER LIMB GROWTH:

A CASE STUDY OF CHILDREN FROM JESSORE DISTRICT

Department of Statistics

University of Rajshahi

Bangladesh.

(Collected data will be used only for research work)

১। উত্তর দাতা শিশুর পরিচিতি নং ঃ (প্রশ্নকর্তা পূরণ করিবে)

২। শিক্ষা প্রতিষ্ঠানের নাম ও ঠিকানা ঃ

৩। উত্তর দাতা শিশুর নাম ঃ

৪। অধ্যায়নরত শ্রেণী ঃ

৫। শ্রেণী ক্রমিক নং ঃ

৬। পিতার নাম ঃ

৭। মাতার নামঃ

৮। স্থায়ী ঠিকানা ঃ

বর্তমান ঠিকানা ঃ

৯। ফোন/ মোবাইল নং ঃ

১০। উত্তর দাতা শিশুর লিঙ্গ ঃ ক) বালক খ) বালিকা *১১। জন্ম তারিখ ঃ

*১২। প্রথম তথ্য সংগ্রহকালীন (তারিখঃ) সময়ে শিশুর বয়সঃ........ বছর ....মাস .... দিন

*১৩। শিশুর পিতা-মাতা সম্পর্কিত তথ্য ঃ

বৈশিষ্ট্য		পিতা	মাতা
পেশা		১) চাকুরী ২) ব্যবসা ৩) কৃষি ৪) দিন মজুর ৫) অন্যান্য	১) চাকুরী ২) ব্যবসা ৩) গৃহিনী ৪)অন্যান্য
জন্ম তারিখ			
শিক্ষাগত যোগ্যতাঃ (class-1=1, two=2,…, S.S.C=10, H.S.C=12 etc.)			
বার্ষিক আয় (টাকা)			
এই শিশু জন্মের সময় বয়স			
Height (cm)			
Weight (kg)			
Upper arm length (cm)	Right		
	Left		
Elbow-Wrist length(cm)	Right		
	Left		
Upper arm circumference(cm)	Right		
	Left		
Chest circumference(cm)			
Head length (mm)			
Head breadth (mm)			
Head circumference(cm)			

*১৪। **Demographical Information:**

১) পরিবারের সদস্য সংখ্যা ঃ জন

২) পরিবারের ধরণ ঃ ক) একক পরিবার খ) যৌথ পরিবার

৩) জীবিত সন্স্থানের সংখ্যা ঃ জন

৪) মৃত সন্স্থানের সংখ্যা (যদি থাকে) ঃ জন

৫) উত্তর দাতা শিশুর জন্ম ক্রম সংখ্যা ঃ

৬) পূর্ববর্তী শিশু ও এই শিশুর জন্ম সময়ের ব্যবধান ঃ .... বছর ....মাস .... দিন

৭) সন্স্থান প্রসবকালীন সময়ে মায়ের অবস্থান ঃ ক) বাড়ী খ) হাসপাতাল/ স্বাস্থ্য কেন্দ্র

৮) প্রসবের ধরণ ঃ ক) স্বাভাবিক ডেলিভারী খ) অপারেশন

৯) শিশুর মাতৃগর্ভে অবস্থান কালীন সময় ঃ ক) ৯ মাস খ) ৮ মাস গ) ৮ মাসের কম

১০) ০-৫ বছর বয়সে শিশুকে প্রয়োজনীয় টিকা/ভিটামিন দেওয়া হয়েছে কি? ক) হ্যা খ) না গ) আংশিক

১১) ছোট-খাট অসুখের সময়ে আপনার সন্স্থানকে কোথায় চিকিৎসা করান?

ক) হাসপাতাল খ) ক্লিনিক গ) MBBS ঘ) হোমিওপ্যাথি ঙ) কবিরাজ চ) পল্লী চিকিৎসা ছ) অন্যান্য

১২) শিশু কি ধরণের খেলা পছন্দ করে? ক) ইনডোর গেম খ) আউটডোর গেম গ) উভয়টি ঘ) কোনটিই নয়

১৩) শিশুর দৈনন্দিন খাবারের ধরনঃ ক)

১৪) যে জাতীয় খাবারের প্রতি শিশুর বেশি আগ্রহ ঃ ক) ফলমূল খ) মিষ্টি গ) ঝাল ঘ) দুধ ঙ) শর্করা (ভাত, রুটি ইত্যাদি) চ) মাছ ছ) গোসত জ) সবজি ঝ) ডিম ঞ) টক ট) অন্যান্য

১৫) শিশু টিভি দেখে ? ক) হ্যাঁ খ) না

১৬) যদি দেখে তবে দৈনিক কত ঘন্টা দেখে ? ক) ১ ঘন্টা খ) ২ ঘন্টা গ) ৩ ঘন্টা ঘ) ৩ ঘন্টার অধিক

১৭) কি ধরণের অনুষ্ঠান বেশি পছন্দ কওে ? ক) কার্টুন খ) নাটক গ) সিনেমা ঘ) বিজ্ঞাপন ঙ) খেলা চ) সংবাদ ছ) গানর জ) নাচ ঝ) প্রতিযোগিতামূলক ঞ) ভ্রমন বিষয়ক ট) অন্যান্য

১৫। **Anthropological Information about child:**

তারিখ বৈশিষ্ট্য		পিতা	মাতা
Height (cm)			
Weight (kg)			
Sitting height (cm)			
Tibia length (cm)	Right		
	Left		
Upper arm length (cm)	Right		
	Left		
Elbow-Wrist length(cm)	Right		
	Left		
Upper arm circumference(cm)	Right		
	Left		
Chest circumference(cm)			
Head circumference(cm)			
Head length (mm)			
Head breadth (mm)			

* চিহ্নিত প্রশ্নের উত্তর শিশুর পিতা-মাতা থেকে সংগ্রহ করতে হবে।