A STUDY ON DEVELOPMENT OF PEDIATRIC REFERENCE CHARTS

Thesis submitted to

THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY,

CHENNAI – 600 032.

by

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A PRE-DOCTORAL FELLOW UNDER THE GUIDANCE OF

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for

THE AWARD OF DOCTOR OF PHILOSOPHY IN

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DECEMBER – 2013

CERTIFICATE

I certify that the thesis entitled "**A study on development of Pediatric reference charts**" submitted for the degree of Doctor of Philosophy by Mr.A.Vengatesan is the record of research work carried out by him during the period from 2009 to 2013 under my guidance and supervision and that this work has not formed the basis for the award of any degree / diploma / associate ship/ fellowship or other titles in this university or any other university or other similar institutions.

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DECLARATION

I, A. VENGATESAN, hereby declare that the thesis entitled **"A STUDY ON DEVELOPMENT OF PEDIATRIC REFERENCE CHARTS"** which is submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfillment of the requirements for the award of Doctor of Philosophy is the record of work carried out by me during the period from 2009-2013 under the guidance of **Dr. L. JEYASEELAN M.Sc, PhD, FRSS, FSMS.**, Professor of the Department of Biostatistics, Christian Medical College , Vellore and has not formed the basis for the award of any degree / diploma / associate ship/ fellowship or other titles in this university or any other university or other similar institutions.

Signature of the candidate

Place: Chennai

Date: 06.12.2013

(A.VENGATESAN)

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ABSTRACT

Title: A study on development of Pediatric reference charts

Rationale: Pediatric growth pattern differences continue even after controlling for various factors such as nutrition, income distribution, environment, maternal/child health care and availability of health care infrastructures. Therefore it is recommended that every country should use reference height and weight curves based on measurements on their own children.

Aim: Aim of the study is to construct pediatric reference centile charts for weight, height and body mass index using maximum penalized likelihood LMS method for boys and girls separately from ages 6 -12 years.

Study Objectives:

The Primary outcome measures were

1) Construction of percentile charts using LMS method
2) Calculation of Z- score using LMS method

Secondary outcome measures were

1) Making Weight-for- age centile chart for boys and girls separately
2) Making Height-for-age centile chart for boys and girls separately
3) Making weight-for-height centile chart for boys and girls separately
4) Making Body Mass Index centile chart for boys and girls separately
5) Calculation of WAZ, WHZ ,HAZ and BMI Z score for boys and girls separately
6) Comparison of American National Center for Health Statistics/ Center for Disease Control (NCHS/CDC2000/WHO2007) references with locally weighted.
7) Estimation of prevalence of malnutrition, overweight and obesity among Tamil Nadu children.

Study Design: Population based cross-sectional multi-site (various schools) study design.

Setting: The study was conducted at the Institute of Child Health and Hospital for children, Egmore, Chennai-8.

Study population: The study population consisted of 6-12 years children from all social groups and from families of high, moderate and low income**.**

Target population: The target population consisted of 6-12 years children in the selected urban–rural middle schools based on a representative sample of 2520 boys and 2520 girls.

Sample Size: Sample size was estimated using previous studies prevalence of normal children in the population 48%, with 5% relative precision and 95% of confidence. The calculated sample size was 1665.This was multiplied by 3 (bringing the sample size up to 4995) to allow for design effect due to application of cluster sampling method. For equal distribution of sample in clusters the ultimate sample size required for the study was determined to 5040 children.

Tools used:
Part I: Socio-demographic data tool

Part II: Anthropometric measurement tool

Outcome variables:

1. Percentile charts
2. Z- score
3. Comparison with NCHS/WHO2007/CDC2000 charts
4. Prevalence of wasted ,stunted, underweight, overweight, obesity

Methodology:

A total of 5040 apparently healthy boys and girls aged 6 to 12 years were recruited using population based cross-sectional multi-site (various schools) study design. Anthropometric measurements were collected as per WHO standards. To construct smoothened percentile reference charts, the lamda-mu-sigma-additional parameter (LMSP) method using Box-Cox power exponential (BCPE) distribution model was adopted. LMSP summarizes the changing distribution with age according to 4 curves representing the median (M), the coefficient of variation (S), skewness (L), and kurtosis (P). BCPE distribution takes the idea of having a range of power transformations (rather than the traditional square root, log, and inverse) available to improve the efficacy of normalizing and variance equalizing for both positively and negatively skewed, and for both leptokurtic-platykurtic variables. Maximum penalized likelihood, the Generalized Additive Models were used. The centile curves of height, weight and BMI were fitted by BCPE (μ, σ, ν, τ) models, and the parameters, μ, σ, ν and τ, were smoothened by cubic smoothing splines. The goodness-of-fit of BCPE models were assessed by worm plot and Q-test. The degrees of freedom, with respect to the parameter curves of μ, σ, ν and τ from BCPE distribution, were selected according as the smallest AIC and GAIC(3), and the centile curves were fitted by BCPE distribution.

Results:

Comparing present study charts with those of NCHS/WHO2007/CDC2000 chart showed significant differences between growth patterns of our children and other populations.

Estimated median 50th percentile shows Tamil Nadu children anthropometric measurements are lower than NCHS/WHO2007/CDC2000 standard children.

The study revealed that total prevalence of overweight was 10.6% (9.8%- 11.5%) and obesity was 3.0% (2.6%- 3.5%) when considering Body Mass Index of children between 6-12 years. Boys are having more overweight and obese than girls based on CDC2000 reference distributions of *Z*-scores for BMI.

Present study shows prevalence of underweight is 31.7%, stunting is 19.7% and wasting is 24% among 6-12 years children. The boys had a risk of 1.23 (95%CI: 1.09- 1.39) times greater to be underweight, 1.05 (95%CI: 0.92- 1.20) times greater to be stunting, and 1.03 (95%CI: 0.88- 1.20) times greater to be wasting than the girls.

Conclusion:

Since there is a secular trend in upward increase both in height and weight, a comparison of growth curves requires both methodological and secular similarity to determine similarity or difference. Local references would then provide a useful tool for health planning and screening inter-population differences. The results of the current study demonstrate the possibility of preparation of local growth charts and their importance in evaluating children's growth. Also their differences, relative to those prepared by global references, reflect the necessity of preparing local charts in future studies using longitudinal data.

Key words: LMS, LMSP, BCPE, worm plot, Q-stat, AIC, GAIC

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ABBREVIATIONS / GLOSSARY

AIC	Akaike Information Criterion
BCPE	The Box-Cox power exponential distribution.
μ	The median of the Box-Cox power exponential distribution.
σ	The approximate coefficient of variation of the Box-Cox power exponential distribution — related to the variance.
ν	The power of the Box-Cox transformation (to the normal distribution) of the Box-Cox power exponential distribution - related to the skewness.
τ	The power exponential parameter of the Box-Cox power exponential distribution — related to the kurtosis.
λ	The power of the age transformation.
BCT	Box-Cox transformation-A power transformation to the normal distribution.
BMI	Body Mass Index
CDC	Centers for Disease Control
CV	Coefficient of variation- The ratio of the standard deviation to the mean.
Cubic spline	A piecewise third-order polynomial function that passes through a set of *m* (or degrees of freedom) control points; it can have a very simple form locally, yet be globally flexible and smooth.
Cut-off	A designated limit beyond which a subject or observation is classified according to a pre-set condition.
DF	Degrees of freedom**-**The number of control points used to fit the cubic splines.
EDF	Equivalent degrees of freedom- 1 edf means a constant, and 2 edf corresponds to a straight line, 3 edf gives a simple curve like a quadratic, and 4 or more edf indicates progressively more complex curve shapes
GAMLSS	Generalized Additive Models for Position, Scale and Shape
GAIC	Generalized Akaike Information Criterion

HAZ	Height-for-age z-score
Kurtosis	An attribute of a distribution describing "peakedness". A high kurtosis portrays a distribution with fat tails in contrast to a low kurtosis, which portrays a distribution with skinny tails.
LMS	Lamda-mu-sigma method
LMSP	Lamda-mu-sigma-additional parameter method
MLE	Maximum-likelihood estimation is a method of estimating the parameters of a statistical model.
NCHS	National Centre for Health Statistics
Percentile	A percentile (or a centile) indicating the value below which a given percentage of observations in a group of observations fall.
P-value	The probability of falsely rejecting the hypothesis being tested. In this report all p-values were compared to a level of significance set to 0.05.
Q-test	A statistical test which combines overall and local tests assessing departures from the normal distribution with respect to median, variance, skewness and kurtosis.
SD	Standard deviation
Skewness	A statistical term used to describe a distribution's asymmetry in relation to a normal distribution.
WAZ	Weight-for-age z-score
WHZ	Weight-for-height z-score
WHO	World Health Organization
Worm plots	A set of detrended Q-Q plots — plots that compare the distribution of a given set of observations to the normal distribution.
Z-score	Standard deviation score -The deviation of an individual's value from the median value of a reference population, divided by the standard deviation of the reference population (or transformed to normal distribution).

CHAPTER -1

1. INTRODUCTION

1.1. Background and Rationale

Construction of reference growth charts using anthropometric measurements was conceived by Quetelet in the 19th century, and subsequently it has under gone much development. Percentile Charts describing the dependence of height, weight, head circumference and a variety of other physical characteristics on age are now in widespread use as screening tools for disease and as reference standards for group health and economic status. Now a days reference charts are used as a graphic presentation of body measurements that aid in the assessment of size of body, and in the observation of trends in growth performance. They are used in the assessment and monitoring of individual children and in screening whole populations [1]. Growth charts illustrate how a child's growth in weight and length or height compares with that of other children. The charts are tools that help to identify children who may be at risk for obesity, overweight, underweight, stunting and wasting. Also, along with accurate dietary, hematological information and health can help you assess a child’s health and nutritional status. Growth charts are not diagnostic and should be used in conjunction with other information when evaluating a child’s general health. These charts are useful in monitoring a child's growth, which is an essential part of child health care.

Normal growth is an indicator of the overall well-being of a child. Due to differences in height and weight of normal children of different population groups in the world, each country should have its own growth standards against which to evaluate children. It can be achieved by carefully selecting samples of children growing in an optimal environment. We can only understand whether a measurement is normal by comparing it with the normal range of measurements for other children of the same age and gender and this is what growth charts allow us to do. Their value resides in helping to determine the degree to which physiological needs for growth and development are met during the important childhood period.

Most of the governmental and United Nations agencies are using growth charts to formulate health related policies, to measure the general well-being of populations, and to plan interventions and monitor their effectiveness beyond their usefulness in assessing children's nutritional status. At the population health level, growth reference charts based on cross-sectional surveys and longitudinal surveys of anthropometric data help to define health and nutritional status for purposes of health care program planning, implementation, monitor and evaluation.

1.1.1 Use of Growth Charts

Now a days growth reference data and growth charts are used in a number of ways.

1. It is used as a surveillance tool to monitor the pattern of an individual child's longitudinal growth. It identifies growth faltering which may indicate underlying physical ill-health and deprivation, and it allows for early intervention

2. It is used as a screening test at a single point of time to indicate possible abnormalities

3. It is used as eligibility criteria for growth hormone replacement

4. It is used as a monitoring tool for individual children aiming to identify early features of obesity and allow intervention to occur and

5. It is used to find trends and projections.

1.1.2 Definition of Growth Charts

A growth reference or growth standard is a dataset representing the distribution of a given anthropometric measurement as it changes with some covariate - usually age based on a specified reference sample of children. The distribution is usually summarized by selected centiles including the median (50th centile), and the mean and standard deviation (or **SD)**. The term 'centile' is also called percentiles it is synonymous with Galton's 'percentile'. The set of centiles chosen to define the standard is conventionally symmetric about the median, with up to seven distinct centiles, and usually including extreme values such as the 3rd and 97th or the 5th and 95th. Centiles corresponding to- 2 SD or - 3 SD are also sometimes used. Thus a growth reference charts consists of several smooth centile curves, which when plotted out make up a growth chart, with the relevant anthropometric measure on the ordinate and age (usually) on the abscissa.

1.1.3 Reference versus Standard charts

There is an important distinction between a growth reference and a growth standard.

A reference is defined as a tool for grouping and analyzing data and provides a common basis for comparing populations without making inferences about the meaning of observed differences. A standard is notion of a norm or desirable target, and thus involves a value judgment. Due to patterns of normality or embody certain characteristics, reference data have been widely used to make inferences about the health and/or nutrition of individuals and populations; that is they have been treated as optimum targets, or standards, and any deviations have been assumed to have a fixed and particular meaning. Much of the justification for this is provided by extensive evidence that, in populations, the effect of genetic differences on the growth of children is small in comparison with the large difference observed due to environmental factors.

Therefore, recognizing that in practice it is almost impossible to prevent the use of reference data as standards for judging the nutritional status of individuals and populations, it is recommended that more care should always be taken to choose references that resemble, as far as possible, true standards, so that the same biological meaning. We can say standard is prescriptive while reference is descriptive .A **reference** describes its sample with-out making any claims about the health of its sample, whereas a **standard** represents 'healthy' growth of a population and suggests a model or target to try and achieve [2,3.] Growth charts currently in use describe existing growth patterns and are therefore references, not prescriptive standards. For example, WHO MGRS 2006 charts[4] are growth standards whereas weight reference curves prepared from affluent populations of today are not a standard. These were prepared from a population of children where the environmental variables were controlled like maternal smoking, breast-feeding, socio-economic class etc. Data were collected from 6 countries *viz*. USA, India, Ghana, Brazil, Oman, and Norway was used. WHO standards calculated are thus prescriptive rather than descriptive. In simple, reference charts tells 'how children grow in a particular region and time' on the other hand standard charts tells 'how children should grow when their environment and nutrition is controlled'.

1.1.4 Local versus International reference charts

To compare the nutritional status of populations in different parts of the world, an international reference (NCHS, CDC, WHO Growth standards) is clearly needed. There is evidence that the growth in height and weight of well-fed, healthy children, or children who experience inadequate growth, from different ethnic backgrounds and different continents is reasonably similar at least up to 5 years of age [5,6] It is accepted that there is some variation in the growth patterns among children of different race or ethnic groups in developed countries; however these variations are relatively minor compared to the large worldwide variation in growth related to health, nutrition and socioeconomic status [7,8]. To show this point using two very different populations, Figure I describes how the growth performance of Indian children not subjected to socio economic and dietary constrains, nearly corresponds to the NCHS/WHO international reference values. Similar pattern of growth is seen among affluent children in seven different cities of India [9]. Several other affluent populations from different ethnic backgrounds have been shown to have a growth pattern similar to the International reference. For this reason, the use of common reference has the advantage of uniform application allowing International comparisons without losing the usefulness for local application. Main disadvantage of this method is pattern of growth shown by the standard may be quite inappropriate in particular regions of the world, as an example, in India; children are considerably smaller than in the USA. Beyond lacking value for international comparisons , there are also several reasons for not developing a local reference or standard; (a) in less-developed countries many populations experience growth deficits as a result of poor health and nutrition, and therefore less screening value for the detection of health and nutritional disorders in reference developed from such populations; (b) significant secular changes in growth status within a relatively short period of time may render a local reference less useful for clinical screening; (c) proper reference development is not a task that can be done easily and frequently, (d) and it is very costly to develop local reference charts.

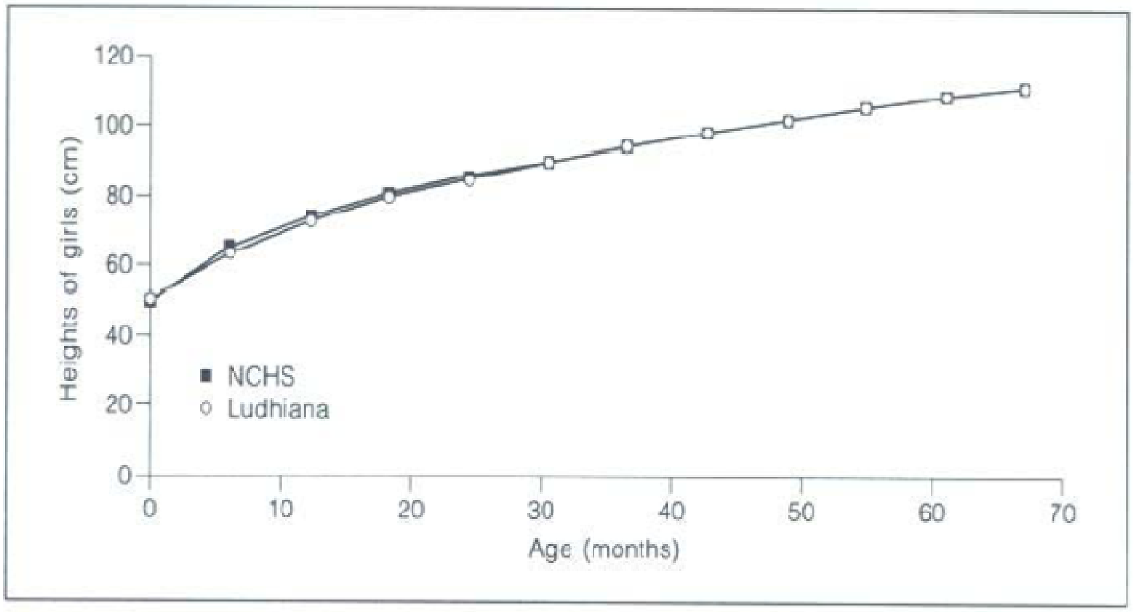

Figure I: Comparison of the 50th percentile of heights of affluent Indian Girls (Ludhiana) with NCHS/WHO reference values. Source: Agarwal et al.

The short answer to the question, International or Local charts depends on for what purpose we are going to use the chart. When International comparisons are required, an International standard simplifies the collection and classification of anthropometry. Conversely if clinical decisions are needed or if a statistical analysis is used to adjust anthropometry for age, then a local standard (ICMR chart, Agrawal KN chart) is probably more appropriate. In practice, most Western countries have developed their own national standards, which are used as local norms for clinical purposes.

1.1.5 Cross sectional versus Longitudinal Designs

Data can be collected using cross-sectional or longitudinal methods. A cross-sectional design involves measuring children on a single occasion, whereas a longitudinal design follows children over time and measures them repeatedly. A mixed longitudinal design combines features of both cross-sectional and longitudinal designs, measuring some children once and others more than once. A cross-sectional design estimates **growth *distance*** (i.e., size), whereas longitudinal or mixed longitudinal designs provide information on both ***growth distance*** and **growth *velocity*.**

Most current National growth references, such as the Center for Disease Control (CDC) 2000 [10], British 1990 [11], and Dutch [12] references, are based on cross-sectional data. However, in the past, longitudinal growth studies, such as the French [13] and British [14-15] studies, recruited children at birth and followed them through to maturity. Important consideration when choosing among the various designs is cost. The costs of the designs depend on recruitment, maintenance, and measurement.

Recruitment involves identifying suitable subjects for the study and persuading them to take part. The corresponding cost per recruit depends on the time required, which in turn depends on the sampling fraction, i.e., the sample size required relative to the available population. Retention involves maintaining contact with previously recruited subjects and retaining highly trained and hence valuable staff in employment. Retention of subjects is important only for longitudinal studies. Measurement is the process of visiting and measuring children, and the cost of each measurement is the same whether the design is cross-sectional or longitudinal. The relative costs of the cross-sectional and longitudinal designs depend on the relative costs of recruitment and retention. For a given number of child-measurement occasions, recruitment costs are minimized with a longitudinal design as the number of subjects is minimized, whereas retention costs in a longitudinal design are minimized if staff numbers are minimized. Elapsed time is a distinct resource that impacts directly on cost. A cross-sectional design is completed more quickly than a mixed longitudinal design, which is in turn more quickly completed than a longitudinal design. Thus, the issues determining which design to be used depends on the uses to which the reference is to be put, in particular the priority attached to assessing velocity(in addition to distance) and the time period over which to measure it; and the time and cost resources likely to be available for data collection.

1.1.6 Distance standard versus Velocity standard

The distance curve (Figure 2) is a measure of size over time; it measures and records height as a function of age and gets higher with age. The velocity curve measures the rate of growth at a given time for a particular body feature such as height or weight. Distance standards (Tanner, 1962) [16]

- Distance standard marked with an extra set of centile-like curves which indicate how much a child's centile can be expected to change over a given time period.
- A one-off measure is used, based on a single measurement, which gives no clues as to the growth pattern that has led the child to its current position.
- It indicates only how extreme the child is in terms of current size or status.

Velocity standards (Emery et al 1965) [17]

- Velocity standard is a tool to quantify changes in measurement centile over time.
- Standards based on growth measured over a period of time
- Measures growth rather than status
- Require two measurements instead of one
- Need to be constructed using longitudinal data.

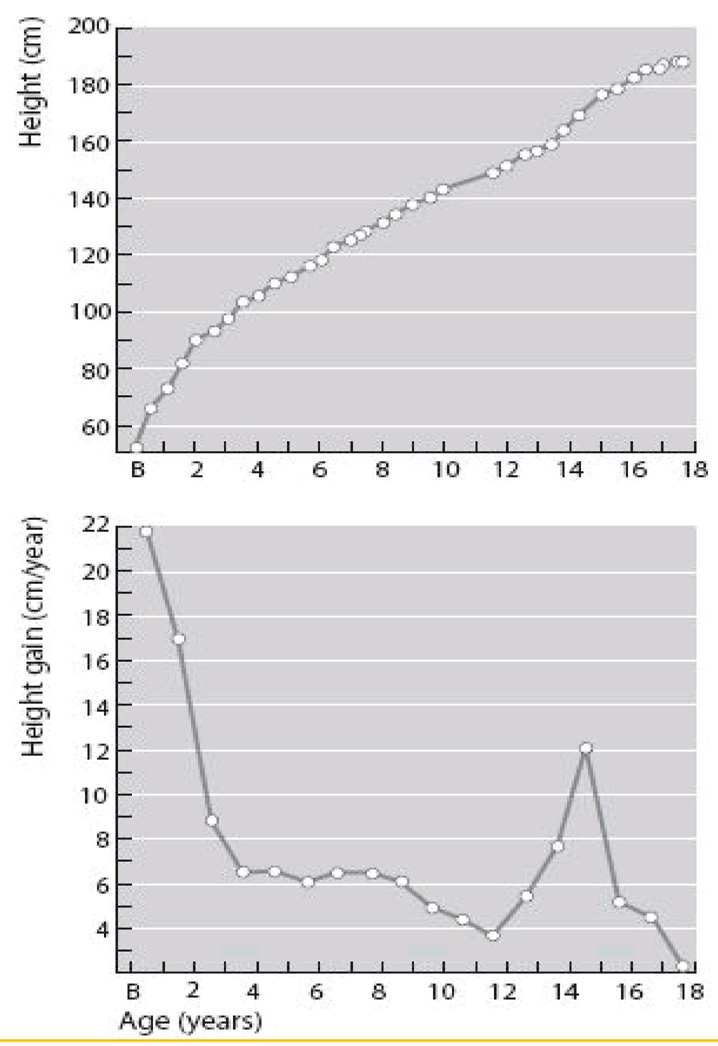

Figure 2: Distance curve (above), shows amount of growth in height achieved at each age of boys; velocity curve (below), shows increments in height from year to year.

1.1.7 Marginal versus Conditional charts

For the construction of reference charts there are two general types of reference chart methods are available. Marginal or unconditional growth curves will refer to curves that depend solely on age; conditional growth curves, or longitudinal growth curves will connote curves that explicitly account for growth history, and possibly other covariates. An unconditional standard is constructed from a reference population where each individual contributes to a single measurement, unadjusted for other information. This is by far the most common form of standard, and it expresses individual subjects in terms of a centile relative to the reference population on which the standard is based. Marginal standards can be applied equally to distance and velocity - individuals from the reference population provide either a single measurement or a single velocity. Infancy velocity standards tend to be unconditional [18], although in practice it is followed longitudinally, and often provide several velocity measurements. Another example, during puberty, velocity standards can be either unconditional or conditional [19].

The alternative to the marginal standard is the conditional standard. It works on the principle that a child's measurement should be expressed as conditional, adjusted for another covariate in addition to age and sex. Conditional standards have been described for height and height velocity during puberty adjusted for tempo conditional [18], height conditional on mid-parent height , birth weight adjusted for sibling birth weight [20] height adjusted for height one year earlier [21].

Marginal or unconditional standards [22]

- Most common form of standard
- Constructed from a reference population where each individual contributes to a single measurement, unadjusted for other information.

- Expresses individual subjects in terms of a centile relative to the reference population on which the standard is based.
- Can be applied equally to distance and velocity - individuals from the reference population provide either a single measurement or a single velocity.
- Velocity standards in infancy tend to be unconditional although in practice such infants are followed longitudinally, and often provide several velocity measurements.

Conditional standards

- It works on the principle that a child's measurement should be expressed conditional on, or adjusted for, another covariate in addition to age and sex.
- Described for height and height velocity during puberty adjusted for tempo (Tempo conditional or clinical longitudinal standards).
- It reduces the variability of the measurement.
- Require a strong correlation between the measurement and the conditioning variable.
- Conditional predictions for individuals in the tails of the distribution are unbiased, whereas velocity standard predictions are often biased.
- The statistical advantage of the conditional standard is that it can be extended naturally to a full regression model with other covariates.

Longitudinal reference centiles over some measure of time (typically age) are almost always implemented repeatedly on the same individual. In this kind of setting the notion of conditional or adaptive centile charts is very appealing, when the within-individual variability is less than that between individuals. While marginal or unconditional centile charts are common in many areas of application, unconditional charts are generally used and conditional charts rarely encountered and further methodological development in this area is needed. Figure 3& 4.shows the charts of girls' height distance and annual height velocity based on the Tanner Whitehouse 1966 standard. The charts show the difference between tempo-conditional (or clinical longitudinal) and unconditional standards.

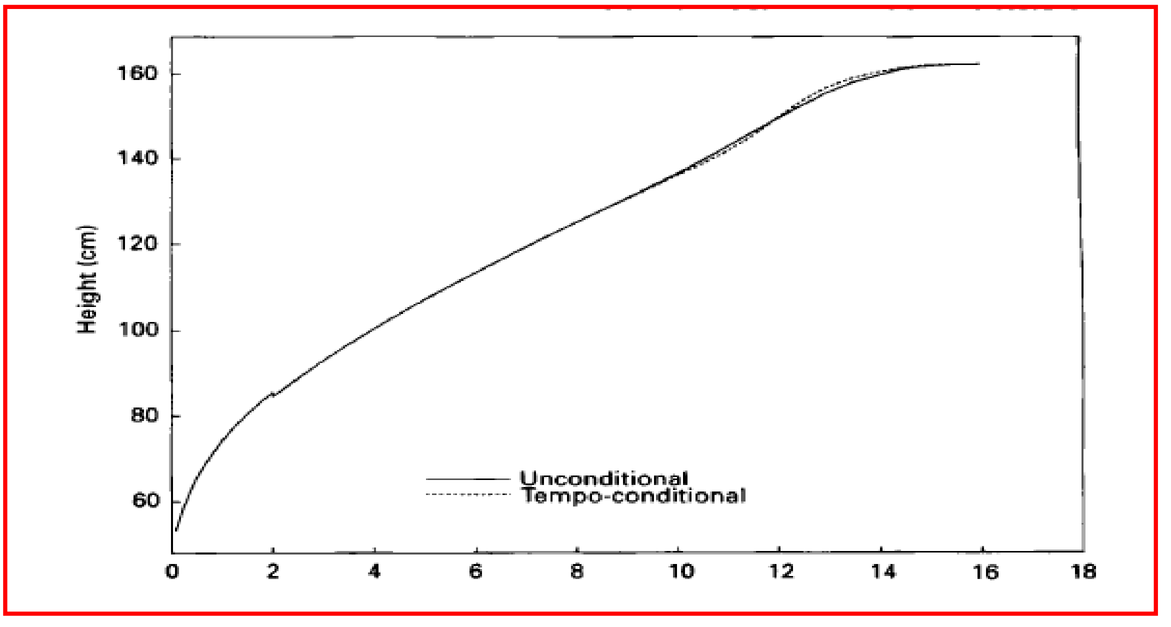

Figure 3: Distance growth chart showing conditional and unconditional standards

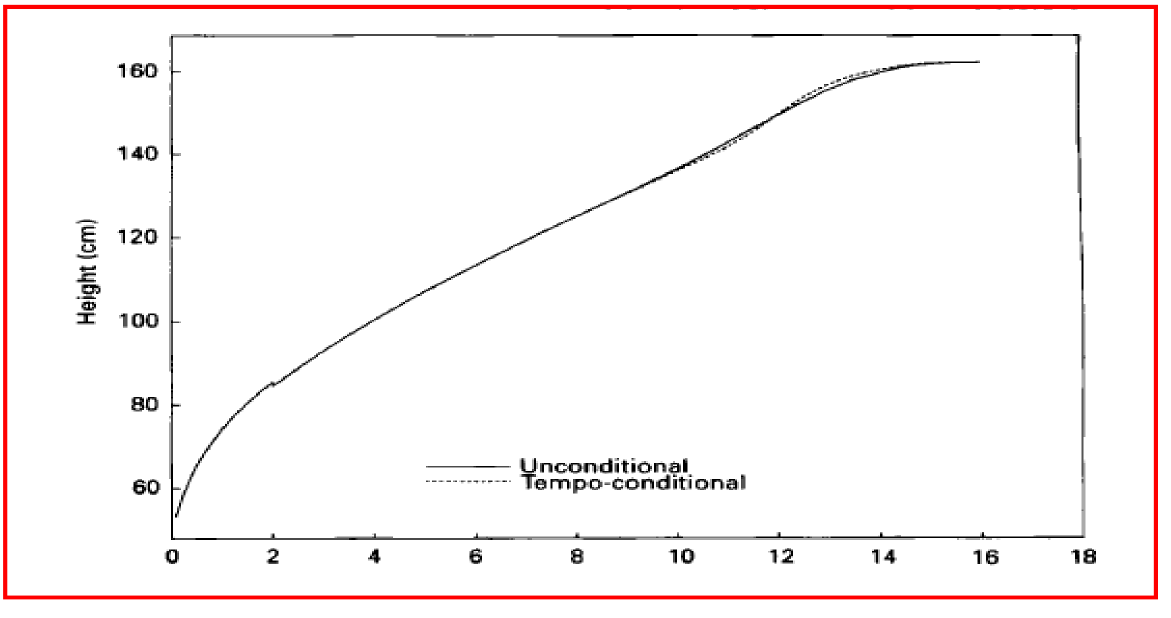

Figure 4: Velocity growth chart showing conditional and unconditional standards

1.1.8 Which chart should we use?

Variations due to ethnic, geographical, and regional factors we have different rates of maturation and adult stature even though the world's children appear to follow a similar growth pattern. Variability in final height of different ethnic groups exists. Thus for assessment, considering a national representative sample of population data are ideal as growth standards. Through basic anthropometric measurements such as body mass index, weight, height and head circumference the growth patterns of children can be evaluated and considerable information can be achieved about their nutritional status and global health. For the past three decades, reference curves recommended by World Health Organization (WHO) have been used to evaluate nutritional status of children in the world [23-24]. However, a child's growth can demonstrate differences due to environmental, genetic and nutritional factors [25]. Growth patterns demonstrate differences among different countries and among populations of different ethnic origin [26]. These differences in growth patterns have been reported to continue even after controlling for various factors such as health services, nutrition, environment, maternal and child health care and income distribution [27]. It is therefore recommended that every country should use reference height and weight curves based on measurements on their own children. These reference charts are constructed using different curve fitting methods. Different types of reference charts construction methods and their distribution methods are given below [28].

Table I. Methods for the construction of attained growth curves.

Method [Reference]	Centiles estimation	Curve-fitting method	Distributional assumptions
Bin methods, no smoothing			
Raw centiles, estimated separately [18]	Separately	None	None
Bin and smooth methods, without distributional assumptions			
Fixed knot splines [9]	Separately	Fixed knot splines*	None
Eye fitting (weight/age) [19]	Separately	Eye fitting*	None
Kernel regression [20, 21]	Separately	Kernel estimation*	None
CDC [14] Step 1	Separately	3-parameter linear*	None
CDC [14] Step 2	Together	Cubic splines*	Box–Cox normal
Bin and smooth methods, with distributional assumptions			
Eye fitting (height/age) [22]	Together	Eye fitting†	Normal
Box–Cox normalization [23]	Together	Eye fitting†	Box–Cox normal
LMS, version-1 [24]	Together	Cubic splines or others†	Box–Cox normal
Variance stabilization (height/age) [25]	Together	Polynomials†	Normal
Polynomial fitting [26]	Together	Polynomials†	Normal
Age handled continuously, without distributional assumptions			
Quantile regression, estimated separately [27]	Separately	Quantile regression*	None
HRY method [28]	Together	Polynomials*	None
Adapted HRY method [29]	Together	Grafted polynomials*	None
Kernel density estimation [30]	Together	Kernel density estimation‡	None
Non-Gaussian quantile curves [31]	Together	Nearest-neighbour kernel density of conditional cdf‡	None
Non-Gaussian quantile curves [32]	Together	4-parameter monotonic function (mean) and linear (dispersion)†	None
Regression quantiles, estimated together [33]	Together	Natural splines†	None
Age handled continuously, with distributional assumptions			
Multilevel models [34]	Together	ML estimation of linear and non-linear models†	Normal
Aitkin [35]	Together	Linear models†	Normal
Thompson and Theron [36]	Together	Polynomials†	Johnson system
LMS, version-2 [15]	Together	Cubic splines†	Box–Cox normal
Wade and Ades [37]	Together	Exponential functions†	Box–Cox normal
Wade and Ades (with correlations) [38]	Together	ML exponential (spread, skewness); polynomial (mean)†	Box–Cox normal
FPET method [39]	Together	Fractional polynomials†	(Modulus)-exponential-normal
Additivity and variance stabilization (AVAS) [40]	Together	Non-parametric regression AVAS†	Normal
Mean and dispersion additive models (MADAM) [41]	Together	Parametric or non-parametric functions (MADAM)†	Normal
S-distribution [42]	Together	Polynomials†	S-distribution
GAMLSS [43]	Together	Linear parametric or additive non-parametric†	Various
LSMT [44]	Together	Cubic splines or (fractional) polynomials†	Box–Cox-*t*
LSMP [45]	Together	Cubic splines or (fractional) polynomials†	Box–Cox-power-exponential

*Applied to centiles.
†applied to distributional parameters.
‡centiles calculated from density fitting.

Present study aims to construct locally weighted reference centile charts considering equal number of children in age wise, gender wise, urban-rural area wise and socio economic status wise between 6 -12 years old children in Tamilnadu.

1.2 Statement of the Problem

A study on development of pediatric reference charts

1.2.1 Aim of the study

Aim of the study is construction of pediatric reference centile charts for weight, height and body mass index using maximum penalized likelihood LMS method for Boys and Girls separately from ages 6 -12 years.

1.2.2 Specific objectives

1) Construction of reference charts for 6 -12 years Boys and Girls separately: Weight-for-age centile charts, Height-for-age centile charts, Weight-for-Height centile charts, Body Mass Index centile charts.
2) Comparison of fitted reference charts with National Center for Health Statistics/Centers for Disease Control/World Health Organization (NCHS/CDC2000/WHO2007) reference charts.
3) Estimation of prevalence of Malnutrition, Overweight and Obesity among Tamil Nadu children.

CHAPTER – II

REVIEW OF LITERATURE

2.1 Need for review of literature

This chapter deals with review of literature which is familiarizing oneself with practical or theoretical issues relating to a problem area often helps to generate ideas. Research literature review involves the identification, critical analysis, selection and written description of existing information on the topic of interest. The main purpose of reviewing relevant literature is to give a broad background knowledge or understanding of the information that is available related to the research problem of what we are interested

Related literature is reviewed in depth so as to broaden the understanding of the selected problem. The idea is to develop a deeper insight into the problem area, identify the psycho social impact of people with epilepsy, methods of assessing and development of tools.

An attempt has been made to review and discuss the research and non-research literature and their findings related to the present study. The literature review was conducted systematically using Medline, Pub Med, Global Health, Scientific Information Database (SID), Yahoo, Google scholar search engines, with the key words related to subject headings: anthropometry, percentile charts, Z-score, LMS, LMSP, BCPE, AIC, GAIC, Worm Plots, Q-test, smoothening procedures, strength and limitations. Reference lists of relevant articles were searched. Emphases were given to recent literature although some older books and articles were also reviewed. Reviews are collected under the following 5 headings:

a) Literature reviews related to history of growth charts

b) Literature related to statistical approaches to the construction of reference charts

c) Literature reviews related to LMS methods for construction of centile charts

d) Literature related to comparison of NCHS/ WHO2007/ CDC2000 charts, with

e) study charts

f) Literature related to prevalence of Obesity, underweight, stunting and wasting

2.2 Literature reviews related to history of growth charts

History of growth chart starts from 19th century onwards. Widely used by health policy makers and practitioners for monitoring the growth and development of infants and children in developed and developing countries for the past seventy-five years.

2.2.1 Galton chart (1885) [29]

Galton had invented anthropometric percentiles, as he called them, to summarize the distribution of body measurements of, "9337 persons measured in his Anthropometric Laboratory at the International Health Exhibition (1884)[29]". He compared the distributions of measurements for both sex by identifying the percentile for each sex where the distributions crossed, counting up for the men and down for the women.

2.2.2 Bowditch chart (1891) [30]

Bowditch [30] charts were published based on Galton's percentiles. Bowditch extended this idea by displaying percentiles of height for Massachusetts children on a chart, so they appeared as curves plotted against age. By putting age on the abscissa he allowed changes in size with age, i.e. national growth, to be displayed at the same time.

2.2.3 Meredith chart (1940) [31]

For individual assessments, many years the pioneer data for children developed in the 1940s by Meredith at Lowa [31] were used. These data were derived from a small and unrepresentative sample of US children, most of who were of a high socio economic status. In the 1960 and 1970, two lowa data sets were often used as growth references: the Harvard growth curves and Tanner growth curve from the UK.

2.2.4 Harvard Growth Curves (1960-70) [32]

In the middle of twentieth century, the use of reference charts expanded considerably. Various sets of reference data for height and weight were developed, most notably the Harvard standards (Vaughan & McKay, 1975) [32].

- In 1966, WHO simplified the Harvard growth curve by introducing the combined sex version
- International growth reference
- Boston children's hospital reference data (1930-56) hospital based , longitudinal study , small sample size and top fed babies were used
- It helps for the purpose of creating an awareness and need for monitoring & growth assessment

It is used in Indian growth charts & for classification of malnutrition since middle of 1970s (50th centile taken as 100%)

2.2.5 British charts (1966-2000) [33, 34]

Tanner-Whitehouse charts

Tanner et al.[33] developed the first growth chart for British children. The Tanner-Whitehouse growth charts were derived from London children measured in 1959 but adjusted slightly to be appropriate for 1965. The major height and weight centiles on the Tanner-Whitehouse chart were 3rd, 10th, 25th, 50th, 75th, 90th and 97th. The height and weight data that contributed to the standard were derived from three sources: Supine lengths, heights and weights from birth to 5.5 years were from a longitudinal sample of around 80 children from central London measured at the London Child study centre [34] heights and weights from 5.5 to 15.5 years were a cross-sectional sample (approximately 1000 boys and 1000 girls for each year of age) taken from the London County Council survey of 1959; and heights and weights from 16.5 to 20 years were a longitudinal sample of 30 children from the Harpenden Growth study .In infancy, the sample size on which the Tanner-Whitehouse charts is based is very small, in view of infancy being such a critical period of a child's growth. However Tanner does suggest that these measures are in reasonable agreement with those taken on 250 children (of each sex) in the Oxford Child health survey. In addition, growth of children in London may not represent the full picture of growth experienced in other areas of the UK.

Obviously, at the time of creation of these charts the computing technology was far behind what is possible today; so much of the smoothing of centile curves was done by eye. In adolescence, children mature at different rates. Tanner et al. gives this the term 'phase-difference'. The shape of the distance curve at adolescence was derived from 49 boys and 41 girls from the Harpenden Growth study that had sufficient data over the adolescent time period. There is a break in the Tanner-Whitehouse height charts at 2 years, the time at which length measurement switches to height measurement. Tanner et al. also presented the first British height and weight velocity references.

The UK 1990 reference and its revision [35-45]

At the time of publication Tanner stated that the growth reference should be updated every 10 to 15 years. Many authors [35,36] raised their concerns that the Tanner-Whitehouse reference was out of date and in need of revision. The main concerns were that the growth data that formed the reference was from the South East of England (mainly London) and the secular trend to earlier maturity and greater adult height [37] Freeman et al. The Tanner-Whitehouse references were based primarily on 'bottle-fed' children, whereas present day feeding practices promote breast-feeding. In infancy use of the Tanner-Whitehouse reference for Cambridge infants that were breast-fed lead to the impression that the child's growth was faltering from 3-4 months after having an initial advantage. In Newcastle, where the proportion of breast-fed and bottle-fed children is unknown, a similar pattern was observed for both the NCHS and Tanner-Whitehouse references [38]. Conventionally, growth charts had always been characterized by the 3rd, 10th and 25th centiles below the median and 75th, 90th and 97th centiles above. The World Health Organization uses cut-offs based on Z-scores [39]. Cole proposed that the format of a growth chart should be revised from a 7 to 9 centile chart, with each centile spaced two-thirds of a Z-score apart. So interpretation of Z-scores and centiles are compatible. In the production of the UK 1990 reference this proposal was put into action. The distribution of UK 1990 reference is summarized by the 0.4th, 2nd, 9th, 25th, 50th, 75th, 91st, 98th and 99.6th centiles. Using the 0.4th centile as cut-off results shows only one normal child in 260 that lie below this cut-off. Growth data from seven sources were used to create the UK 1990 growth reference for height and weight. The reference sample totaled over 25000 individuals from growth surveys between 1978 and 1990 [37]. The National Study of Health and Growth (NSHG) height and weight measurements were used as the reference data set as these were the most recent. The other data frames were then adjusted accordingly. Ethnic minorities were excluded because these populations are known to exhibit different growth patterns Cole [40] published the first UK reference for the body mass index. This was derived from the same data sources as the original UK 1990 reference [37]. The body mass index of children changes substantially with age [40]. In infancy it rises steeply to a peak at about 8 months, it then falls in the preschool years and flattens out around 5.5 years (often termed the 'adiposity rebound') and finally rises into adulthood. It is often thought to be indicative of later obesity, degree of skewness in the distribution of body mass index than for weight .The original UK 1990 reference was shown to have a sex bias for weights in infancy. There were two and half times more girls than boys with weights below the third centile during the first year. The UK 1990 reference was then revised according to Preece et al., [41] and according to Cole et al., [42] there is no longer a sex bias in the current reference. UK 1990 reference data were analyses by maximum penalized likelihood using the LMS method (Cole and Green 1992). It assumes positive skewed data can be normalized using power transformation [43]. The values of LMS parameters coefficients are available in Microsoft Excel format or as text files from the Child Growth Foundation [44]. Four growth references Gairdner-Pearson, Buckler-Tanner, Tanner-Whitehouse and the UK 1990 growth reference are widely used at present or in the past. The overall consensus was that the Gairdner-Pearson and Tanner-Whitehouse references were obsolete and that for clinical purposes the use of the revised UK 1990 reference is advocated. According to Cameron [45] Buckler-Tanner reference charts more useful for adolescence.

2.2.6 National Centre for Health Statistics (NCHS) growth reference and its revision [46]

Clinicians used various growth charts before 1977, based on samples of children that did not represent the U.S. population. Many expert groups suggested the need to develop charts based on nationally representative survey data. Based on these suggestions, NCHS Growth Chart Task Force, developed separate growth percentile curves for boys and girls. These growth references are known as the 1977 NCHS growth charts [46].

NCHS growth reference was derived from four sources: Fels longitudinal study (1929-1975)" from birth to 3 years and nationally representative data from the National Health Examination Surveys (NHES II and III : 1963-70) and the first Health and Nutrition Examination Survey (HANES I : 1971-74) from 2 to 18 years.

The NCHS created references for two age groups: birth to 36 months and 2 to 18 years. This resulted in a discontinuity in the growth reference, with some discrepancy in the age range 2-3 years. In the age range, charts were created for weight-for-length, weight, length and head circumference for birth to 3 years. From 2 to 18 years; charts were created for height and weight. Weight-for-height charts were only created for prepubescent boys and girls (up to 10 years). Major centiles on these growth charts were the 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th}. These were smoothened using least-squares-cubic-splines. The NCHS growth reference was adopted in the late 1970's by the World

Health Organization (WHO) to provide an international growth reference. The reference was based on a restricted sample of American children and regarding technical and biological aspects it had some weaknesses that did not completely make it suitable for monitoring of fast changing growth of early childhood. Weakness is absence of curves for body mass index and more formula fed children.

2.2.7 Center for Disease Control and Prevention (CDC) charts [47,48]

To overcome the limitations of NCHS/WHO charts, after many discussions for updating the NCHS/WHO reference has undergone revision and is now known as the Centers for Disease Control and Prevention (CDC) 2000 growth reference [47.] Major changes to the NCHS reference are the inclusion of the third and ninety-seventh centiles, Fels longitudinal infancy data replaced by nationally representative data, extension of charts to 20 years and elimination of disjunction between curves for infants and older children. The CDC 2000 growth charts include a new BMI-for-age reference covering the age range: 2 to 20 years. The BMI growth chart also includes the 85th percentile because this is the recommended threshold for identifying overweight children. The CDC 2000 growth reference was constructed from five national health examination surveys collected from 1963 to 1994 (NHES II and III, and NHANES I, II and III) and five supplementary data sources. In order to avoid the influence of increased body weight and BMI in the most recent national survey, data from NHANES III above the age of 6 years was excluded.

The centiles of the CDC 2000 growth reference were derived using a two stage process. Initially the empirical centile curves were smoothened using either parametric or non-parametric approaches depending on the growth variables considered. In infancy the

Guo et al.[48] model was applied to length, weight and head circumference data. Whereas in childhood a non-linear model was applied to stature data, a polynomial regression model was applied to weight-for-stature data, and a locally weighted regression procedure was applied to weight and BMI data. In the final stage smoothened centile curves were estimated using a modified LMS estimation procedure.

2.2.8 World Health Organization (WHO) growth curves [49]

Between 1997 and 2003, WHO generated this reference for children between 0-5 years old in two component forms of cross-sectional and longitudinal surveys. In the longitudinal surveys, cohorts of 882 newborns were measured from birth through 2 months. Based on WHO recommendations, the reference included at least 4 months exclusive breastfeeding and for at least 12 months continued breastfeeding. Complementary feeding started from 6th month. In the cross-sectional component 6669 children aged between 18-71 months with a minimum duration of 3 months exclusive breastfeeding were included. The standard was prepared as weight-for-height, weight-for-age, height-for-age, and BMI. Raising some question about the previous standards and to prevent the limitations of previous standards that were limited to a certain location, WHO and United Nations university started a study from 1997 with the aim of formulating a new international standard for assessing the growth and development of infants and young children worldwide with an age between birth to 5 years. This was actually a Multicenter Growth Reference Study (MGRS) and its data was gathered from several countries. To compare the world wise growth pattern of children, greater than 8,000 healthy children from 6 different countries (Brazil, Ghana, India, Norway, Oman, and the United Sates) were surveyed.

The children were selected in optimal life and environment conditions provided with good healthcare and without any acute diseases. Their mothers were nonsmokers before after pregnancy and followed WHO feeding criteria such as:

1. Exclusive or dominant breastfeeding at least for 4 months
2. Introduction of complementary foods at the age of 6 months.
3. Still on breastfeeding at 12 months

For the first time, the standard created a harmony between breastfeeding instructions and assessment of child growth. It has more accurate assessments of breastfeeding and complementary feeding with the help of new standards. Or we can say child growth standards of WHO is a new tool to provide the best healthcare and nourishment for the children worldwide. There are also some speculations that these standards are not applicable to Asian countries and separate standards should be generated reflecting lower growth rate and poorer socioeconomic status. Countries like The Netherlands, United Kingdom, France, Norway, India and China have created standards for their countries.

2.2.9 The WHO Reference 2007 (5-19 years) [50]

Previously WHO recommended the National Center for Health Statistics (NCHS)/WHO international reference for assessing growth in children and adolescents above 5 years of age. However this reference had several drawbacks: The BMI reference data starts only at 9 years of age and it has only 5^{th}-95^{th} limited percentile range. Also the NCHS reference curves were constructed using a different method compared to what was used for the WHO standards.

The NCHS data were merged with the records of the 18-71 year-olds of the WHO standards sample and this new data set was used to derive a new reference by applying state-of-the-art growth curve construction methods.

The growth curves for ages 5 to 19 years were constructed using 30907 observations (15537 boys, 15370 girls) for the height-for-age curves, 30100 observations (15136 boys, 14964 girls) for the weight-for-age curves, and 30018 observations (15103 boys, 14915 girls) for the BMI-for-age curves.

The resulting curves for BMI-for-age, height-for-age, and weight-for-age (up to ten years of age) are considered new charts. The reconstructed charts for school-aged children and adolescents have been named the WHO Reference 2007.

2.2.10 Indian charts [51,52]

In India, the first growth chart construction attempt was made by the Indian Council of Medical Research (ICMR) [51] and these ICMR standards have been hitherto used for evaluation of the growth of normal Indian children, but these were drawn mainly from the lower socio-economic group of children. Thus, surveyed reference population could not have been truly "normal". Due to chronic under- nutrition many of the subjects might have been stunted. Also, this study was conducted five decades ago (1956-1965). Since then there has been improvement in the socio-economic status of the general population. The general improvement in health care facilities and nutrition has resulted in an upward trend in growth in many countries. There is a need for new reference data from healthy well-nourished Indian children. Many Indian studies tried to formulate such reference data, but in all these studies, the sample size was very small. The growth charts compiled by Agarwal, *et al.*, [52] are based on affluent urban children from all major zones of India surveyed during 1989-91. These percentile charts provide information on growth from birth to 18 years. These charts are suitable for growth monitoring in Indian children and are recommended for use by the Growth Monitoring Guidelines Consensus Meeting of the IAP.

2.2.11 Comparison of NCHS, CDC and WHO charts [53-55]

Today, three growth charts are available for the health professionals to monitor the nutritional state of children from 0 to 5 years of age: a) National Center for Health Statistics (NCHS/1977), [53] b) Centers for Disease Control and Prevention (CDC/2000) [54] and c) WHO/2006 [55]. For the validation and development of these charts, studies were conducted in several populations to identify the differences between these three charts. Similarly there are three growth charts available for the health professionals to monitor the nutritional status of children from 0 to 20 years of age. In the **NCHS/1977 charts**, all age groups and social classes were included in the group between **2 and 18 years old**, but only middle class white individuals were included in the age group between 0 to 36 months old. In the **CDC/2000 charts**, American individuals of different ethnic diversity, between **0 to 20 years old**, were included, lower and upper stature limits were extended, advanced statistical tests were made and new percentiles were presented to the 16 charts available. In the **WHO/2007 charts**, designed for children from **5 to 19 years old** from different ethnic groups (data collected in several countries), were based on what is considered as “ideal” growth of these individuals, without environmental, nutritional, economic, or genetic limitations to their development.

Available standards and references:

According to Khadilkar V, Phanse S. [56] in India as on 2013, following growth charts are available

1. WHO MGRS standards for children under the age of 5 years
2. NCHS (American) References for children from 0-19 years
3. Indian Academy of Pediatric growth charts - Growth monitoring guidelines 2007 for 0-18 years (Khadilkar *et al*. Derived from 1989-92 data by K.N. Agarwal *et al.*,)
4. Khadilkar *et al.* 2007 Indian growth references for height, weight, and BMI for 2-18 years
5. International Obesity Task Force (IOTF) BMI charts for 5-18 years old children
6. Khadilkar *et al.* 2012 - BMI cut offs for 23 and 28 adult equivalent BMI values for 5-18 year old Indian children.

2.3. Literature related to statistical approaches to the construction of reference charts [57]

Age-related reference intervals are not only used in the construction of 'growth charts' it is also used in construction for other variables such as CD4 counts, weight gain during pregnancy, serum cholesterol and blood pressure. They are commonly used in the routine monitoring of individuals; here interest is in detecting extreme values, such as those below the second centile or above the ninety eighth, possibly indicating abnormality. [57]

The quality of a growth reference depends on two factors, namely the data used to derive it and the statistical approach used to arrive at the centiles.

Generally, method of estimation of centile charts are divided into two broad categories: parametric (based on modeling the distribution) and non-parametric (empirical).

2.3.1 Mean and SD model [58]

In this most common parametric method, the basic assumption is that at each age the measurement of interest has a normal distribution with a mean and SD that varies smoothly with age. A desired centile curve is then calculated using formula

$$c_{100\alpha} = \mu + k \cdot SD$$

where k is the corresponding centile of the normal distribution (e.g. for 10th and 90th centile k is ±1.28, for 5th and 95th centile k is ±1.645, etc.) and mean (μ) and Standard deviation (SD) at the required age for the reference population. Least-squares regression analysis helps to model both the mean and the SD curves as polynomial functions of age[58].

2.3.2 Logarithmic transformation[59]

Mean and SD model is based on normality assumption. Weight, body mass index measurements often present skewness in the distribution, generally positive, right tail is longer than the left. To overcome this logarithmic transformation is useful. The solution at the same time stabilizes the variance in case the SD increases rapidly with age [59].

Royston [59] suggests if residuals from the initial model show a positive skew to perform a logarithmic transformation on the original value y and refit the model on log (y). If refitted model residuals are skewed, then it is recommended to try a shifted logarithmic transformation of the form log (y + C), with C>0 for residuals negatively skewed and C<0 for positively skewed. Once the model is finalized it is important to back-transform the curves using antilog.

2.3.3 Fractional polynomials [60]

Conventional polynomials are having many disadvantages. Small level order polynomials offer only a few curve shapes and thus do not always fit the data well, whereas high level order ones may fit badly at the extremes of the observed range. Also, they do not have asymptotes and cannot fit data where limiting behavior is expected. Royston and Altman [60] proposed an extended family of curves, called fractional polynomials (FPs), whose power terms are restricted to a small pre-defined set of non-integer &integer values. Conventional polynomials are a subset of this type of family. Suppose polynomial is of a form

$$a + b \,.\, t + c \,.\, t^2 + d \,.\, t^3 + \ldots$$

FPs are defined as

$$a + b \,.\, t^{p1} + c \,.\, t^{p2} + d \,.\, t^{p3} + \ldots$$

where p_1, p_2, ... are chosen from the set {-2, -1, -0.5, 0, 0.5, 1, 2, 3}. Conventionally, the power 0 represents natural logarithmic transformation, so that t^0 equals to $\log_e(t)$. In this case, the second term is multiplied by $\log_e(t)$. For example, an FP of degree 3 with powers (0, 2, 2) is then of a form

$$a + b.\ log_e(t) + c \,.\, t^2 + d.\ t^2.\ log_e(t)$$

An FP of first degree is of the form $a + b.t^p$. For a given data set, the best value of p is found by fitting eight separate linear regressions using $t^{-2}, t^{-1}, \ldots, t$. Regarding FPs of the second degree ($a + b.t^{p1} + c.t^{p2}$), using the standard set detailed above would involve fitting a model for each of permissible combinations of powers. Smallest residual SD model is chosen as the best. The use of FPs can often give a better fit even with fewer terms compared to conventional polynomials.

2.3.4 LMS method [61,62]

The Lamda-mu-sigma (LMS) method, introduced by Cole [61,62] and further refined by Cole and Green [63], is an extremely flexible and widely applicable semi-parametric method which can produce smooth centile curves even for complex shape data. It also helps to smooth skewness, which cannot be taken into account with classical logarithmic transformation. Suitable power transformation was taken to remove skewness and normalize the data. This type of transformations is that proposed by Box and Cox [64], with the optimal power λ at a given age calculated from the data to completely remove the skewness.

The distribution of the variable of interest y changes smoothly with age and is completely summarized by three parameters λ (skewness), μ (median) and σ (coefficient of variation), the initials of which (L, M and S) give the name to the method.

The LMS method assumes that anthropometric data can be transformed to normality using a power transformation, thus removing any skewness. Cole also says in using the LMS method there is no guarantee that once the skewness is removed the resulting distribution will be normal. Cole states that after the power transformation the distribution will be nearer to normal, in particular, the mean and median will be closer together on the transformed scale than on the original scale. However, there is no certainty that the higher moments of the transformed distribution, such as the kurtosis, will coincide with those from the normal distribution nevertheless, kurtosis tends to be less important than skewness as a contributor to non-normality.

2.3.5 LMSP method [65]

The Lamda-mu-sigma-additional parameter (LMSP) method of Rigby and Stasinopoulos [65] is a generalization of the LMS approach. It uses a Box-Cox power exponential distribution (BCPE) to remove the problems of kurtosis. The BCPE distribution has four parameters (μ, σ, ν and τ) which may be interpreted as relating to location (median), scale (Coefficient of variation), skewness (transformation to symmetry) and kurtosis (power exponential parameter). This distribution provides a flexible model for both skewness and kurtosis (platykurtosis or leptokurtosis).maximum penalized likelihood is used to fit the model.

2.3.6 HRY method [66,67]

Healy, Rabash and Young [66] (hence HRY) proposed a non-parametrical procedure based on the technique of Cleveland [67] locally weighted regression for smoothing a scatter plot. This approach makes no assumption about the nature of the distribution .At the same time it is expected that both centiles themselves and the intervals between centile at a fixed age should behave smoothly. In this method Spacing between centiles can be expressed as a low-order polynomial in the underlying Z-score.

2.3.7 Quantile regression method [68,69]

Quantile regression [68] approaches for constructing the reference curve is non-parametric method. Parametric distributional assumptions not needed, thus they are valuable in case that any transformation method is not able to achieve normality over the full range of relevant ages. It is robust method when presence of outliers and all the smoothing parameters are determined adaptively. Kernel estimation, local constant kernel estimation and double kernel estimation of conditional quantile curves methods are proposed by Gannoun et al. [69].

2.3.8 Comparison of different methods of age-related references centile charts [70-74]

Age-related reference charts can be constructed using different methods. Each method is having both advantages and disadvantages. Hence, it is unlikely that a single one would be appropriate in all circumstances.

According to Hynek M [70] The parametric 'mean and SD model' is simple and easy to use and this techniques available in most basic statistical packages. It is based on normality approach. The approach is able to cope with some heteroscedasticity by modeling the SD as age-varying and skewed data may sometimes be corrected by logarithmic or shifted logarithmic transformation. However, skewness and kurtosis cannot be easily accommodated. The fact that the method suffers from the well-known limitations of a polynomial curve shape can be greatly improved by using the family of fractional polynomials.

The LMS method, also known as lamda-mu-sigma method, semi-parametric method is extremely flexible and widely applicable method which can produce smooth centile curves even when the data appear to have a complex shape. Also, time-varying skewness, which cannot be taken into account with classical logarithmic transformation, can be easily dealt with LMS procedures. Suitable power transformation can remove skewness and normalize the data. The distribution of the variable of interest y changes smoothly with age and is completely summarized by three parameters λ (skewness), μ (median) and σ (coefficient of variation), the initials of which (L, M and S) give the name to the method.

The LMS method has been increasingly used in recent years and it was the chosen procedure for creating the 2000 CDC Growth Charts for the United States [71]. The introduction of specially designed programs (LMSChartmaker by Cole and Pan [72] and packages for general statistical programs (package lmsqreg by Carey [73] for R) made the method rather accessible.

Generalization of LMS method is called LMSP method. LMSP method based on BCPE distribution, which is more flexible as it takes into account the presence of skewness as well as kurtosis in the distribution when constructing age related smooth percentiles.

HRY method is not required for making any assumption about the nature of distribution. It is flexible and capable of handling many patterns of growth, with the suggestions of Goldstein and Pan [74] making it even more so. Also, considerable experience and trial requires for choice of degrees of polynomials, and it is not always clear how to improve the fitting of the curve. Estimation of the Z-score and centile value not simple and this method is vulnerable to outliers.

Quantile regression is non-parametric, robust, and extremely flexible, provide a much better fitting to the data than other methods, the possibilities of applications are very wide. It is having the ability to find the features in the data undetected by other methods and is rapidly entering mainstream statistics. It is having ability to extend the conventional unconditional models depending only on the age to models that incorporate prior growth and other covariates. Another advantage is availability of statistical software to build statistical models.

Main drawback of this approach lacks an explicit formula to convert measurement into quantile and *Z*-score. Fitted curves may be irregular near the extremes, and are generally less pleasing.

The explicit formula that allows one to convert a measurement into centile or Z-score was one of the requirements set forth by a WHO expert committee. So empirical methods, such as the HRY method and quantile regression approach are excluded. Hence, the choice is basically left to the simplicity and usability of parametric approaches. More flexible and applicable but less user-friendly models of LMS and LMSP methods are widely accepted for the construction of age related centile charts.

2.4 Literature reviews related to LMS methods for construction of centile charts

Maryam Emdadi et al (2011) [75] used the LMSP model, a generalized model of LMS method. LMSP provides a model for a dependent variable which shows both skewness and kurtosis. Also, LMSP method summarizes the changing distribution with age according to 4 curves representing the median (*M*), the coefficient of variation (*S*), skewness (*L*), and kurtosis (*P*). In this method the maximum penalized likelihood is used. The use of the maximum penalized likelihood approach allows us to provide smooth estimates of *L, M, S, P* curves directly. In this paper they constructed percentile curves of body mass index for Iranian boys and girls. The paper compares the results with the recent World Health Organization (WHO) and Center for Disease Control (CDC) results.

The study of **Ms. Rachana Patel** et al (2010) [76] was conducted for determining Cut-off Points of Malnutrition of Indian Children, they have taken 7679 (4206 boys and 3473 girls) children centile curves are constructed using LMSP method of BCPE distribution . New curves have good fit for both girls and boys. Finding shows Indian children had relatively low mean z-scores for height at each age as compared with the WHO standard while pace of growth in height is almost same as WHO standard at each age. Children were considerably stunted by WHO standard as compared to New Growth curve.

Yuanyuan Han et al (2007) [77] describes in his research paper as LMS, and LMSP methods are all helpful to output the centiles we need, but the LMS and LMSP deal the age could predict any centile and centile curves. These methods are more suitable for cross sectional data. Besides, if we use the first method, the centile curves would be significant when it is a linear model, which is too weak to meet our smoothening aim. So the LMS and LMSP have advantages in this field, what's more, LMSP is more convinced and reliable.

Ahmet ÖZTÜRK et al (2012) [78] states that, LMS method which uses Box-Cox Normal (BCN) distribution is the most used method for fitting growth curves models. Even though its popularity, it cannot fit the kurtosis of the measurements. A more recent LMSP method which uses BCPE distribution can both fit skewness and the kurtosis of the measurements. In this study, they addressed LMSP method and an application indicating its superior performance than the other methods.

WHO Multicenter Growth Reference Study Group (2006) [79] describes the methods used to construct the percentile charts based on length/height, weight and age. The Box-Cox power exponential (BCPE) distribution, cubic splines curve smoothing was used to construct the curves. The BCPE distribution method accommodates normal, skewed or kurtotic, as necessary. Goodness of fit methods was used to detect possible biases in estimated percentiles or z-score curves

Marjan Mansourian et al (2012) [80] constructed the growth chart of a nationally representative sample of Iranian children aged 10–19years, and to explore how well these anthropometric data match with international growth references. The Box-Cox power exponential (BCPE) method was used to calculate height-for-age and BMI-for-age Z-scores for participants. Normal, overweight, obesity and thin children were identified using the BMI-for-age z-scores. Stunted children were detected using the height-for-age z-scores. The percentile curves of the Iranian children was generated and smoothened by cubic splines.

2.5: Literature related to comparison of NCHS/CDC/WHO2007 charts with study charts

In **Marwaha RK** et al (2011) [81] study, they found height of boys and girls was consistently higher at all ages when compared with earlier India data. Height was 2–4 cm lower than WHO multicentre study of 2007. Weight for age percentiles showed a rising trend both in boys and girls. Approximately 4 kg more median weight at all ages in both boys and girls than that reported in affluent Indian children two decades earlier.

Razzaghy Azar M et al (2006) [82] study describes, in boys, there were some significant differences of mean standard deviation scores (SDS) of height and BMI from zero, but no significant differences observed in weight. In girls, the mean SDS of BMI, weight and height were significantly lower than zero, specifically for 7-9 years of age. 12-13-year-old girls, the mean SDS of BMI, weight and height came closer to zero, but the differences were not statistically significant. After that, although girls seemed to be shorter than US reference measures, their BMI and weight did not differ significantly from reference values.

Mitra Abtahi et al (2011) [83] European and Asian countries study shows that the performed results of height and weight curves of these children were different from WHO and NCHS growth standards. In Iranian children the mean height and weight of girls and boys were increased. Even though height and weight are increased, the median height and weight of Iranian boys and girls under 15 years was under 20th percentile of the United States National Center for the Health Statistics.

Ayatollahi SMT et al (2010) [84] study shows that in boys and girls Weight-for-height centiles were nearly close to each other, but children of older age in which boys' centiles lay below those of girls. Present study centiles study better than the previous one. For a given height, both male and females CDC weights were greater than those of Iranians.

Yi-Fang Jiang et al (2006) [85] in his study observed that the overweight prevalence in Shanghai boys is close to that of the USA, but in Shanghai girls it is lower, or similar to that of the Netherlands and Singapore. This result indicates the marked difference in overweight prevalence between boys and girls in Shanghai. The different percentiles on BMI cut off points in these countries are also associated with sampling time of the database.

Sina Aziz et al (2012) [86] study shows, the difference between mean Z score for Body mass index, weight and height were statistically significant compared with the CDC charts. Also they admit the facts that the individual anthropometric measurements of Pakistani children were less compared to the CDC charts.

Mushtaq, M.U et al (2012) [87] study shows Pakistani school-aged children significantly differed from the WHO and USCDC references. However, mean z score relative to the WHO reference were closer to zero as well as USCDC reference. Obesity and overweight were significantly higher while underweight and thinness were significantly lower relative to the WHO reference as compared to the USCDC reference and the IOTF cut-offs.

Mathieu Nahounou Bleyere et al (2013) [88] Pakistan school going children study shows more undernutrition rates observed in children aged 5 to 11 years are lower compared to those established by the WHO standards.

2.6 Literature related to obesity, underweight, stunting and wasting

Manu raj et al (2007) [89] found that, overweight was 7.33% among boys and 5.87% in girls , obese was 2.47% among boys and 1.34% in girls based on large sample study of 20263 children between 5-16 years children.

Vigneswari Aravindalochanan et al (2012) [90] study shows overall prevalence of overweight is 14.9% and obesity is 17.2 among 9 – 10 years Central Board of Secondary Education School going children of Chennai-metropolitan city in 2012.

Manu raj et al (2012) [91] reported in his study an overall prevalence of obesity in 4.2% (3.2% in boys, 5.5% in girls) based on a study of 1083 school-going Indian children (12–17 years).

Vohra R et al (2011) [92] found overweight was 4.17 and obesity 0.73% among school-going 5-12 years children of Lucknow city.

Khadilkar VV et al (2011) [93] study shows overall prevalence of overweight and obesity is 23.9% based on multicenter study (20 243 children) conducted in eleven affluent urban schools from five geographical zones of India in the 5-17 years age group

Srihari G et al (2007) [94] in a meta-analysis, based on literature search using Medline literature database search, followed by review of full length journal papers and unpublished materials such as research reports, pointed out, Overweight and obesity were prevalent among 8.5-29.0% and 1.5-7.4% respectively among school children.

Anjum Fazili et al (2012) [95] from Kashmir study reported 11.2%, 9.25% and 12.3% prevalence for underweight, stunting and wasting respectively. Mean weight and height were higher in females than males. The overall prevalence of under nutrition was 19.2%. The prevalence of underweight was lowest in 5 year female (0.0%) and highest in 6 year male (21.5%). For Stunting 7 year males recorded the lowest (0.0%) and 12 year males the highest (28.5%) prevalence. The highest and lowest prevalence of wasting was recorded in 6 year old females (2.56%) and 9 year old males (24.6%) respectively.

Mendhi G K et al (2006) [96] reported in Assam 6-8 year old children wasting was 21.1%, stunting 47.4% and underweight 51.7%. Prevalence of stunting and thinness was 53.6% and 53.9% respectively among the children in the age group of 9-14 years age group. They also pointed out there was no significant differences in the prevalence wasting, stunting and underweight between boys and girls.. They found a definite age trend in the prevalence of wasting but no such trend was seen in case of stunting and underweight.

Bandopadhyay D et al (1988) [97] from Navinagar Mumbai reported prevalence for wasting17.0%, stunting 16.8%, and underweight 42.3%. **Mitra M** et al (2007) [98] from Chatisgarh reported prevalence of underweight 90.0% and stunting 47.5%. **Chowdhary SD** et al (2008) [99] from Puriliya West Bengal also reported figures of underweight 33.7%, wasting 29.4% and stunting 17.0%. **Samiran Bisai** et al (2011) [100] West Bengal study shows24.4%, 16.0% and 1.7% of children were found to be stunted, underweight and wasted respectively.

Midha T et al (2012) [101] Meta-analysis based on 9 studies (92862 children) shows prevalence of overweight is 12.64% and obesity is 3.39 in India. **Unnithan AG** et al (2008) [102] study conducted at Kerala shows, among 3886 school going children 17.73% were overweight and 4.99% were obese. **Chhatwal J** et al (2004) [103] *a* Punjab study shows 14.2% were overweight and 11.1% were obese for 9-15 years children. **Kalpana CA** et al (2011) [104] *a* Coimbatore based study shows, among 11470 schools going 7-12 years children 7.6% were overweight and 5.6% were obese. **Kaur S** et al (2008) [105] study shows, among 16595 (2-18 years) children 8.7% were overweight and 2.8% were obese. A study by **Sood A** et al (2007) [106] shows among 9-18 years children 13.1% were overweight and 4.3% were obese. **Mahajan PB** et al (2011) [107] form Pondicherry study shows prevalence of overweight and obesity was 4.98% and 2.24% respectively among 6-12 years children. **Jahnavi V** et al (2011) [108] study from Hyderabad shows prevalence of overweight and obesity was 6.6% and 2.8% among 11-16 years children.

CHAPTER –III

METHODOLOGY

3.1. Study Design

Population based cross-sectional multi center (various schools) study design was used to collect the Demographic information's and Anthropometric measurements of School children (both boys and girls) in the age group of 6–12 years, studying in government and private schools located in 3 districts of Tamilnadu were studied from July 2010 to December 2012. Children were categorized according to yearly intervals based on completed years of age. The study protocol was approved by the institutional ethical committee of the Institute of Child health and Hospital for Children (ICH &HC). Prior consent for the study was taken from the school administrations. At the time of initiating the study, the parents of each participant were informed about the study protocol and written consent of parents was obtained prior to their child's participation.

3.2. Study site

This study was carried out in Tiruvallore, Trichy and Madurai districts of Tamil Nadu. Data was collected from Urban as well Rural areas in these three districts. Urban and rural areas are Tiruvallore taluk-Palliput taluk (Tiruvallore District) , Srirangam taluk –Musiri taluk (Trichi District), Thirumangalam taluk –Usilampatti taluk (Madurai District). Tiruvallore district is situated in north part of Tamil Nadu. Trichy district is situated in central part of Tamil Nadu. Madurai district is situated in south part of Tamil Nadu.

3.3. Study population

The study population consisted of 6-12 years children from all social groups and from families of high, moderate and low income**.** Target population consist of 6-12 years children in the selected urban–rural middle schools based on a representative sample of 2520 boys and 2520 girls examined between 2010- 2012, and are appropriate for the developing reference charts.

3.4 Inclusion and Exclusion criteria

Inclusion criteria for study subject are healthy well-nourished both male and female children in the age group of 6 -12 years are eligible to participate if their parents gave their consent.

Exclusion criteria are sick children excluded as those with physical disabilities that interfered with anthropometric measurements, endocrine disorders, chronic neurological disease, and dehydration.

3.5. Data collection tool

Data collection tool was developed based on literature review from textbooks, journals, Workshops, Conference and by Internet searching. Opinion from experts in the field of Statistics and Pediatrics was obtained.

Data collection tool was divided into 2 main parts as Socio-demographic data tool and Anthropometric measurement tool. Socio-demographic data tool is a pre-designed questionnaire, it consist of 6-12 years school children information as well as their parents information. Anthropometric Measurements tool designed to record 6-12 years school children Weight, Height Body Mass Index measurements.

Part I

Socio demographic profile consists of child age, Education, Religion, Community, Residence, Age of parents, Educational status of parents, Marital status, Occupational Status, and Type of family.

Part II

Anthropometric measurements consist of 6-12 years children Height, Weight and Body Mass Index

3.6. Duration of the study

The study was conducted in 24 middle schools in Tamil Nadu (8 schools per district) from Jan 2011 to December 2012. To conduct the study a written permission was obtained from State level educational officer. School list, total number of children list, private/public middle school details and permission for conducting survey was obtained from concerned District Education Officer office. Anthropometric measurements were taken with the guidance of School Health Program Medical officers and their health team.

3.7. Standard operating procedure for anthropometric measurements data collection

Weight: Bathroom scale (Krupp) with minimal accuracy of 500 gram will be used for taking weight. Zero error was checked before weighing every child. Child with minimal clothing (shirt and drawer/blouse and shirt) and without chapple/shoes was asked to stand on the bath room scale. Weight was recorded to a minimal accuracy of 500 grams.

Height: It was measured using a measuring tape. The tape was fixed to the wall vertically, using cellophane tape, and height measured by making the child stand with heels in apposition with the wall taking care that there is no bending of the knees. He / she should be barefoot. The child should look straight with heels, buttocks, shoulders and back of head in contact with tape. A wooden scale is approximated close to scalp and height is measured to the nearest 0.5cm.

Body Mass Index: BMI was calculated using weight and height measurements, it is defined as body weight in kilograms divided by height in meters squared. The following equation can be used to determine BMI. BMI = weight (kg)/height $(m)^2$. It is also known as the Quetelet's index, BMI is the most commonly used height-weight index. BMI was used to assess obesity in children. In children, a BMI above the 85th percentile for age on the CDC growth charts was used as a screening index for being overweight. A BMI above the *95th* percentile for age was used as an index for childhood obesity.

Equipment Maintenance and Calibration: Maintenance is a regular, daily event. Scales be checked and ‘zeroed’ before each daily visit. A scale is zeroed by being sure that when there is nothing being weighed, the scale registers zero.

Calibration is a monthly event. Scales be ‘tested’ with standard weights on at least a monthly base. Movable scales are calibrated after each time the scale is moved.

3.8. OPERATIONAL DEFINITIONS

Indicators and cut-offs

The four *measures* used to undertake anthropometric assessment are: 1) Age, 2) Sex, 3) weight and 4) Height . Each of these variables provides one piece of information about a person. When they are used together they can provide important information about a person's nutritional status. When two of these variables are used together they are called an index. These combinations of measurements are called anthropometric *indices* [109,110,111]. So, it is evident that a value for weight alone has no meaning unless it is related to age or height.

Indices have two functions: they are necessary for the interpretation of measurements and for grouping them. They may take different forms; for example, the relationship of weight to height may be expressed arithmetically, e.g Body Mass Index (BMI) of Quetelet (Wt/Ht^2) or by relating the weight to that of a reference subject of the same height. The term "indicator" relates to the use or application of indices and the indicator is often constructed from them. e.g weight for height is an indicator of body composition. These indices are expressed as Z scores, percentiles or percentage of the median. Further, these indices are used to compare an individual or a group with a reference population. Three indices are commonly used in assessing the nutritional status of children: Weight-for-age, Height-for-age and Weight-for-height

The advantages and disadvantages of these indices are summarized below:

Weight-for-height (W/H) measures body weight relative to height, and has the advantage of not requiring age data. Weight-for height is normally used as an indicator of current nutritional status, and can be useful for screening children at risk and for measuring short-term changes in nutritional status. Low weight-for-height relative to the child of the same sex and age in a reference population is referred to as "*thinness*". Extreme cases of low weight-for height are commonly referred to as "*wasting*". Wasting may be the consequence of starvation or severe disease (in particular diarrhea), but it can also be due to chronic conditions. It is important to note that a lack of evidence of a wasting in a population does not imply the absence of current nutritional problems such as low height-for-age.

Height-for-age (H/A) reflects cumulative linear growth. H/A deficits indicate past or chronic inadequacies nutrition and/or chronic or frequent illness, but cannot measure short-term changes in malnutrition. Low H/A relative to a child of the same sex and age in the reference population are referred to as "*shortness*". Extreme cases of low H/A, where shortness is interpreted as pathological, is referred to as "*stunting*". H/A is primarily used as a population indicator rather than for individual growth monitoring.

Weight-for-age (W/A) reflects body mass relative to age. W/A is, in effect, a composite measure of height-for-age and weight-for-height, making interpretation difficult. Low W/A relative to a child of the same sex and age in the reference population is referred to as "*lightness*", while the term "*underweight*" is commonly used to refer to severe or pathological deficits in W/A. W/A is commonly used for monitoring growth and to assess changes in the magnitude of malnutrition over time. However, W/A confounds the effects of short- and long-term health and nutrition problems.

The three indices are used to identify three nutritional conditions: underweight, stunting and wasting.

Underweight: Underweight, based on weight-for-age, is a composite measure of stunting and wasting and is recommended as the indicator to assess changes in the magnitude of malnutrition over time.

Stunting: Low length-for-age, stemming from a slowing in the growth of the fetus and the child and resulting in a failure to achieve expected length as compared to a healthy, well-nourished child of the same age, is a sign of stunting. Stunting is an indicator of **past growth failure.** It is associated with a number of long-term factors including chronic insufficient protein and energy intake, frequent infection, sustained inappropriate feeding practices and poverty. In children over 2 years of age, the effects of these long-term factors may not be reversible. For evaluation purposes, it is preferable to use children under 2 years of age because the prevalence of stunting in children of this age is likely to be more responsive to the impact of interventions than in older children. Data on prevalence of stunting in a community may be used in problem analysis in designing interventions. Information on stunting for individual children is useful clinically as an aid to diagnosis. Stunting, based on height-for-age can be used for evaluation purposes but is not recommended for monitoring as it does not change in the short term such as 6 - 12 months.

Wasting: Wasting is the result of the weight, falling significantly below the weight expected of a child of the same height. Wasting **indicates current or acute** malnutrition resulting from failure to gain weight or actual weight loss. Causes include inadequate food intake, incorrect feeding practices, disease, and infection or, more frequently, a combination of these factors. Wasting in individual children and population groups can change rapidly and shows marked seasonal patterns associated with changes in food availability or disease prevalence to which it is very sensitive. Because of its response to short-term influences, wasting is not used to evaluate Title II programs but may be used for screening or targeting purposes in emergency settings and is sometimes used for annual reporting. Weight-for-height is not advised for evaluation of change in a population since it is highly susceptible to seasonality.

Edema: Edema is the presence of excessive amounts of fluid in the intracellular tissue. Edema can be diagnosed by applying moderate thumb pressure to the back of the foot or ankle. The impression of the thumb will remain for some time when edema is present.

Edema is diagnosed only if both feet show the impression for some time. As a clinical sign of severe malnutrition, the presence of edema should be recognized when using short term indicators such as wasting. The presence of edema in individuals should be recorded when using weight-for-height for surveillance or screening purposes. When a child has edema, it is automatically included with children counted as severely malnourished, independently of its wasting, stunting, or underweight status. This is due to the strong association between edema and mortality. Edema is a rare event and its diagnosis is used only for screening and surveillance and not for evaluation purposes.

Anthropometric indices are constructed by comparing relevant measures with those of comparable individuals (in terms of age and sex) in the reference data. There are three ways of expressing these comparisons:

a) *Z-score (standard deviation score):* the difference between the value for an individual and the median value of the reference population for the same age or height, divided by the standard deviation of the reference population.

$$\text{Z- Score} = \frac{\text{(Observed value)} - \text{(Median reference value)}}{\text{Standard deviation of reference population}}$$

The three anthropometric indices can be expressed as weight-for-age z-scores (WAZ), height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ). Z-scores are more commonly used by the international nutrition community because they offer two major advantages. First, using Z-scores allows us to identify fixed point in the distributions of different indices and across different ages. For all indices for all ages, 2.28% of the reference population, lie below a cut-off -2 Z-scores. The second major advantage of using Z-scores is that useful summary statistics can be calculated from them. The approach allows the mean and standard deviation to be calculated for the Z-scores for a group of children. Also, Z-scores are gender and age independent, thus permitting the presentation of children's growth status by combining both males and females. The Z-score application considered the simplest way of describing the reference population and making comparison to it. A fixed Z-score interval implies a fixed height or weight difference for children of a given age.

The Z-scores based on the modified 1977 NCHS growth curves indicate that a z-score from minus two standard deviations (-2SD) to smaller than or equal to plus two standard deviations (≤ +2SD) indicates a normal weight or height [109]. The z-score classifications of anthropometric indices in children based on the 2000 CDC values as compiled by the International Centre for Diarrheal Disease Research (ICDDR, 2004) [112] are indicated in Table 2. The z-score classification of anthropometric indices in children according to the new WHO standards is shown in Table 3 (WHO, 2009) [113].

b) ***Percent of the median:*** The percentage of the median is defined as the ratio of a measured or observed value in the individual to the median value of the reference data for the same sex and age or height for the specific sex, expressed as a percentage. The median is the values at exactly the midpoint between the largest and smallest. If a child's measurement is exactly the same as the reference population we say that they are 100% of the median.

$$\text{Percent of median} = \frac{\text{observed value}}{\text{median value of reference population}} \quad 100$$

c) **Percentile**: A percentile is the "rank position of an individual on a given reference distribution, stated in terms of what percentage of the group the individual equals or exceeds" [23]. The use of cut-off enables the different individual measurements to be converted into prevalence statistics. Cut-offs are also used for identifying those children suffering from or at a higher risk of adverse outcomes.The NCHS major percentiles of the growth charts include the 5^{th} , 10^{th} , 25^{th} , 50^{th} , 75^{th} , 90^{th} and 95^{th} percentiles, and the main percentiles were retained in the revised growth chart of the 2000 CDC charts.

The more representative survey data of both breastfed and formula-fed infants in the USA was used for the development of the 2000 CDC growth chart percentiles. The percentile cut-off points include the 3^{rd} , 5^{th} , 10^{th} , 25^{th} , 50^{th} , 75^{th} , 90^{th} and 97^{th} percentiles [114,115]. In a clinical setting, percentiles are commonly used because the interpretation of percentiles is straightforward.

According to WHO(2006) [116], the percentiles which fall below the 3^{rd} percentile indicate underweight, wasting or stunting; the 15^{th} to less than the 85^{th} percentiles indicate healthy weight or height, while 85^{th} to 97^{th} percentile indicates overweight. The percentile equal to or greater than the 97th percentile indicates obesity or above normal height.

The weight and height status of the children refers to their current weight and height, expressed as weight for height (W/H), weight for age (W/A), height for age (H/A) and BMI for age (BMI/A). W/H, W/A, H/A and BMI/A were interpreted using Z-scores (Table 2 and Table 3). According to the WHO (2009), a Z-score classification of <-2 to ≥-3SD indicates the cut-off points for underweight, stunting and wasting (Table 3), while the 2000 CDC Z-score indicates the cut-off points at <-2 to -3SD for moderate underweight, moderate stunting and moderate wasting. Cut-off points for severe stunting, severe underweight and severe wasting are <-3SD according to the 2000 CDC and WHO classifications (ICDDR, 2004; WHO, 2009).

Table 2: Z-score classification to determine nutritional status of children (WHO 2009)

Z-score classification	WAZ	WHZ	HAZ	BMI/A
< -3SD	Severely underweight	Severely wasted	Severely stunted	Severely wasted
-3SD to < -2SD	Underweight	Wasted	Stunted	Wasted
-2SD to < -1SD	Mild underweight	Mildly wasted	Mild stunted	Normal
-1SD to +1SD	Normal WAZ	Normal WHZ	Normal height	Normal weight
>+1SD to ≤ +2SD	Possible growth problem	Possible risk of overweight	Normal height	Possible risk of overweight
>+2SD to ≤ +3SD	Possible growth problem	Overweight	Normal height	Overweight
>+3SD	Possible growth problem	Obese	Above normal	Obese

Table 3: Z-score classification of anthropometric indices in children (ICDDR, 2004)

Z-score classification	WAZ	WHZ	HAZ	BMI/A
> +2SD	Overweight	Overweight	Above normal	Overweight
≥ -1SD to ≤ +2SD	Normal weight	Normal weight	Normal height	Normal weight
< -1SD to ≥ -2SD	Mildly underweight	Mildly wasted	Mildly stunted	Mildly underweight
< -2SD to ≥ -3SD	Moderately underweight	Moderately wasted	Moderately stunted	Moderately underweight
< -3SD	Severely underweight	Severely wasted	Severely stunted	Severely underweight

3.9. Sample size

Sample size was calculated using the formula

$$N = g * Z^2 P (1-P)/d^2$$

where

Z = Level of confidence

P = the proportion of normal children

d = Relative precision   g= Design effect

Sample size was estimated using previous studies prevalence of normal children in the population [117,118,119] 48%, with 5% relative precision and 95% of confidence, the calculated sample size was 1665. This was multiplied by 3 (bringing the sample size up to 4995) to allow for design effect due to application of cluster sampling method. For equal distribution of sample in clusters, the ultimate sample size required for the study was determined as 5040 children.

3.10 Pilot study and revision

A pilot study was conducted with 50 samples to assess the Validity and Reliability of the tool. These samples were not included in the main study. Before commencing the interview, the parents of each participant were informed about the study protocol and written consent of parents was obtained prior to their child's participation. Pilot testing was necessary when working with children. It provided the researcher with the experience needed to better prepare for the tasks that needed to be accomplished without any unexpected events occurring.

The two main purposes of the pilot test were:

1) to organize and achieve a smooth process in the nutritional assessment procedures and

2) to test the length of time required per children during collection of data.

The main purpose of the pilot study was to evaluate and scrutinize the data collection process and determine whether the participants understood the questions correctly. Experts suggested certain modifications in tool. After modification in the tool, school children could understand the questions and give relevant information. Modified tool was used for main study. Based on pilot study, Validity and Reliability of the tool was calculated.

3.11 Sampling technique

Multistage cluster sampling technique was used for data collection. For ensuring equal sex ratio, urban-rural ratio and socio economic status ratio and each age wise representation of children, following data collection procedure was adopted.

In this study, samples are selected using a 3-stage, stratified, cluster sampling method. Calculated Sample size was n=5040. Samples are selected from 24 clusters. (210 children per clusters, cluster is middle school)

In the first stage, list of Districts is the sampling frame. 3 districts selected from stratified North, Central and South of Tamilnadu. The selected Districts are Tiruvallore (North), Trichy (Central) and Madurai (South).

In the second stage, the lists of all urban and rural area are the sampling frame. One urban and one rural area are selected from the list in each district. Selected Urban-Rural areas are Tiruvallore-Palliput (Tiruvallore District), Srirangam-Musiri (Trichi District), Thirumangalam-Usilampatti (Madurai District).

In the third stage, the list of all private and public middle schools in the selected urban- rural areas are the sampling frame. Two schools selected from the list of private and public school in urban area as well as in rural area using the simple random sampling method. In each school, 210 children are surveyed. If the required samples not covered in the school, an adjoining school included to complete the sample of a cluster. The children between 6-12 years of age will be identified with the help of school records for inclusion in the study. Age (6-12 years) and sex wise 15 males and 15 females are selected randomly in each school.

3.12 Validity and Reliability

Once the objectives of the study were clearly laid down, detailed listing of the information needed was identified after extensive review of literature and in consultation with experts. Validity of the tool was assessed using content validity. The validity of an instrument is "the extent to which the instrument measures what it is supposed to measure" [120] .The tools were validated by three medical, two statistical experts. All the experts were in agreement with the content of the tool. After scrutinize the adequacy of content, experts approved the tool with slight modification. Few suggestions were made for the changes of question pattern were incorporated in the tool.

After pilot study reliability of the tool was assessed. "Reliability is the consistency with which a measuring instrument yields a certain result when the entity being measured has not changed" [120]. To improve reliability of the tool, the tool was translated from English into Tamil (the local language). Translators were consulted to check if the English and Tamil interview schedules had the same meaning. The measurements were tested for reliability (Interrater reliability method). Anthropometric reliability correlation coefficient values were 0.90(weight), 0.88(height). These correlation coefficients were very high and it is good tool for assessing anthropometric measures of school children for the construction of percentile reference charts.

3.13. Main outcome measure

The Primary outcome measures were

1. Construction of percentile charts using LMS method
2. Calculation of Z score using LMS method

Secondary outcome measures were

1. Making Weight-for- age centile chart for boys and girls separately.

2. Making Height-for-age centile chart for boys and girls separately.

3. Making weight-for-height centile chart for boys and girls separately.

4. Making Body Mass Index centile chart for boys and girls separately.

5. Calculation of WAZ, WHZ and HAZ Z score for boys and girls separately.

6. Comparison of American National Center for Health Statistics /Center for Disease Control/World Health organization (NCHS/CDC2000/WHO2007) reference population with locally weighted population.

7. Estimating prevalence of malnutrition, overweight and obesity among Tamil Nadu children.

3.14 Delimitation of the study

Only 6-12 years old school children are taken for this study.

Not all districts are included in this study.

3.15 Variables

Variables are anthropometric (Weight, Height, Body Mass Index) measurements and socio-demographic variables. The questionnaire covered the education, occupation, religion, caste, marital status and area of residence (urban or rural) of the parents and children age, sex, education and nutrition status.

3.16 Data cleaning

The data was cleaned using SPSS 16 software. Anthropometric indices WAZ, HAZ and WHZ score were calculated using WHO anthro plus software. Duplicate entries (observations recorded more than once) were identified and excluded. Above 12 years and below 6 years are checked and excluded. All very low (<-5) and high (>+5) values for WAZ, WHZ and HAZ were checked and all of their measurements were checked for consistency. If measurements were found not to be consistent with the child's other measurements were excluded. Scatter plots were drawn from height and weight measurements of boys and girls separately. All possible outliers were checked by identifying the individuals and checking all of their measurements. If those measurement were found to be consistent with child's other measurements, they were considered valid. Otherwise they were excluded.

3.17 Statistical Analysis

Data were collected using multistage cluster sampling method. Data were recorded on paper forms and later transferred to SPSS 16 for statistical analysis. After entering the data, it was checked for accuracy and also checked statistically and inconsistencies were resolved with the raw data. Incomplete or unclear forms and "impossible" outliers were excluded.

Collected anthropometric measurements Height, Weight and Body Mass Index were represented as the mean/median and standard deviations (SD) for each age and sex separately and socio demographic variables are expressed as frequencies with their percentages.

Age wise Coefficient of Variation was calculated using Mean and SD for anthropometric measurement data.

Normality of weight and height distribution was examined using normality plots (Histogram, Quantile-Quantile plot, Detrended Q-Q plot), kolmogrove-smirnov normality test, skewness and kurtosis methods.

Differences in height, weight and BMI between sexes were tested by using independent t-test. For comparison of present chart median percentiles with NCHS, CDC2000 and WHO2007, Z-score indexes of Weight-for-age (WAZ), Height-for-age (HAZ), Weight-for-age (WHZ) and BMI-for-age were calculated.

To construct smoothened percentile reference charts the Lamda-mu-sigma-additional parameter (LMSP) method was adopted. GAMLSS parameters and Box-Cox Power Exponential (BCPE) distribution were used for model fitting to data. To determine the best model maximum penalized likelihood, Akaike Information Criteria(AIC) and Generalized Akaike Criteria with penalty equal to 3 [GAIC(3)] were used. To assess the goodness of fit Worm plot and Q-test were used.

Z-scores were used to compare data against known reference values to facilitate interpretability by showing how distant from a reference point is a measured parameter. Using the Z-scores derived from the NCHS, CDC and WHO2007 standards, the nutritional status of the subjects (in terms of shortness, underweight and overweight) were determined and the prevalence of each form of malnutrition were compared.

For analysis of data Statistical Package for the Social Sciences (SPSS), version 16.0, lmsChartMaker light program (version5.4, Medical Research Council, UK). Generalized Additive Model for Location, Scale and Shape (*GAMLSS*) package in R software version 2.15.1, WHO Anthro plus Version 1.0.4, EPI INFO version 3.5.1 were used.

All the tests were 2-tailed, and a p value of less than 0.05 was taken as statistically significant.

3.18 Construction of centile charts

LMS model

The centile charts are generally constructed using LMS (Lambda-Mu-Sigma) method, also known as Cole's method or the Box-Cox normal method.

Conventional multiple regression analysis is based on four assumptions:

(1) a linear relationship, (2) constant variability of values around the mean across the range of height and age, (3) a normally distributed outcome variable, and (4) the combined effect of the covariates is additive.

Data collected using cross-sectional surveys, raw nonparametric centiles of weight or height distributions conditional on age show irregular patterns .The distribution of BMI in the population depends on age and tends to be positively skewed. Height follows a normal distribution; however, weight distribution usually does not. Raw values of anthropometric measurements are hard to interpret as they naturally differ systematically with sex and age and are also highly skewed.

The usual assumptions for data analysis are the standard assumptions of the linear model, i.e. normality of the variables, the existence of additive effects, the constancy of variance and the independence of observations. Above four assumptions are not satisfied, two alternatives are possible: transform the data in order to meet these assumptions or devise a new analysis that meets these assumptions. Instead of developing new method, it is almost always easier to use a satisfactory transformation. Tukey [121] suggested a family of transformations with an unknown power parameter λ and Box and Cox [122] modified it. The Box–Cox power transformation of the dependent variable is a useful method to alleviate heteroscedasticity for dependent variables with an unknown distribution.

LMS method assumes that the data can be normalized by using a power transformation, which removes skewness from the data set by extending one tail of the distribution and reducing the other. The maximum power required to obtain normality was calculated for each age group series and the trend was then summarized by a smooth *(L)* curve. The trends observed for the mean *(M),* and coefficient of variation *(S)* were similarly smoothed. These LMS curves contained information to enable any centile curve to be drawn and to convert measurements into exact standard deviation scores

So LMS method is an extension of regression analysis that includes three components: (1) the median (mu), which represents how the outcome variable changes with an explanatory variable (e.g., height or age); (2) the coefficient of variation (sigma), which models the spread of values around the mean and adjusts for any non-uniform dispersion; and (3) the skewness (lambda), which models the departure of the variables from normality using a Box-Cox transformation. LMS method takes explicitly into account the skewness and non-normality of the distribution of weight and height in the reference population. In this approach, the z-score for a given anthropometric measure is calculated using mean and standard deviation not of the same measures in the reference group, but of a Box-Cox transformation of the measure.

L values of 1 indicate normality and smaller values represent progressively greater skewness. The M curve is the 0 SDS line or 50^{th} centile curve for BMI. The S curve defines the coefficient of variation, and multiplied by 100 it can be interpreted as a percentage.

LMS method is used to model the data, smooth the model parameters, and then estimate smoothed percentiles from the model parameters. The LMS method models the entire distribution taking into account degree of skewness (L), central tendency (M), and dispersion (S). The L, M, and S parameters are estimated and then smoothed using any of a variety of methods. Any desired percentile or *z* score can then be calculated from the smoothed L, M, and S parameters. This method requires more assumptions and it is less obvious how sampling weights should be incorporated. Its advantages are that it permits calculation of Z-scores as well as percentiles and allows calculation of any desired percentile.

The LMS method models the variable *y* as a semi parametric regression function of the dependent variable *x*, so that the distribution of *y* changes smoothly when plotted against *x*. The distribution is summarized by three spline curves: the Box–Cox power that converts *y* to normality (*L*), the mean (*M*) and the coefficient of variation (*S*). The main application of this method is to generate reference centile curves. The transformed observations are independent and normally distributed with constant variance. The Box–Cox transformation is defined as

$$y^*(\lambda) = \frac{y^\lambda - 1}{\lambda},$$

where *y* is the response variable and λ is the transformation parameter.

For λ = 0, the natural log of the data is taken instead of using the above formula, since the ratio is undefined.

Based on this family of transformations, the LMS method described by Cole and Green [62,63] assumes that it is appropriate to consider the transformed variable

$$\tilde{y}(\lambda) = \frac{(y/\mu)^{\lambda} - 1}{\lambda}, \quad \text{for } \lambda \neq 0$$

and

$$\tilde{y}(\lambda) = \log\left(\frac{y}{\mu}\right), \quad \text{for } \lambda = 0$$

where μ is the median of *y*. This transformation maps the median of *y* to $\tilde{y}(\lambda)$= 0, and it is continuous at λ = 0. Denoting the standard deviation of $\tilde{y}(\lambda)$by σ, the variable

$$z = \frac{(y/\mu)^{\lambda} - 1}{\lambda\sigma}, \quad \text{for } \lambda \neq 0$$

and

$$z = \frac{\log(y/\mu)}{\sigma}, \quad \text{for } \lambda = 0.$$

is assumed to have a standard normal distribution.

Assuming now that the distribution of *y* varies with covariate *x*, and that λ, μ and σ at *x* are read off the smooth curves *L*(*x*) (Box–Cox power), *M*(*x*) (median) and *S*(*x*) (coefficient of variation). The initials of these parameters give the name of the LMS method. So the formula

$$z = \frac{(y/M(x))^{L(x)} - 1}{L(x)S(x)}, \quad L(x) \neq 0$$

and

$$z = \frac{\log(y/M(x))}{S(x)}, \quad L(x) = 0$$

converts the measurement *y* to its normal equivalent deviate *z*.

Rewriting the previous equation, we can estimate the centile curves of y at x .The measurement centile is given by

$$C_\alpha(x) = M(x)(1 + L(x)S(x)z_\alpha)^{1/L(x)}, \quad L(x) \neq 0$$
or
$$C_\alpha(x) = M(x)\exp(S(x)z_\alpha), \quad L(x) = 0$$

where Zα is the normal equivalent deviate at level α. In this article, a centile curve is defined as a boundary line between two consecutive intervals of a 100-interval distribution, each interval of which contains 1% of the population total. Percentile is set of divisions that produce exactly 100 equal parts in a series of continuous values such as blood pressure, height, weight, etc.

Maximum penalized likelihood

Cole and Green pointed in the discussion of their article that for *n* independent observations y_i at corresponding values x_i, the log-likelihood function derived from [63] is proportional to

$$l(L, M, S) = \sum_{i=1}^{n} \left(L(x_i) \log \frac{y_i}{M(x_i)} - \log S(x_i) - \frac{1}{2} \left\{ \frac{[y_i/M(x_i)]^{L(x_i)} - 1}{L(x_i)S(x_i)} \right\}^2 \right)$$

and the curves $L(x)$, $M(x)$ and $S(x)$ are estimated by maximizing the penalized likelihood

$$l(L,\ M,\ S) - \frac{1}{2}\alpha_L \int \{L''(x)\}^2 \mathrm{d}x - \frac{1}{2}\alpha_M \int \{M''(x)\}^2 \mathrm{d}x - \frac{1}{2}\alpha_S \int \{S''(x)\}^2 \mathrm{d}x$$

The α_L, α_M and α_S values are usually called the smoothing parameters i.e. edf (Cole and Green,1992) [63], which stands for 'equivalent degrees of freedom'. The edf of each L, M and S curve is a measure of its complexity. 1 edf means a constant, and 2 edf corresponds to a straight line, 3 edf gives a simple curve like a quadratic, and 4 or more edf indicates progressively more. They are used for each of the *L, M* and *S* curves, where larger values correspond to stronger smoothing.

The L, M and S curves convert measurements to exact SD scores using the formula:

$$\text{SD-score} = \left(\frac{[measurement / M(t)]^{L(t)} - 1}{L(t)\, S(t)} \right)$$

where measurement is the measurement is the height or weight values of the children and L(t), M(t) and S(t) are values read from the smooth curves for the child's age *t* and sex.

The centiles were estimated from the following expression

$$C_{\alpha} = M[1 + LSZ_{\alpha}]^{\frac{1}{L}}$$

L is the value of the parameter λ of the Box-Cox transformation;

M is the median of the original data;

S is the coefficient of variation of the original;

Data $Z\alpha$ is the centile of the normal distribution.

The models were checked for goodness of fit using the detrended Q-Q plot, Q-test and worm plots.

Computation of Z score:

$$\text{SD-score} = \left(\frac{[measurement / M(t)]^{L(t)} - 1}{L(t)\, S(t)} \right)$$

Compute the final z-score $\left(z^{*}_{ind}\right)$ of the child for that indicator as:

$$z^{*}_{ind} = \begin{cases} z_{ind} & if \quad |z_{ind}| \leq 3 \\ 3 + \left(\dfrac{y - SD3pos}{SD23pos}\right) & if \quad z_{ind} > 3 \\ -3 + \left(\dfrac{y - SD3neg}{SD23neg}\right) & if \quad z_{ind} < -3 \end{cases}$$

$SD3pos$ is the cut-off 3 SD calculated at t by the LMS method:

$$SD3pos = M(t)[1 + L(t) * S(t) * (3)]^{1/L(t)};$$

$SD3neg$ is the cut-off -3 SD calculated at t by the LMS method:

$$SD3neg = M(t)[1 + L(t) * S(t) * (-3)]^{1/L(t)};$$

$SD23pos$ is the difference between the cut-offs 3 SD and 2 SD calculated at t by the LMS method:

$$SD23pos = M(t)[1 + L(t) * S(t) * (3)]^{1/L(t)} - M(t)[1 + L(t) * S(t) * (2)]^{1/L(t)};$$

and $SD23neg$ is the difference between the cut-offs -2 SD and -3 SD calculated at t by the LMS method:

$$SD23neg = M(t)[1 + L(t) * S(t) * (-2)]^{1/L(t)} - M(t)[1 + L(t) * S(t) * (-3)]^{1/L(t)}$$

Using the LMS method there is no guarantee that once the skewness is removed the resulting distribution will be normal. Cole (1993) [22] states that after the power transformation the distribution will be nearer to normal, in particular, the mean and median will be closer together on the transformed scale than on the original scale. However, there is no certainty that the higher moments of the transformed distribution, such as the kurtosis, will coincide with those from the normal distribution.

There are three main advantages of this approach. Firstly, it estimates extreme percentiles more efficiently than the simpler "sort and count" procedure, and it allows skewness in the distribution. Secondly it can generate any required percentiles in addition to the conventional set of seven. Thirdly, percentiles constructed by LMS method allow data to be converted directly to Zα, represented by the formula:

LMSP model

LMSP method, which is a generalization of the LMS method, contains one more parameter than LMS model, as well as one more edf to modify the smoothness of the model. It is based on Box-Cox Power Exponential (BCPE) distribution.

The model introduces the fourth parameters τ (power exponential parameter), which is remove kurtosis, into the location parameter μ (median), scale parameter σ (approximate coefficient of variation), skewness ν (transformation to symmetry). The distribution can be defined as BCPE (μ,σ,ν,τ). The BCPE is a flexible distribution that offers the possibility to adjust for kurtosis, thus providing the framework necessary to test if fitting the distribution's fourth moment improves the estimation of extreme percentiles. It simplifies to the normal distribution when ν=1 (skewness) and τ=2 (kurtosis), and when ν≠1 and τ=2, the distribution is the same as the Box-Cox normal (Location, Median and Scale (LMS) method's distribution). The BCPE is defined by a power transformation (or Box-Cox transformation) Y^{υ} having a shifted and scaled (truncated) power exponential (or Box-Tiao) distribution with parameter τ (Rigby and Stasinopoulos, 2004) [123]. Apart from other theoretical advantages, the BCPE presents as good as or better goodness-of-fit than the modulus exponential- normal or the other distributions.

Let Y be a positive random variable having a Box-Cox power exponential distribution, denoted by BCPE (μ, σ, υ, τ), defined through the transformed random variable Z given by

$$Z = 1/ \sigma \upsilon [(y/ \mu)^{\upsilon} -1], \text{ if } \upsilon \neq 0$$

$$1/ \sigma \log(y/ \mu), \quad \text{if } \upsilon=0 \ldots\ldots\ldots\ldots (1)$$

for $0 < Y < 1$ where $\mu > 0$ and $\sigma > 0$, and where the random variable Z is assumed to follow a standard power exponential distribution with power parameter, $\tau > 0$, treated as a continuous parameter. This parameterization (1) was used by Cole and Green (1997) [124] who assumed a standard normal distribution for Z. The probability density function of Z, a standard power exponential variable, is given by

$$f_Z(z) = \tau /[c^2(1+1= \tau) !(1/ \tau)] \exp(-0.5|z/c|^{\tau}) \ldots\ldots\ldots\ldots (2)$$

for $- \infty < z < +\infty$ and $\tau > 0$, where $c^2 = 2^{-2}/ \tau !(1/ \tau)[! (3/ \tau)]^{-1}$. This parameterization, used by Nelson (1991)[(125)], ensures that Z has mean 0 and standard deviation 1 for all $\tau > 0$. $\tau = 1$ and $\tau = 2$ correspond to the Laplace (i.e. two sided exponential) and normal distributions respectively, while the uniform distribution is the limiting distribution as $\tau \rightarrow \infty$ [the exact distribution of Z in (1) is a truncated standard power exponential distribution.] From (1), the probability density function of Y, a BCPE (μ, σ, υ, τ) random variable, is given by

$$f_Y(y) = f_Z(z)|dz/dy|= y^{\upsilon-1}/\mu^{\upsilon} \sigma f(z) \ldots\ldots\ldots\ldots (3)$$

Choice of smoothing technique

Using the GAMLSS in R software [126,127,128,129], cubic spline technique is used for smoothing length/height for- age and weight-for-age curves. A number of combinations are tried among the different parameter curves, considering the Akaike Information Criterion (Akaike, 1974) [130], AIC, defined as:

$$AIC = -2L-2p$$

where L is the maximized likelihood and p is the number of parameters (or the total number of degrees of freedom). According to this criterion, the best model is the one with the smallest AIC value. The cubic spline smoothing technique offered more flexibility than fractional polynomials in all cases.

Choice of method for constructing the curves:

In summary, the BCPE method, with curve smoothing by cubic splines, is selected as the approach for constructing the growth curves. Modeling the mean (or median) of the growth variable under consideration as well as other parameters of its distribution that determine scale and shape. The simplified notation to describe a particular model within the class of the BCPE method is:

$$BCPE(x=x, df(\mu)=n1, df(\sigma)=n2, df(\nu)=n3, df(\tau)=n4),$$

Where df(･) are the degrees of freedom for the cubic splines smoothing the respective parameter curve and x is age (or transformed age) or length/height. Note that when df(･)=1, the smoothing function reduces to a constant and when df(･)=2, it reduces to a linear function. Dr.Huiqi Pan and Professor Tim J. Cole (2004) provided the software LMS light and pro, which offers the fitting of growth curves using the LMS method in interactive way, including some of the available diagnostics for choosing the best set of degrees of freedom for the cubic splines and goodness-of-fit statistics.

Selecting the best model using GAIC value:

Models are grouped in classes according to the parameters to be modeled. The alternative to modeling parameters was to fix them, e.g. $\nu=1$ or $\tau=2$. The criteria used to choose among models within the same class were the AIC and the generalized version of it with penalty equal to 3(GAIC (3)) as defined in Rigby and Stasinopoulos (2004) [123].

GAIC = -2L-3p

where L is the maximized likelihood and p is the number of parameters (or the total number of degrees of freedom). While the use of the AIC enhances the fitting of local trends, smoother curves are obtained when the model's choice is based on the GAIC (3) criterion. Consistency in the use of these two criteria was attempted across all indicators. For selecting the best combination of df(μ) and df(σ), both criteria were used in parallel. In cases of disagreement, AIC is used to select df(μ) and GAIC(3) to select df(σ), overall favoring the options which offered a good compromise between keeping estimates close to the empirical values and producing smooth curves. Only GAIC (3) values are examined to select df(ν).

Model Fitting

Model used: BCPE(x=age $^{\lambda}$, df(μ)=n1, df(σ)=n2, df(ν)=n3, τ =2)

a) Age transformation power.
b) Degrees of freedom for the cubic splines fitting the median (μ).
c) Degrees of freedom for the cubic splines fitting the coefficient of variation(σ).
d) Degrees of freedom for the cubic splines fitting the Box-Cox transformation power (ν).

e) Parameter related to the kurtosis fixed (τ=2).

f) f ν=1: Normal distribution

In Model fitting, the fit of the current model as measured by the Global deviance. This is hard to interpret on its own. Change in degree of freedom (df) and the corresponding change in deviance has been adopted when model changes. The change in deviance is approximately distributed as Chi-square with the number of df changed. This provides a simple way to judge the importance of changes to the model. In theory a change of 4 units of deviance for 1 df is just significant at the 5% level. In practice the change in deviance needs to be appreciably larger, say 8 or more, before it becomes important. With very large samples (n > 10,000) large changes in deviance (>20) may correspond to tiny and trivial changes in the shapes of the fitted curves.

Choosing Degree of Freedom (df): The order for choosing df values

Choose df values for L, M and S in the following order:

i) Optimize the M curve by increasing and/or decreasing the df by 1 until the change in deviance is small. For small datasets (e.g. n < 500) the default df of 5 may be adequate. For larger datasets (n > 10,000) the df may reach 15 or more.

ii) Optimize the S curve. In many cases 3 df will be sufficient, though df up to 10 or more may be needed for larger datasets.

iii) Optimize the L curve. 3 df may be too large in many cases, a value of 0, i.e. no skewness adjustment, then 1, which is a constant adjustment at all ages. In general df for M> S> L

There are 4 main advantages of this approach.

a) It estimates extreme percentiles more efficiently than the simpler "sort and count" procedure, and it allows positive/negative skewness and lepto/platy kurtosis in the distribution.

b) It can generate any required percentiles in addition to the conventional set of seven.

c) Percentiles constructed by LMSP method allow data to be converted directly to Z score, represented by the formula:

$$SD\ score = \frac{[measurement/M\ (t)]^{L(t)} - 1}{\mathrm{S}\ (t)\ \mathrm{L}\ (t)}$$

d) The BCPE presents as good as or better goodness-of-fit than the modulus exponential- normal or the other distributions.

Goodness-of-fit

Worm plot is the ideal tool for preliminary model building and the Q-test is useful to determine the final model. Interpretation of worm plot pattern is given in Table4.

Table 4: Interpretation of various patterns in the worm plot (Stef and Miranda , 2001) [132]

Shape	Moment	If the worm	Then the
Intercept	Mean	passes above the origin,	fitted mean is too small.
		passes below the origin,	fitted mean is too large.
Slope	Variance	has a positive slope,	fitted variance is too small.
		has a negative slope,	fitted variance is too large.
Parabola	Skewness	has a U-shape,	fitted distribution is too skew to the left.
		has an inverted U-shape,	fitted distribution is too skew to the right.
S-curve	Kurtosis	has an S-shape on the left bent down,	tails of the fitted distribution are too light.
		has an S-shape on the left bent up,	tails of the fitted distribution are too heavy.

In this present study, percentile charts for boys and girls were constructed by *LMSP* method proposed by Rigby and Stasinopoulos, using Generalized Additive Model for Location, Scale and Shape (*GAMLSS*) package in R software [128]. In LMSP method, *GAMLSS* parameters [131] and the Box-Cox power exponential distribution (*BCPE*) were used for model fitting to data [123]; Also Worm plot and Q-test were used for goodness of fit test [132,133]. The *GAMLSS* is a general class of statistical models for a univariate response variable. For maximizing the penalized likelihood of data under *GAMLSS*, Rigby and Stasinopoulos and Cole and Green algorithms were used [127]. The *BCPE* distribution has 4 parameters and is denoted as *BCPE* μ, σ, ν, t. The parameters μ, σ, ν and t may be interpreted as relating to location (median), scale (approximate coefficient of variation), skewness (transformation to symmetry) and kurtosis (power exponential parameter), respectively.

Smooth centile curves are drawn by modeling each of the 4 parameters of the distribution as a smooth non-parametric function of an explanatory variable [123]. For checking goodness of fit test two tools are used in this research. 1) Worm plot: This is a graphical diagnostic tool for assessing goodness of fit and for analysis of residuals. The shapes of the Worm plot indicate how the data differ from the assumed underlying distribution, and suggest useful modifications of the model [132]; 2) Q-stats: Q-stats are described by Royston and Wright [133]. Q-stats are calculated for all the model parameters, providing four values: Q1, Q2, Q3 and Q4. The distribution of adjusted z scores is tested for normality in each interval range of the explanatory variable (age) using the Shapiro-Wilk test and D'Agostino TST modified for asymmetry and kurtosis. This provides one indication of which distribution moments (mean, asymmetry or kurtosis) are being inadequately modeled in each range of the independent variable. Q1, Q2, Q3 and Q4 statistically significant values show possible inadequacy of the respective parameter of the model in that specific range of the independent variable. On GAMLSS, $|Q| > 2$ values considered to be model inadequacy.

Worm plot and Q-stat tests include tests for location, scale, skewness, kurtosis and non-normality [134]. Comparison of the 2 tools for goodness of fit shows that the Worm plot is the ideal tool for preliminary model building and the Q-test is useful to determine the final model. In fitting procedure, before fitting the model, an age transformation was needed to stretch the age scale for values close to zero. For this, a power transformation is applied to age, i.e. $f(\lambda)=age^{\lambda}$. Therefore, at first search the best λ for the age power transformation and then determine the age power transformation and then determine the best degrees of freedom for the parameter curves.

In order to draw centile curves by the *LMSP* method, the following sequence of steps are implemented. At first, the *M* curve is selected and then *S* curve, then *L* curve and finally *P* curve. The sequence of steps is sensible because the *M* curve describes the most important variation, while the influence of *S*, *L* and *P* is relatively small. Also in order to select the best model for μ parameter, Akaike Information Criteria (AIC) [130] was used. It was defined as: $AIC=-2l+ 2p$, where l is the penalized maximum likelihood and p is the number of parameters (or the total number of degrees of freedom); to determine the best model for σ, υ and τ, we had used the Generalized Akaike Criteria with penalty equal 3 [GAIC (3)] as defined in Rigby and Stasinopoulos: $GAIC=-2l+3p$. According to these 2 criteria, the best model was the one with smallest AIC or GAIC value.

STANDARD OPERATING PROCEDURES/ METHODOLOGY

Review of Literature

↓

Formulation of Research Problem .

↓

Instrument Design.

↓

Ethical committee approval & Pilot study & content validity.

↓

Data Collection.
(Sampling, Selection criteria, Randomization, Consent, Interview & Observation)

↓

Data Entry & validation of analysis

↓

Interpretation of Results.

↓

Formulation of strategies / Discussion

↓

Recommendation & Reporting.

CHAPTER – IV

ANALYSIS AND INTERPRETATION

4.0 Demographic and anthropometric information of children

This study was conducted in Tamil Nadu, a total of 5040 children in the age group of 6-12 years, studying in class I-VII, from government and private schools of urban as well as rural areas in Madurai, Trichy and Tiruvallore districts, from which the study sample was selected as based on population based cross sectional study.

5040 school children were selected from 24 schools in all the three districts of Tamil Nadu. 2510 (50.0%) boys and 2510.(50%) girls were selected for the construction of centile charts. Each age wise , male-female gender wise and urban-rural area wise, children were selected equally.[Figure 5].

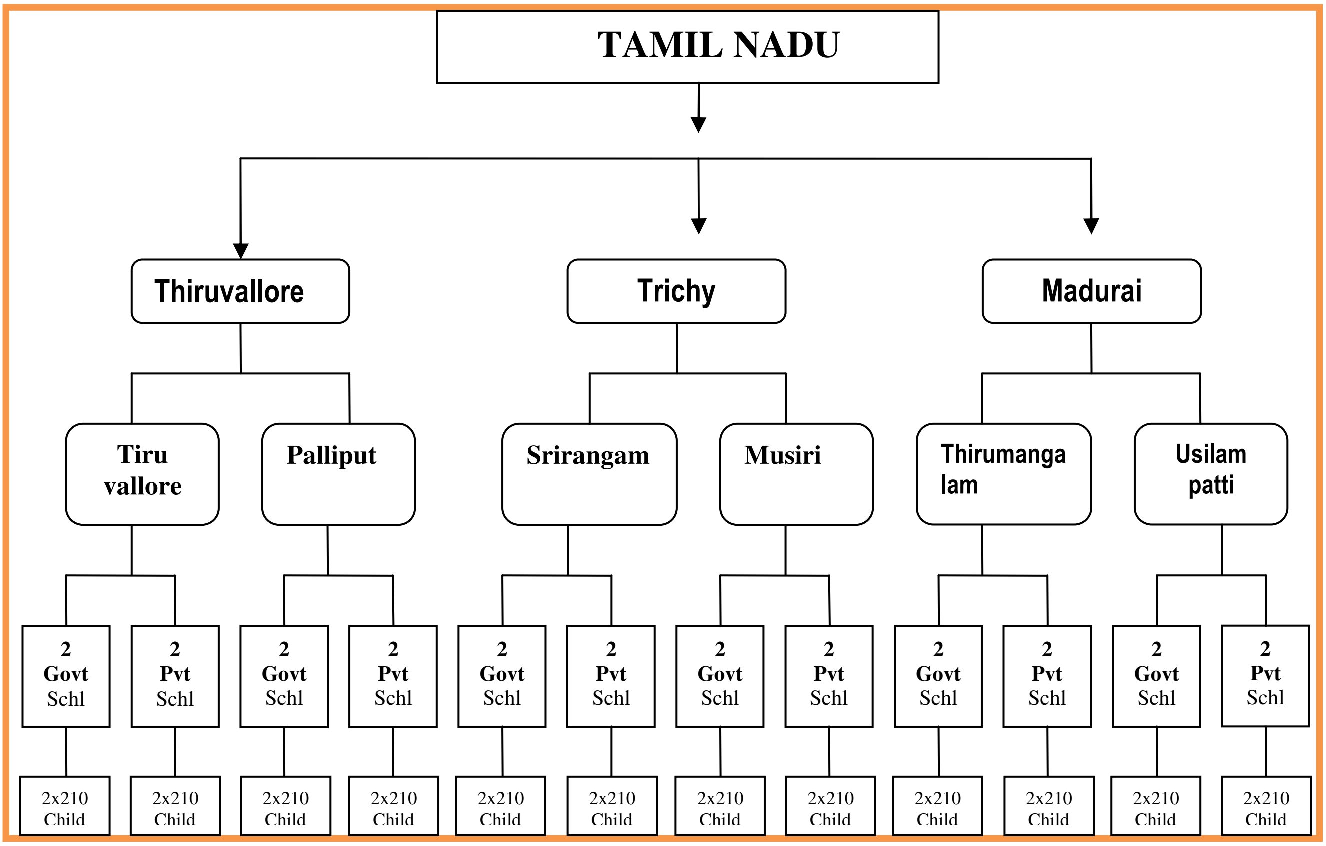

Figure 5: Flow chart for 5040 school children between 6-12 years covered in Tamilnadu

Table 5: Age wise, Sex wise, Area wise, School wise and District wise distribution of school children

age	District																							
	Tiruvallur								Trichy								Madurai							
	Tiruvallur				Pallipattu				Srirangam				Musiri				Thirumangalam				Usilampatti			
	Govt		Private		Govt		Private		Govt		Private		Govt		Private		Govt		Private		Govt		Pri vate	
	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f	m	f
6	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
7	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
8	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
9	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
10	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
11	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
12	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Table 5 shows Age wise, Sex wise ,Area wise, School wise and District wise distribution children. In each district wise 1680 children were taken for the study. 2520 boys taken from government school and 2520 girls were taken from private school. 210 children data were collected from 24 schools. Each age wise 360 boys and 360 girls were taken.

Table 6: Children Demographic profile

Demographic variables		Sex			
		Male(2520)		Female(2520)	
		n	%	n	%
Age	6 years	360	14.3%	360	14.3%
	7 years	360	14.3%	360	14.3%
	8 years	360	14.3%	360	14.3%
	9 years	360	14.3%	360	14.3%
	10 years	360	14.3%	360	14.3%
	11 years	360	14.3%	360	14.3%
	12 years	360	14.3%	360	14.3%
Religion	Hindu	1962	77.9%	2001	79.4%
	Muslim	258	10.2%	238	9.4%
	Christian	300	11.9%	281	11.2%
Community	OC	29	1.2%	35	1.4%
	BC	1830	72.5%	1855	73.6%
	MBC	347	13.8%	335	13.3%
	SC	314	12.5%	295	11.7%

Table 6 shows the children demographic information. 2520 boys and 2520 girls were taken for the study. 50% of them are boys and 50% of them are girl children. The ratio of Girls: Boys was 1:1.

Considering age distribution, minimum age of Children is 6 years and maximum age of children is 12 years. Each age group wise equal number children were taken for study. It means 14.3% of children for each age group.

Considering religion status, among boys 77.9% of them are belongs to Hindus, 11.9% of them are Christians and 10.2% of them are Muslims whereas among girls 79.4% of them are belongs to Hindus, 11.2% of them are Christians and 9.4% of them are Muslims.

Considering community status, among boys 1.2% of them are belongs to OC, 72.6% of them are BC, 13.8% of them are MBC and 12.5% of them are SC and among girls 1.4% of them are belongs to OC, 73.6% of them are BC, 13.3% of them are MBC and 11.7% of them are SC.

Table 7: Mother Socio Demographic information

Demographic variables		Children			
		Male		Female	
		n	%	n	%
Mother age	21-30 years	1474	58.7%	1510	60.2%
	31 -40 years	950	37.8%	923	36.8%
	41- 50 years	86	3.4%	77	3.1%
Mother education	Illiterate	105	4.2%	134	5.3%
	Primary school	518	20.6%	558	22.2%
	Middle school	370	14.7%	534	21.3%
	High school	783	31.2%	637	25.4%
	HSc	621	24.7%	522	20.8%
	College	113	4.5%	125	5.0%
Mother occupation	Housewife	2137	85.1%	2057	82.0%
	Agriculture	43	1.7%	52	2.1%
	Daily wage	286	11.4%	294	11.7%
	Govt employee	10	.4%	35	1.4%
	Private employee	34	1.4%	72	2.9%
Marital status	Married	2483	98.9%	2474	98.6%
	Widow	24	1.0%	33	1.3%
	Separated	3	.1%	3	.1%

Table 7 shows the mothers socio demographic information mothers.

Considering mothers age, among boys, 58.7% of the mothers are between 21-30 years, 37.8% of them are between 31-40 years and only 3.4% of them are between 41-50 years. Among girls, 60.2% of the mothers are between 21-30 years, 36.8% of them are between 31-40 years and only 3.1% of them are between 41-50 years.

Considering mothers education status only 4.2% of boys mothers and 5.3% of the girls mothers are illiterates. Considering mothers occupation, 85.1% of the boys' mothers and 82% of the girls' mothers are housewives. Considering marital status, only 1.1% of the boys and 1.4% of the girls children mothers are widowed or separated.

Table 8: Father Socio Demographic information

Demographic variables		Sex			
		Male		Female	
		n	%	n	%
Father age	21-30 years	445	17.9%	401	16.2%
	31 -40 years	1772	71.3%	1875	75.7%
	41- 50 years	263	10.6%	197	7.9%
	51 -60 years	6	.2%	5	.2%
Father education	Illiterate	63	2.5%	20	.8%
	Primary school	380	15.3%	327	13.2%
	Middle school	497	20.0%	556	22.5%
	High school	549	22.1%	588	23.8%
	HSc	789	31.8%	791	32.0%
	College	205	8.3%	190	7.7%
Father occupation	Business	224	9.0%	230	9.3%
	Agriculture	70	2.8%	39	1.6%
	Daily wage	2014	81.0%	2068	83.5%
	Govt employee	105	4.2%	66	2.7%
	Private employee	73	2.9%	75	3.0%
Monthly income	< Rs.5000	1996	79.5%	2049	81.6%
	Rs.5001 -10000	464	18.5%	374	14.9%
	Rs.10001 -20000	41	1.6%	63	2.5%
	> Rs.20000	9	.4%	24	1.0%

Table 8 shows the mothers socio demographic information mothers.

Considering fathers age, among boys, 17.9% of the fathers are between 21-30 years, 71.3% of them are between 31-40 years, 10.6% of them are between 41-50 years and only 0.2% of them are between 51-60 years. Considering fathers age, among girls, 16.2% of the fathers are between 21-30 years, 75.7% of them are between 31-40 years, 7.9% of them are between 41-50 years and only 0.2% of them are between 51-60 years.

Considering fathers education status only 2.5% of boys fathers and 0.8% of the girls fathers are illiterates. Considering fathers occupation, 4.2% of the boy's fathers and 2.7% of the girl's fathers are government employees. Considering monthly income, 79.5% of the boys and 81.6% of the girls' fathers' income is less than Rs.5000.

Table 9: Mean and Standard deviations (SD) for Height, Weight and BMI of boys aged 6- 12 years

Age (years)	Height(cm)		Weight(kg)		Body Mass Index (kg/m2)	
	Mean	SD	Mean	SD	Mean	SD
6 years	111.12	5.77	17.34	2.33	14.06	1.74
7 years	116.42	5.20	19.71	2.31	14.57	1.76
8 years	120.32	6.21	20.62	3.70	14.20	1.90
9 years	124.65	7.27	22.23	4.21	14.23	1.77
10 years	131.15	6.28	25.13	5.49	14.52	2.35
11 years	135.56	6.80	26.18	4.29	14.27	2.19
12 years	140.17	5.24	31.06	5.75	15.82	2.86

Table 9 shows 6-12 year boys age wise mean height, weight and Body mass index. It shows there is a gradual increase in height and weight. Variation of standard deviation is more in weight when comparing with height of boys. Range of height standard deviation is (5.20 cm -7.27 cm). Range of weight standard deviation is (2.31 kg – 5.75 kg).

Table 10: Mean and Standard deviations (SD) for weight, height and BMI of girls aged 6- 12 years

Age (years)	Height(cm)		Weight(kg)		Body Mass Index (kg/m2)	
	Mean	SD	Mean	SD	Mean	SD
6 years	109.58	5.71	16.22	2.07	13.52	1.46
7 years	114.38	4.95	18.45	2.89	14.10	1.97
8 years	118.78	5.92	19.49	3.32	13.78	1.82
9 years	123.16	6.18	21.32	3.61	14.02	1.82
10 years	129.35	6.09	24.46	4.98	14.52	2.12
11 years	137.57	5.95	28.63	4.81	15.15	2.47
12 years	142.31	4.65	33.11	5.27	16.34	2.41

Table 10 shows 6-12 years girls age wise mean height, weight and Body mass index. It shows there is a gradual increase in height and weight.

Table11: Age and gender wise Coefficient of variation

Age	Gender					
	Male			Female		
	Height	Weight	BMI	Height	Weight	BMI
6 years	5.2%	13.4%	12.4%	5.2%	12.8%	10.8%
7 years	4.5%	11.7%	12.1%	4.3%	15.7%	13.9%
8 years	5.2%	17.9%	13.4%	5.0%	17.0%	13.2%
9 years	5.8%	18.9%	12.4%	5.0%	16.9%	13.0%
10 years	4.8%	21.8%	16.1%	4.7%	20.4%	14.6%
11 years	5.0%	16.4%	15.3%	4.3%	16.8%	16.3%
12 years	3.7%	18.5%	18.1%	3.3%	15.9%	14.9%

Table 11 shows 6-12 years gender wise coefficient of variation for height, weight and Body mass index. It shows there is more variation in weight and body mass index coefficient of variation than height coefficient of variation.

Table 12: Comparison of Height among Boys and Girls

Age (years)	Boys			Girls			Student's independent t-test
	Mean	SD	Increment	Mean	SD	Increment	
6 years	111.12	5.77	-	109.58	5.71	-	t=3.60 p=0.001***
7 years	116.42	5.20	5.30	114.38	4.95	4.80	t=5.40 p=0.001***
8 years	120.32	6.21	3.90	118.78	5.92	4.40	t=3.41 p=0.001***
9 years	124.65	7.27	4.33	123.16	6.18	4.38	t=2.94 p=0.01**
10 years	131.15	6.28	6.50	129.35	6.09	6.19	t=3.89 p=0.001***
11 years	135.56	6.80	4.41	137.57	5.95	8.22	t=4.21p=0.001***
12 years	140.17	4.61	3.10	142.31	4.65	4.74	t=5.80 p=0.001***

* Significant at P≤0.05 ** highly significant at P≤0.01 *** very high significant at P≤0.001

Table 12 shows the means and standard deviations of the height for both boys and girls by age groups while the mean values are plotted against age in Figure 6. The distance curve shows that there is a gradual increase in average Height for both boys and girls from 6 to 12 years of age. It is observed that boys are taller than girls in all age groups, and the differences are significant at in all ages. Increment of growth is more in boys' form 6-10 and it is more in girls in 11-12 years. Statistical significance was calculated using student independent t-test.

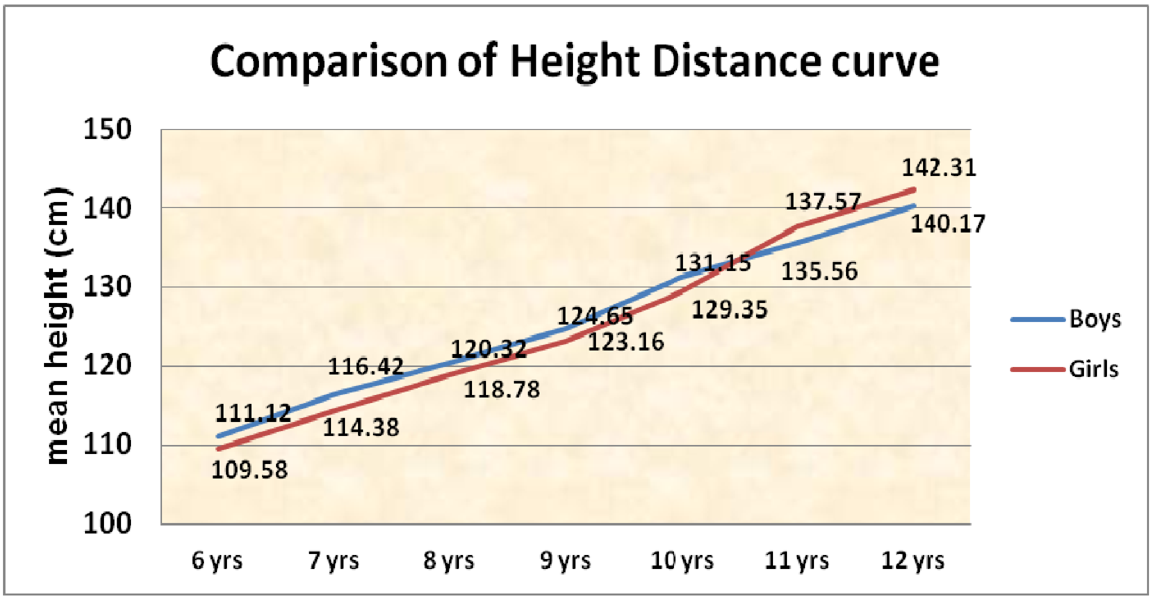

Figure 6: Distance chart shows amount of growth in height achieved during from 6-12 years

Table 13: Comparison of Weight among Boys and Girls

Age (years)	Boys			Girls			Student's independent t-test
	Mean	SD	Increment	Mean	SD	Increment	
6 years	17.34	2.33	-	16.22	2.07	-	t=6.81p=0.001***
7 years	19.71	2.31	2.37	18.45	2.89	2.23	t=6.44 p=0.001***
8 years	20.62	3.70	0.91	19.49	3.32	1.04	t=4.32 p=0.001***
9 years	22.23	4.21	1.61	21.32	3.61	1.83	t=3.10 p=0.002**
10 years	25.13	5.49	2.90	24.46	4.98	3.14	t=1.71 p=0.08
11 years	26.18	4.29	1.05	28.63	4.81	4.17	t=7.20p=0.001***
12 years	31.06	5.75	4.88	33.11	5.27	4.48	t=5.00 p=0.001***

* significant at P≤0.05 ** highly significant at P≤0.01 *** very high significant at P≤0.001

Table 13 shows the means and standard deviations of the weight for both boys and girls by age groups while the mean values are plotted against age in Figure 7. The distance curve shows that there is a gradual increase in average weight for both boys and girls from 6 to 12 years of age. It is observed that boys are heavier than girls from 6 -10 years and girls are heavier from 11-12 years and the differences are not significant at in all ages except 6th year and 8th year. Statistical significance was calculated using student independent t-test.

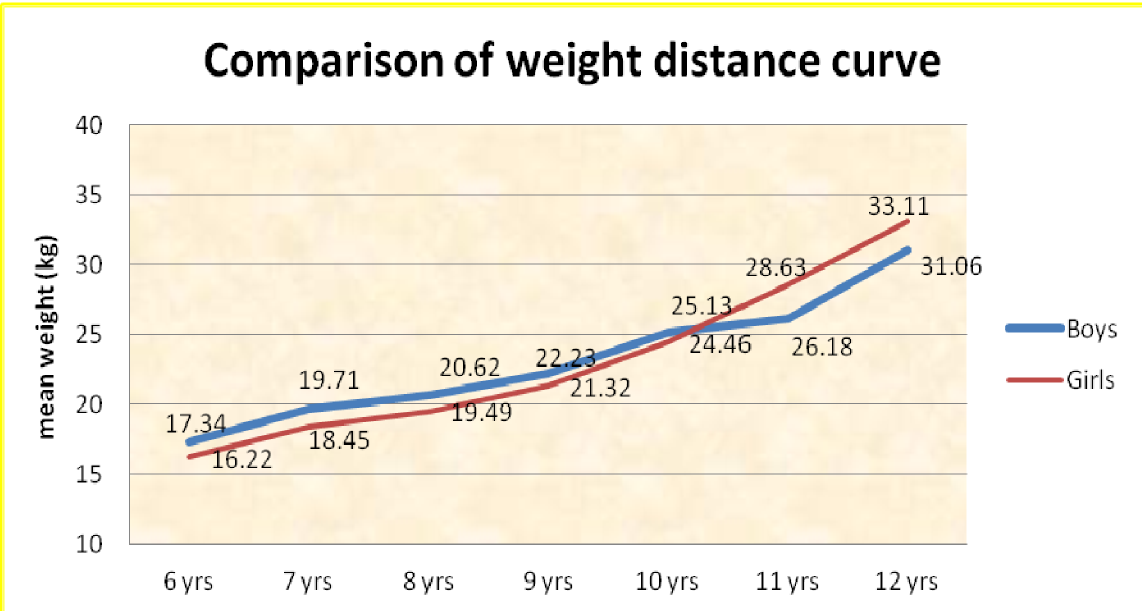

Figure7: Distance chart shows amount of growth in weight achieved during from 6-12 years

Table 14: Comparison of Body Mass Index among Boys and Girls

Age (years)	Boys			Girls			Student's independent t-test
	Mean	SD	Increment	Mean	SD	Increment	
6 years	14.06	1.74	-	13.52	1.46	-	t=4.52 p=0.001***
7 years	14.57	1.76	0.51	14.10	1.97	0.58	t=3.36 p=0.001***
8 years	14.20	1.90	-0.37	13.78	1.82	-0.32	t=2.97 p=0.01**
9 years	14.23	1.77	0.03	14.02	1.82	0.24	t=1.54 p=0.12
10 years	14.52	2.35	0.29	14.52	2.12	0.5	t=0.03 p=0.97
11 years	14.27	2.19	-0.25	15.15	2.47	0.63	t=5.04p=0.001***
12 years	15.82	2.86	1.55	16.34	2.41	1.19	t=2.61 p=0.01**

* significant at P≤0.05 ** highly significant at P≤0.01 *** very high significant at P≤0.001

Table I4 shows the means and standard deviations of the BMI for both boys and girls by age groups while the mean values are plotted against age in Figure 8. The distance curve shows that there is a static curve form 6-10 years except 11th -12th years. It is observed that boys are having more BMI than girls except 11-12 years and the differences are significant at all ages except 9th& 10th years. Statistical significance was calculated using student independent t-test.

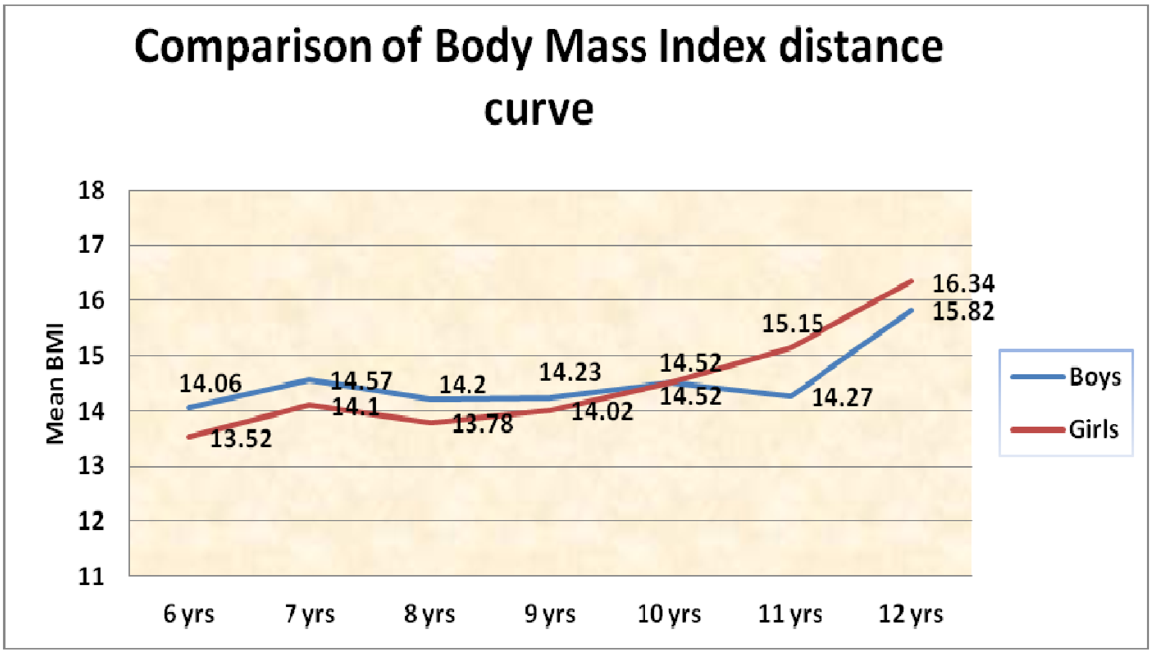

Figure8: Distance chart shows amount of growth in body mass index among 6-12 years boys and girls

4.1 Construction of Weight-for-age reference chart for boys

4.1.1 Sample size and mean weight

There were 2520 weight observations for boys. Cross-sectional sample size, mean weight and standard deviation for each age group are shown in Tables 15.

Table 15: Cross-sectional sample sizes for weight-for-age for boys

Age (years)	No. of boys	Weight(kg)	
		Mean	SD
6 years	360	17.34	2.33
7 years	360	19.71	2.31
8 years	360	20.62	3.70
9 years	360	22.23	4.21
10 years	360	25.13	5.49
11 years	360	26.18	4.29
12 years	360	31.06	5.75

Each age group wise 360 boys were taken for the study. Mean weight of boys shows there is a gradual increase for each age.

4.1.2 Normality checking

Normality of weight distribution was checked using graphical and mathematical methods. Graphically it was tested using Histogram & Quantile-Quantile plot (normal Q-Q plot) (figures 9-12) and mathematically it was tested using Kolmogorov-Smirnov normality test (z=6.01 p=0.001), skewness(1.14) & kurtosis(1.57).

Kolmogorov-Smirnov normality test (KS test) is mathematical method of finding normality of distribution for larger sample size data. Calculated KS test value is Z=6.01 and it is statistically significant, it indicates that the 6-12 years boys weight is not distributed normally.

Skewness talks about the “deviation of normality of data” and kurtosis talks about “peakedness of data”. If the data follows normality, skewness value should be “0” value and kurtosis value should be “3” value. If the skewness value is more than “0”, it is called positively skewed, if the skewness value is less than “0”, it is called negatively skewed and if the skewness value is equal to “0” then it is called no skewness (normal). In this study, calculated skewness value is 1.14, so it shows presence of positive skewness among 6-12 years boys weight.

Similarly, if the data follows normality, kurtosis value should be “3” value. If the calculated value is equal to “3” it is called mesokurtic (normal height), if the calculated value is above “3” it is called leptokurtic (above normal) and if the calculated value is below “3” it is called platykurtic (below normal). In this study, calculated kurtosis value is 1.57, so it is having lower height than normal distribution height, so it shows presence of platykurtic among 6-12 years boys weight. In this study observed weight distribution of 6-12 years boys data skewness (1.14) and kurtosis (1.57) values indicating that the variable is highly skewed to right with a less peak than normal distribution.

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Table16: Weight(kg) Mean, SD and percentiles for Male children

Age	Mean	Median	SD	Skewness	Kurtosis
6 years	16.78	17.00	2.15	0.41	-0.26
7 years	19.32	19.71	2.36	0.16	-0.32
8 years	20.14	20.62	4.19	1.63	3.11
9 years	22.09	22.63	4.23	1.06	1.53
10 years	25.04	25.13	5.41	1.53	3.13
11 years	26.11	26.18	4.29	1.59	4.73
12 years	30.93	31.00	5.86	0.51	0.39

Table 16 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years boys weight. Each age wise skewness values are above "0", so boys weight is positively skewed for all ages. Similarly each age wise kurtosis values tells, 6^{th} , 7^{th} , 9^{th} and 12^{th} year old boys weights are platykurtic and 8^{th} ,10^{th} and 11^{th} year old boys weights are leptokurtic. So the 6-12 years boys weight data shows skewness as well as kurtosis.

Most of the parametric tests follow the assumption of normality. Normality means that the distribution of the test is normally distributed with 0 mean, with 1 standard deviation and a symmetric bell shaped curve. As the normal distribution is very important for statistical inference point of view so it is desired to examine the assumption to test whether the data is from a normal distribution. We can use a statistical test and or statistical plots to check the sample distribution is normal. Histogram is a graphical method of checking normality of the observed data. Histogram gives the idea of whether or not data follows the assumption of normality. Histogram with normal curve shows in Figure 9 and figure 10 tells, 6-12 years boys weight is not normally distributed and it is skewed to right side.

In order to determine normality of the data graphically, we can use the output of a normal Q-Q plot and detrended normal Q-Q plot. Normal Q-Q Plot is a plot of the percentiles (or quintiles) of a standard normal distribution against the corresponding percentiles of the observed data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Detrended normal Q-Q plot means that each empirical quantile is subtracted from its corresponding unit normal quanitile. If the data are normally distributed, the data points will be close to the diagonal line. If the data points stray from the line in an obvious non-linear fashion, the data are not normally distributed. Figure 11 and figure 12 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution. Figure 11 of Detrended normal Q-Q plot data points are not close to the diagonal line and points are upward directions. Figure 11 & Figure 12 of normal Q-Q plot and Detrended normal Q-Q plot shows, the weight data is not normally distributed.

4.1.3 Model selection and results

The search for the best model was done in an add-up stepwise form, starting from the simplest class of models comprising the age transformation, if any, and the fitting of the μ and σ curves, while keeping fixed $\boldsymbol{\nu}$=1 and $\boldsymbol{\tau}$=2. The next step was to fit the $\boldsymbol{\nu}$ curve, using $\boldsymbol{\tau}$ =2 df(μ) and df(σ) selected in the previous step. Once the best model within this class of models was selected, Q-test and worm plot goodness of fit results were evaluated to inform the decision on whether or not to select the more complex model.

The model BCPE(x=age $^{\lambda}$, df(μ)=5, df(σ)=3, ν=1, τ=2) served as a starting point to construct the weight-for-age reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 17 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power λ=0.80. This smallest deviance value of λ value was taken for model fitting.

Table 17: Global deviance (GD) for models within the class BCPE(x=age $^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for weight-for-age for boys

Power(λ)	**Global Deviance(GD)**
0.10	13983.12
0.20	13897.79
0.30	13897.16
0.40	13896.56
0.50	13895.99
0.60	13895.43
0.70	13889.91
0.80	**13872.42**
0.90	13890.95
1.00	13895.52

Model used :BCPE(x=age $^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2)

age $^{\lambda}$	=	Age transformation power
df(μ)	**=**	Degrees of freedom for the cubic splines fitting the median (μ)
df(σ)	**=**	Degrees of freedom for the cubic splines fitting the coefficient of variation (σ).
ν	=	Degrees of freedom for the cubic splines fitting the Box-Cox transformation power (ν).
τ	=	Parameter related to the kurtosis.

After choosing the age-transformation power λ=0.80, then search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom.

$$GAIC = -2L-3p$$

where L is the maximized likelihood and p is the number of parameters (or the total number of degrees of freedom). While the use of the AIC enhances the fitting of local trends, smoother curves are obtained when the model's choice is based on the GAIC (3) criterion. Consistency in the use of these two criteria was attempted across all indicators. For selecting the best combination of df(μ) and df(σ), both criteria were used in parallel. In cases of disagreement, AIC is used to select df(μ) and GAIC(3) to select df(σ), overall favouring the options which offered a good compromise between keeping estimates close to the empirical values and producing smooth curves. Only GAIC(3) values are examined to select df(ν).

So the final selected model is BCPE(x=age $^{0.8}$, df(μ)=4, df(σ)=3, ν=1, τ=2).

4.1.4 Goodness-of-fit assessment fitted model for 6-12 years boys

Goodness-of –fit for the selected model BCPE($x=age^{0.80}$, $df(\mu)=4$ $df(\sigma)=3$, $\nu=1$, $\tau=2$) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

Worm plot is a graphical diagnostic tool for assessing goodness of fit and for analysis of residuals. The shapes of the Worm plot indicate how the data differ from the assumed underlying distribution, and suggest useful modifications of the model. The worm plot consists of a collection of detrended Q-Q plots, each of which applies to one of successive age groups. The vertical axis of the worm plot portrays, for each observation, the difference between its location in the theoretical and empirical distributions. The data points in each plot forms a worm-like sting. The shape of the worm indicates how the data differ from the assumed underlying distribution, and when taken together, suggests useful modification to the model. A plot worm indicates that the data follow the assumed distribution in that age group. The worm plot for fitted model shown in figure13 (overall) and in figure14 (age wise) do not indicate any upward or downward shifts except12th year. This may be due to some extreme values in that age group. There is no evidence of worm plot shows misfit and all the worm plots are within 95% confidence interval.

Table 18: Q-test for z-scores from the model BCPE(0.80, 4,3,1,2)for weight-for-age for boys

Age	Z1	Z2	Z3	Z4
6 years	-0.454	1.209	-1.594	-0.507
7 years	1.299	-1.081	-1.543	-1.479
8 years	-0.993	1.352	0.920	1.067
9 years	-0.314	1.493	0.997	-1.210
10 years	1.914	1.824	1.317	-0.055
11 years	-1.787	-1.946	1.430	**2.677**
12 years	1.344	0.848	**-2.207**	1.822
TOTAL Q stats	16.608	43.407	39.812	21.695
Degrees of freedom for Q stats	2.0	5.0	6.0	6.0
P-value for Q stats	0.14	0.12	0.09	0.07

Note: Absolute values of z1, z2, z3 or z4 larger than 2 indicate that, they are misfit for calculating mean, variance, skewness and kurtosis.

Q test is a statistical test which combines overall and local tests assessing departures from the normal distribution with respect to mean, variance, skewness and kurtosis. The aim of Q test is whether the Z-scores are normally distributed independent of age. Q-tests are calculated for all the model parameters, providing four values: z1, z2, z3 and z4. The distribution of adjusted z scores is tested for normality in each interval range of the explanatory variable (age) using the Shapiro-Wilk test and D'Agostino TST modified for asymmetry and kurtosis. This provides one indication of which distribution moments (mean, asymmetry or kurtosis) are being inadequately modeled in each range of the independent variable. z1, z2, z3 and z4 statistically significant values show possible inadequacy of the respective parameter of the model in that specific range of the independent variable.

In table 18, the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3 and z4. Absolute deviations greater than 2 noted in the 11th year z3=2.207 and 12th year z4=2.677, however overall p-value for the Q –test is not significant (0.14, 0.12, 0.09, 0.07). So it does not suggest any significant departure of the fitted model z-scores from normality at the 5% level of significance.

Table 19: Final model Skewness and kurtosis for 6-12 years boys

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Summary of the Quantile Residuals

mean	=	0.0008197484
variance	=	1.000375
coef. of skewness	=	-0.01752476
coef. of kurtosis	=	3.115267
Filliben correlation coefficient	=	0.9983552

Among Worm plot and Q-test of two goodness of fit methods, Worm plot is the ideal tool for preliminary model building and the Q-test is useful to determine the final model. Ideal model should have mean is close to “0”, variance is close to “1” skewness is close to “0” and kurtosis is close to “3”. Table 19 shows after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.0008197484 against 0, variance =1.000375 against 1, skewness =-0.01 against 0, kurtosis=3.11 against 3. It was shown graphically in figure 15.

Filliben correlation coefficient or probability plot correlation coefficient (PPCC) tests for normality which has the several attractive features. This test statistics is conceptually easy to understand because it combines two fundamental simple concepts of the probability plot and the correlation coefficient. This test allows a comparison of the results in both a graphical (probability plot) and a numerical (correlation coefficient) form. This test is computationally simple since it only requires computation of a simple correlation coefficient. This test statistics is readily extendible for testing some non-normal distributional hypothesis. This test compares favorably with seven other tests of normality on the basis of empirical power studies performed by filliben et.al. This test is invariant to the parameter estimates procedure employed to fit the probability distribution. If the data Final model correlation coefficient is 0.99, it shows very high correlation in the fitted model.

Figure 15 shows the residual distribution of weight-for-age in males: quantile (standardised) residuals plotted against fitted values and against age, the density estimate with rug plot, and the quantile–quantile plot. The distribution is normal. A straight 1:1 line (plot on RHS bottom) indicates a good fit of the GAMLSS model.

4.1.5 LMS values and percentiles for 6-12 years Boys

Percentiles are the most commonly used clinical indicator to assess the size and growth patterns of individual children. Percentiles rank the position of an individual by indicating what percent of the reference population the individual would equal or exceed. As per WHO guideline, the percentiles which fall below the 3rd percentile indicate underweight, wasting or stunting; the 15th to less than the 85th percentiles indicate healthy weight or height, while 85th to 97th percentile indicates overweight. The percentile equal to or greater than the 97th percentile indicates obesity or above normal weight.

Table 20 shows 6-12 year old boys standard predicted percentiles 3rd, 10th, 25th, 50th, 75th, 90th and 97th weight values with their respective lamda-mu-sigma values. Less than 3rd percentile is underweight. Less than 13.8 kg among 6 year old boys are considered underweight, less than 15.8 kg among 7 year old boys are considered underweight, less than 15.7 kg among 8 year old boys are considered underweight, less than 16.5 kg among 9 year old boys are considered underweight, less than 17.9 kg among 10 year old boys are considered underweight, less than 19.7 kg among 11 year old boys are considered underweight and less than 22.1 kg among 12 year old boys are considered underweight. Figure 16A shows the age related smoothened percentile reference chart for standard values and Figure 16B shows the WHO standard percentile curve.

Table 20: LMS values and percentiles for 6-12 years Boys

Age	L	M	S	SD	Percentiles(weight in kg)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	17.1	0.0074	2.3	13.8	14.7	15.7	17.1	18.7	20.4	22.4
7 years	1	19.3	0.0072	2.3	15.3	16.3	17.6	18.8	21.2	23.4	25.9
8 years	1	20.2	0.0075	3.7	15.7	16.9	18.4	20.2	22.5	25.1	28.2
9 years	1	21.6	0.0076	4.2	16.5	17.8	19.5	21.9	24.3	27.3	31
10 years	1	23.8	0.0072	5.5	17.9	19.5	21.3	24.2	26.8	30.3	34.8
11 years	1	26.3	0.0066	4.3	19.7	21.4	23.5	27.5	29.7	33.7	38.7
12 years	1	29.7	0.0060	5.7	22.1	24.1	26.5	30.9	33.7	38.4	44.3

4.1.6 LMS values and Z-score for 6-12 years Boys

The Z-score is widely recognized as the best system for analysis and presentation of anthropometric data because of its advantages compared to the other methods. The Z-score system expresses the anthropometric value as a number of standard deviations or Z-scores below or above the reference mean or median value. Less than -2SD is considered underweight. Table 21 shows 6-12 year old boys standard predicted z scores -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD weight values with their respective lamda-mu-sigma values. Less than -2SD is underweight. Less than 13.6 kg among 6 year old boys are considered underweight, less than 15.1 kg among 7 year old boys are considered underweight, less than 15.5 kg among 8 year old boys are considered underweight, less than 16.2 kg among 9 year old boys are considered underweight, less than 17.6 kg among 10 year old boys are considered underweight, less than 19.4 kg among 11 year old boys are considered underweight and less than 22.0 kg among 12 year old boys are considered underweight. Figure 17 shows the age related Z-score reference chart.

Table21: LMS values and Z score for 6-12 years Boys

Age	L	M	S	SD	Z score(weight in kg)						
					-3	-2	-1	0	1	2	3
6 years	1	17.1	0.0074	2.3	12.3	13.6	15.2	17.1	19.6	22.8	27.3
7 years	1	19.3	0.0072	2.3	13.5	15.1	16.9	19.3	22.3	26.5	32.4
8 years	1	20.2	0.0075	3.7	13.8	15.5	17.6	20.2	23.8	28.9	36.4
9 years	1	21.6	0.0076	4.2	14.4	16.2	18.6	21.6	25.8	31.9	41.4
10 years	1	23.8	0.0072	5.5	15.6	17.6	20.3	23.8	28.6	35.8	47.4
11 years	1	26.3	0.0066	4.3	17.1	19.4	22.3	26.3	31.7	39.9	53.3
12 years	1	29.7	0.006	5.7	19.2	22.0	25.2	29.7	36.1	45.7	61.8

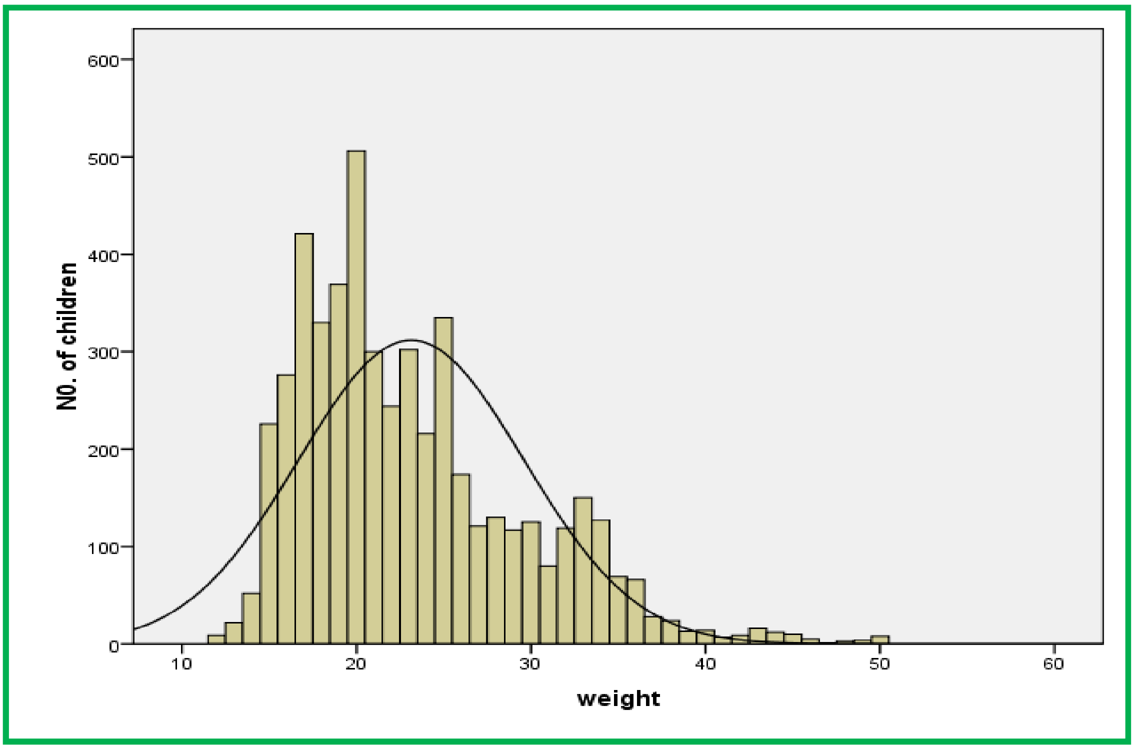


Figure 9: Histogram with normal curve shows the positively skewed distribution for 6-12 years old boys (mean =23.2 median=22.0 skewness=1.14 kurtosis=1.57)

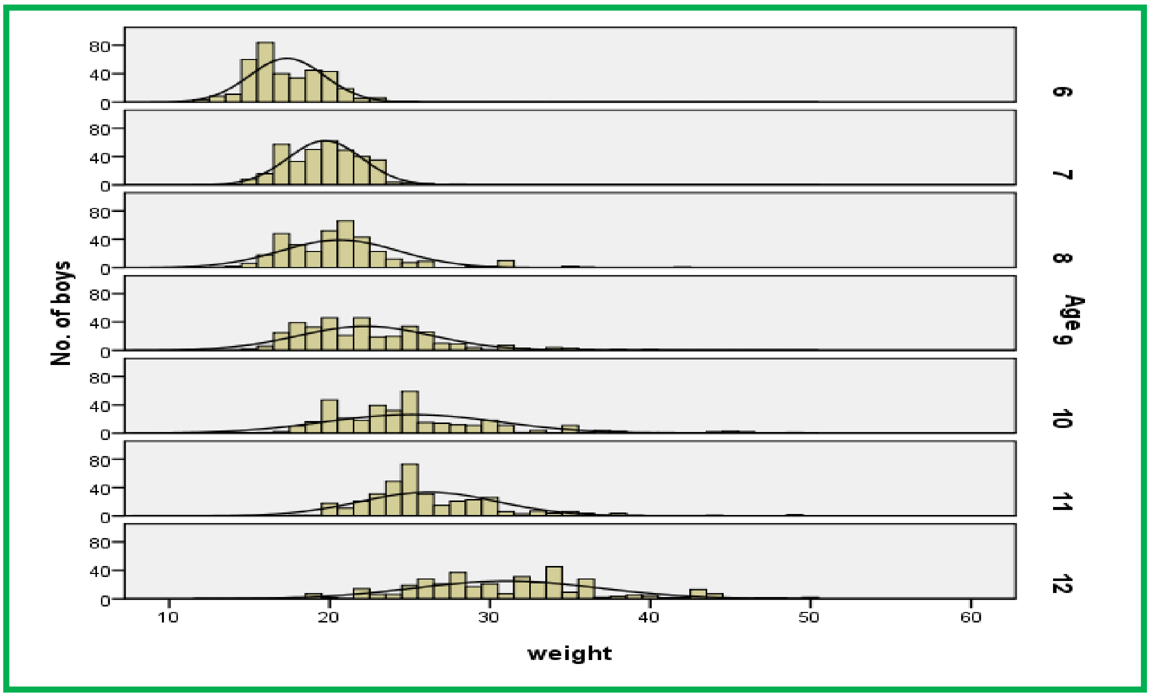
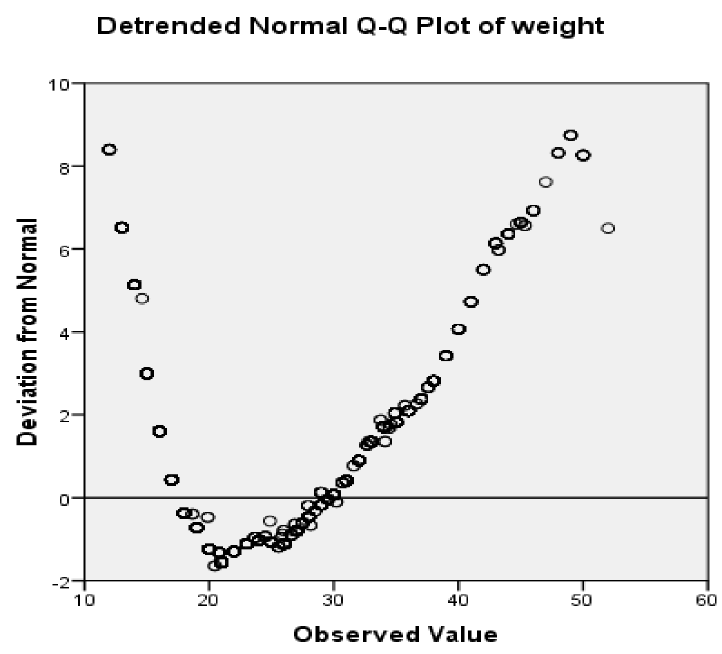


Figure 10: Each age wise Histogram with normal curve assess the normality of weight of 6-12 years old boys



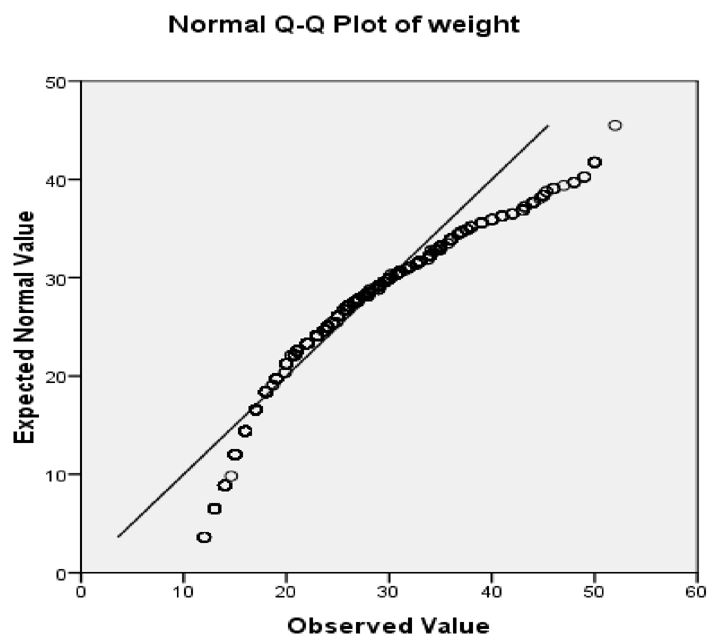


Figure11: Normal Q-Q plot and detrended normal Q-Q plot shows rightly skewed and moderately peaked distribution pattern for 6-12 years boys weight

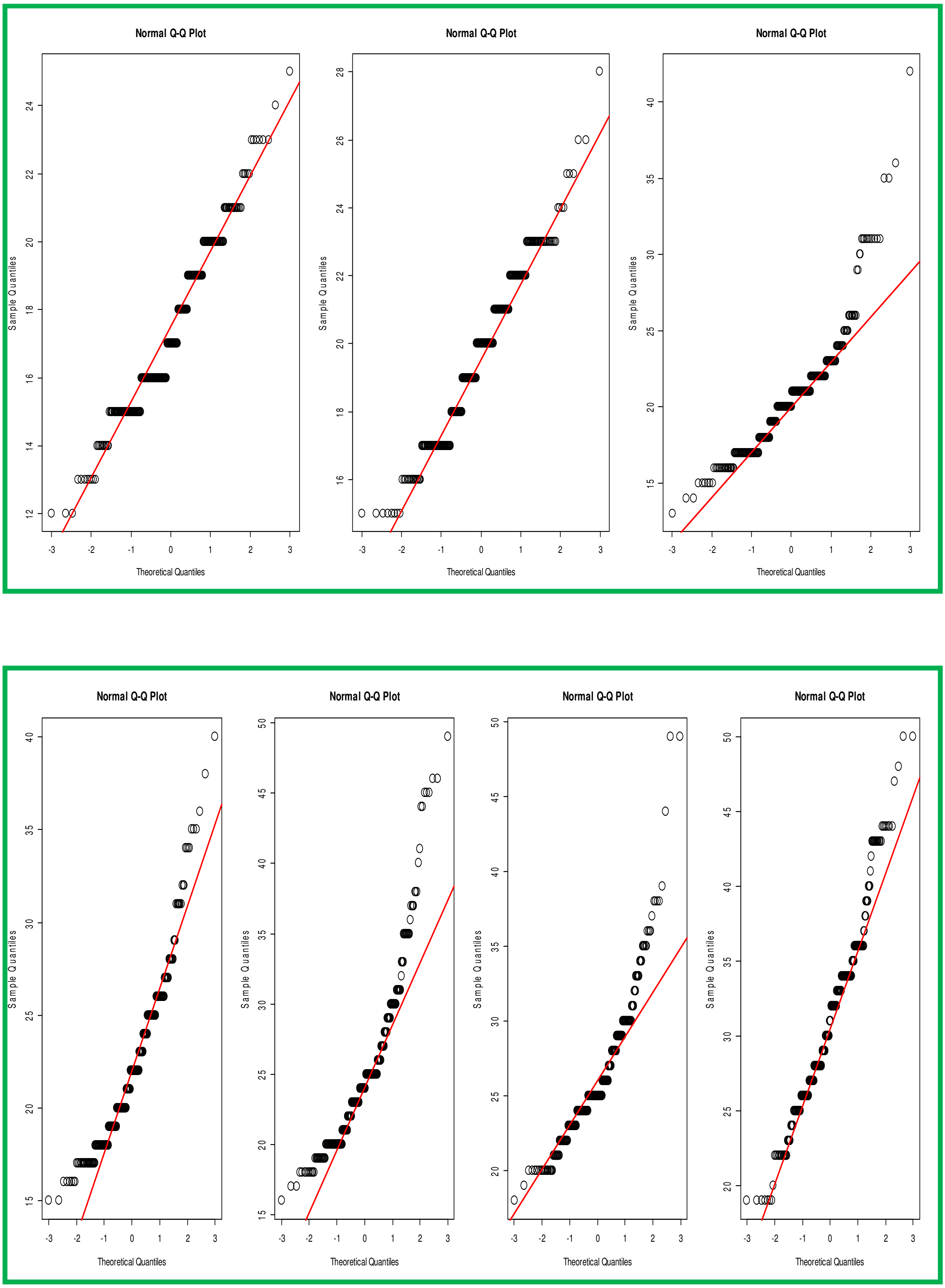


Figure12: Normal Q-Q plot assess the each agewise normality of

Weight among 6-12 years boys

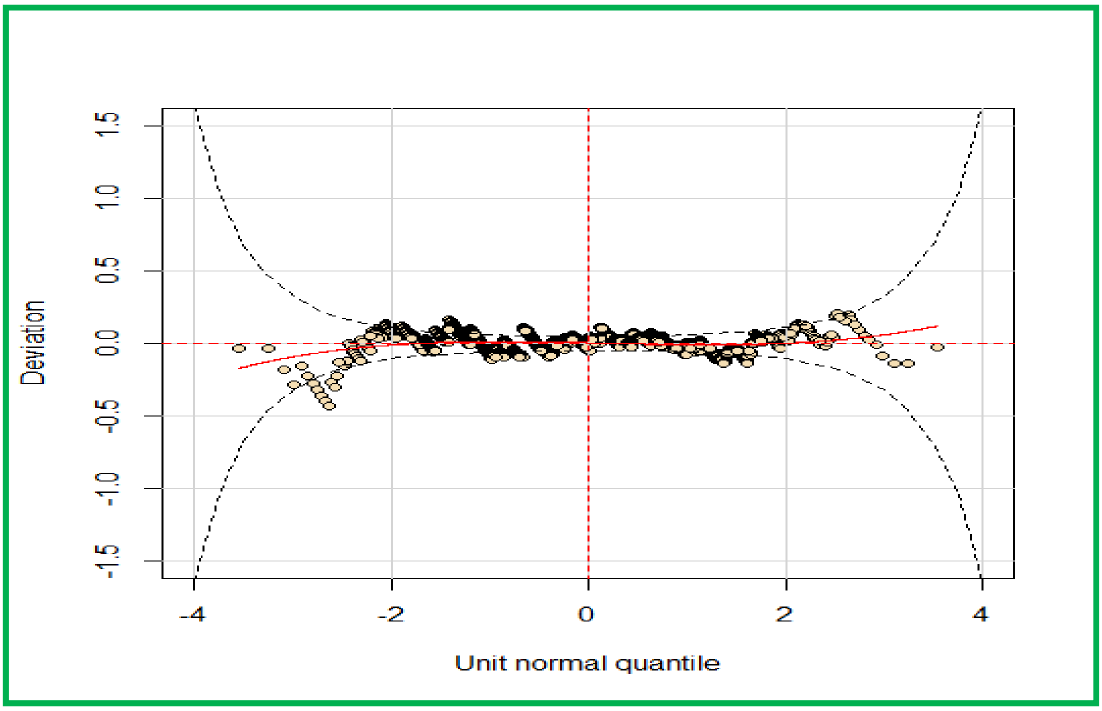


Figure13: Worm plot assess the normality of fitted weight-for-age data for 6-12 years boys

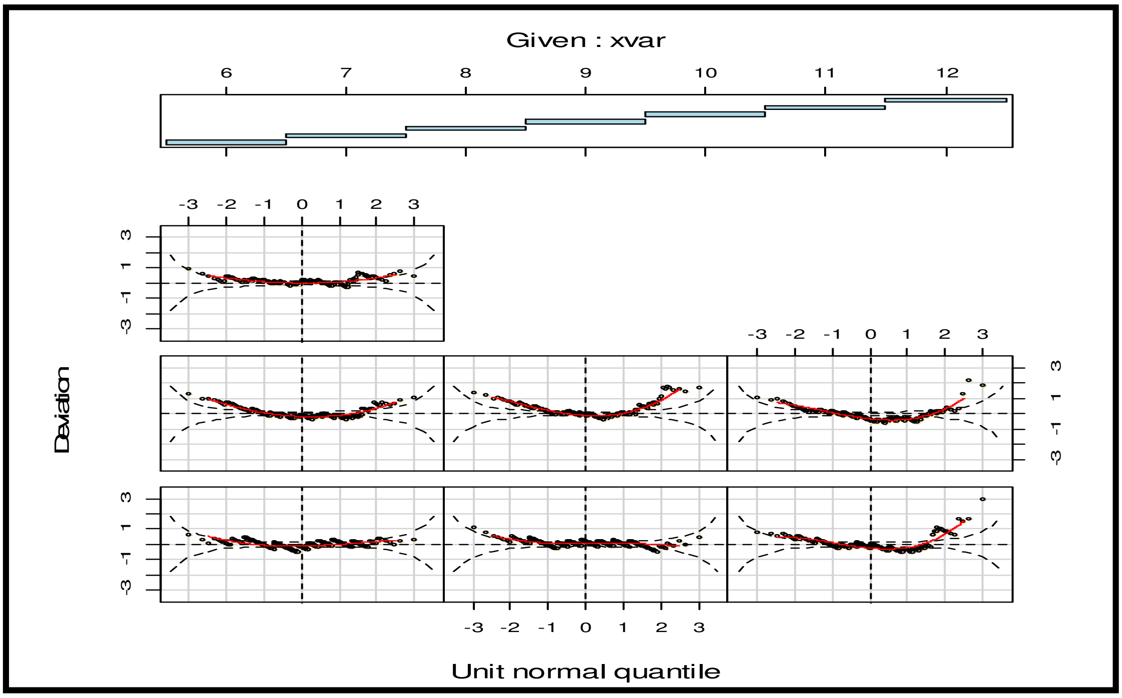


Figure14: Worm plots of Z scores model of df(μ)=4 df(σ)=3, ν=1, τ=2 with age transformation x=age $^{0.80}$ for 6-12 years weight-for-age of boys

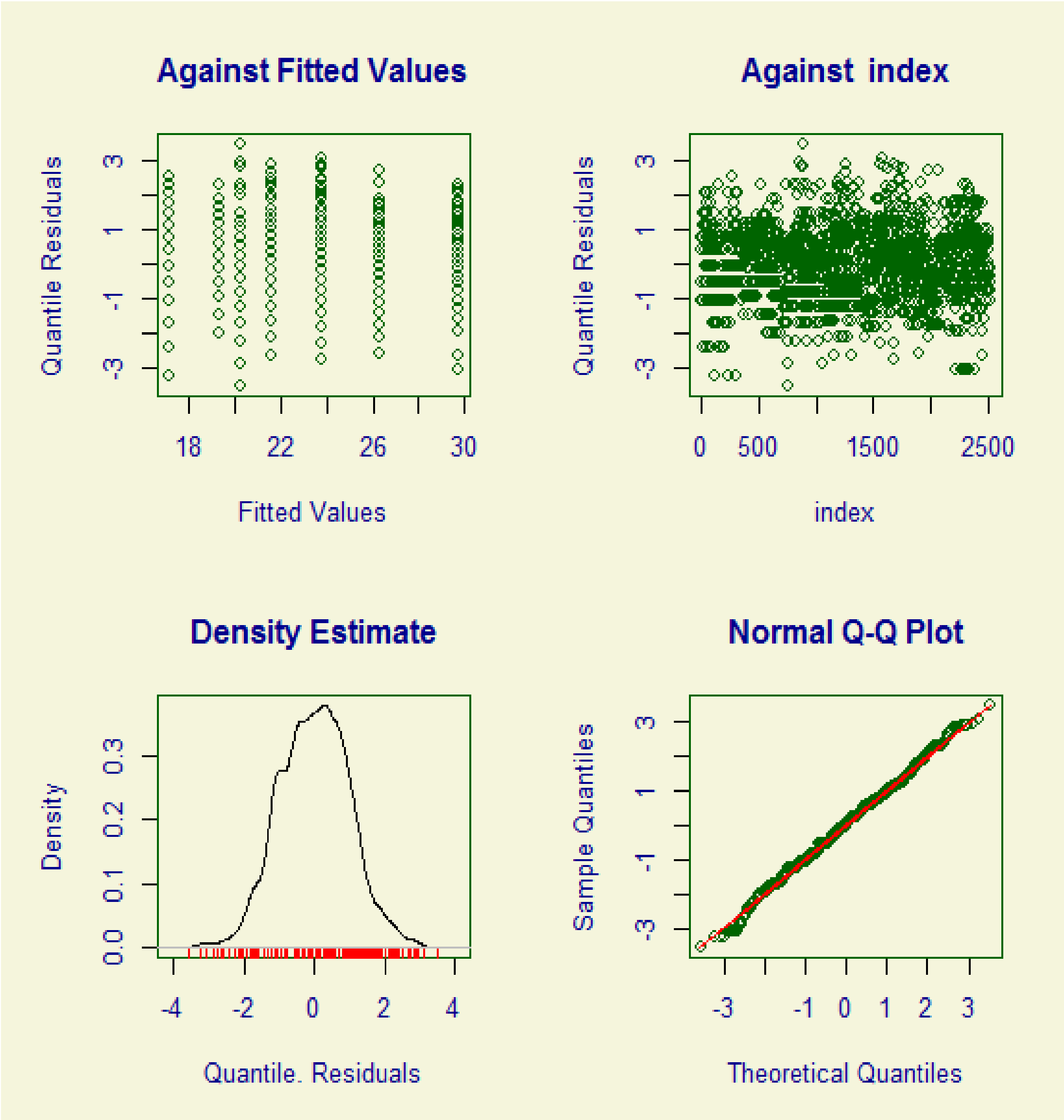


Figure 15: Normalized residue charts of fitted model BCPE(x=age $^{0.80}$ df(μ)=4 df(σ)=3, ν=1, τ=2) for 6-12 years weight-for age of boys.

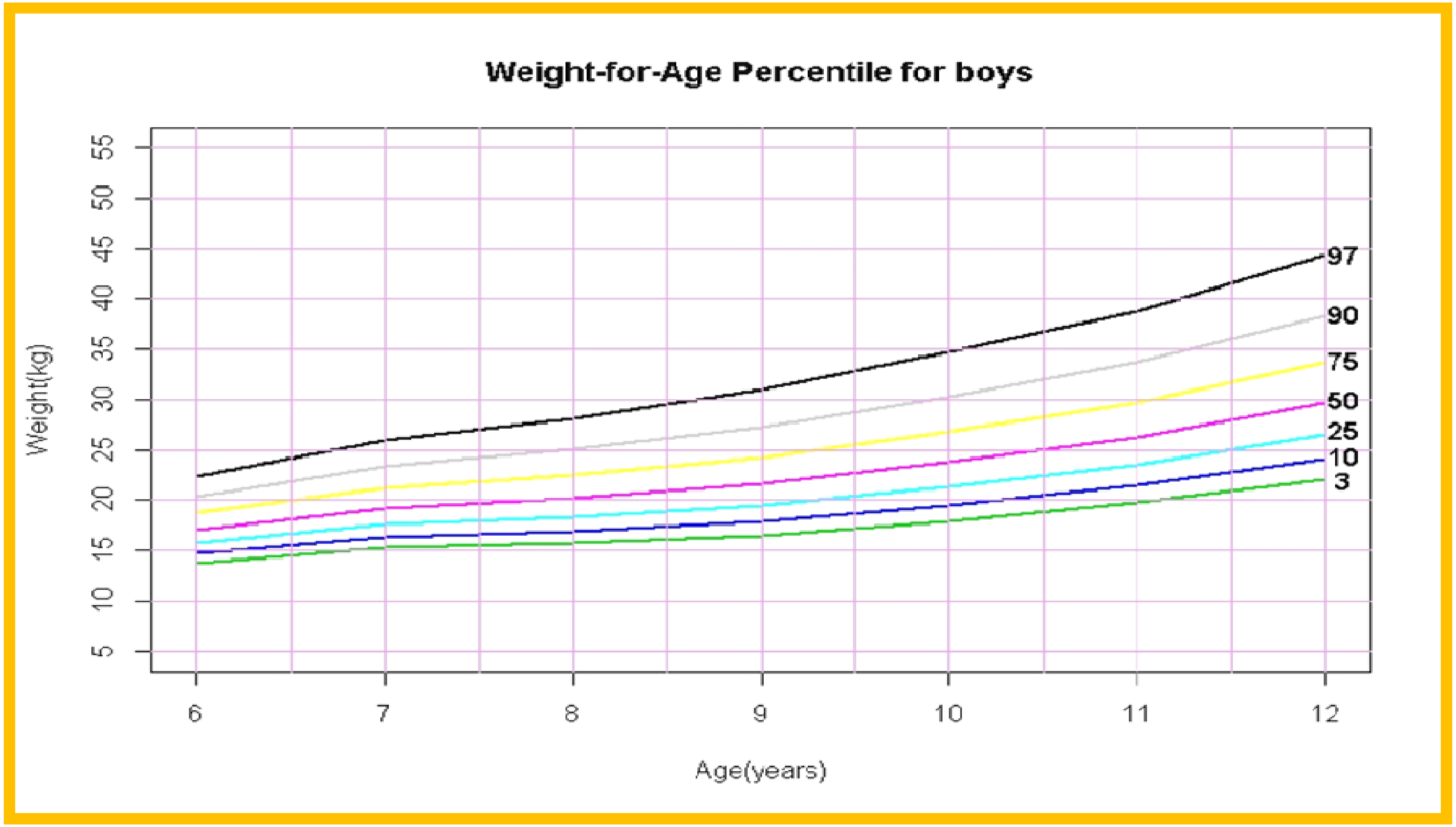


Figure16A: Weight-for age smoothened percentile curves for boys from 6 to 12 years

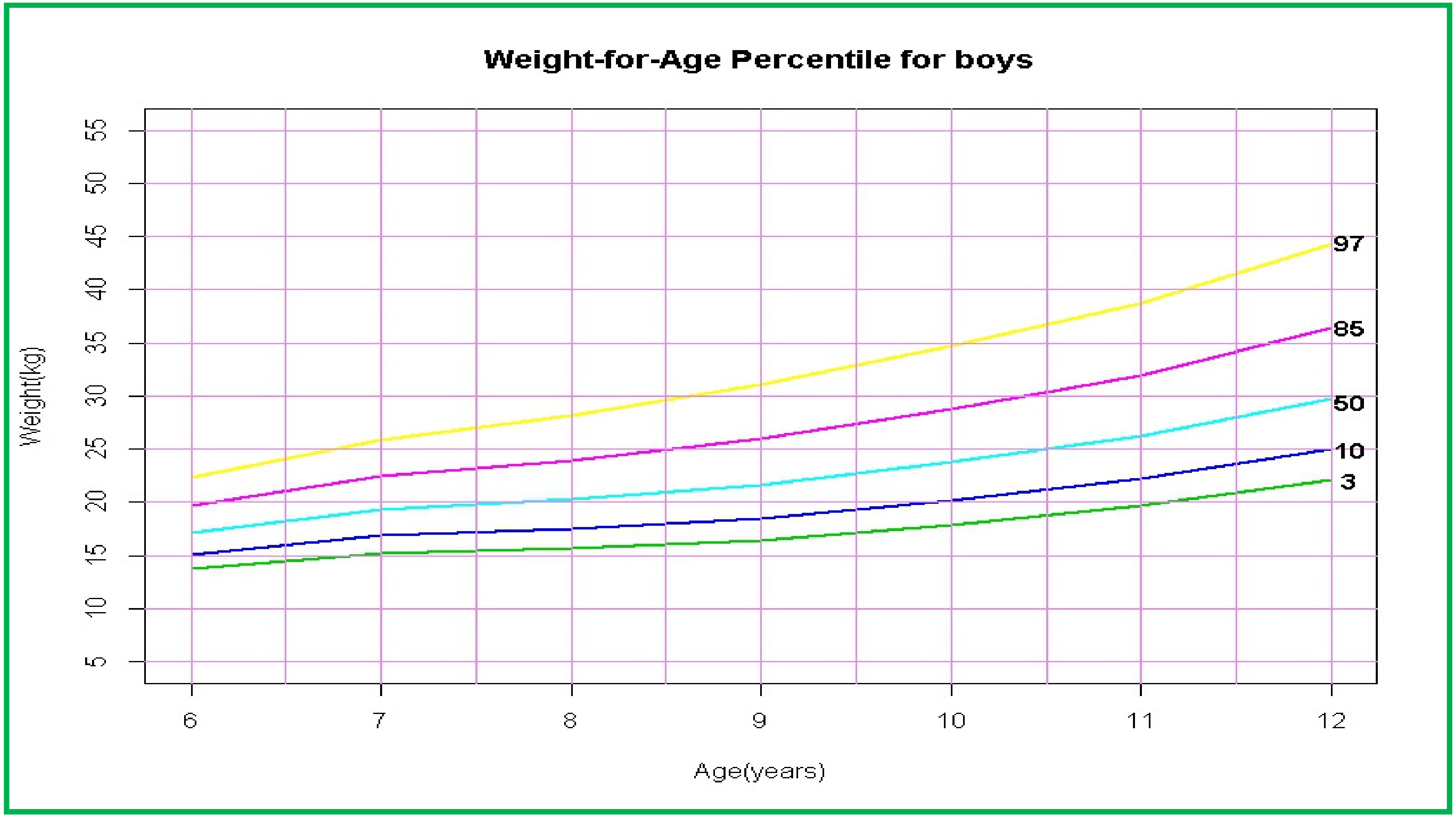


Figure16B: WHO standards weight-for age percentiles for boys from 6 to 12 years

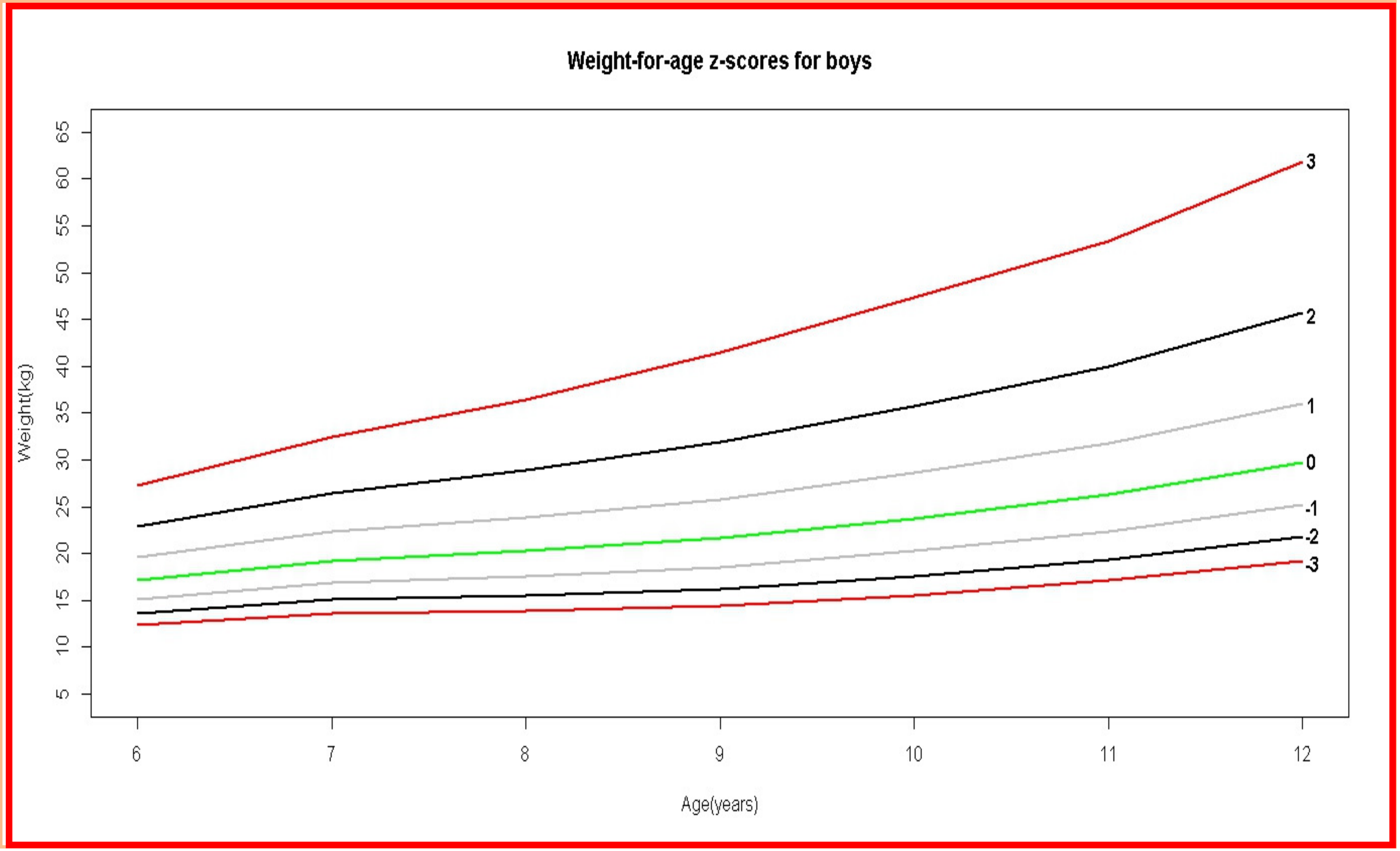


Figure17: Weight-for age Z scores for boys from 6 to 12 years

4.2 Construction of Weight-for-age reference chart for girls

4.2.1 Sample size and mean weight

There were 2520 weight observations for girls. Cross-sectional sample sizes, mean weight and standard deviation for each age group are shown in Tables 22.

Table 22 Cross-sectional sample sizes for weight-for-age for girls

Age (years)	No. of girls	Weight(kg)	
		Mean	SD
6 years	360	16.22	2.07
7 years	360	18.45	2.89
8 years	360	19.49	3.32
9 years	360	21.32	3.61
10 years	360	24.46	4.98
11 years	360	28.63	4.81
12 years	360	33.11	5.27

Each age group wise 360 girls were taken for the study. Mean weight of girls shows there is a gradual increase for each age.

4.2.2 Normality checking

Normality of weight distribution was checked using graphical methods and mathematical methods. Graphically it was tested using Histogram & normal Q-Q plot (Figures18-21) and mathematically it was tested using Kolmogorov-Smirnov normality test (z=5.13 p=0.001), skewness (1.13) & kurtosis (0.28).

Calculated Kolmogorov-Smirnov normality test value is Z=5.13 and it is statistically significant, it indicates that the 6-12 years girls weight is not distributed normally.

In this study, calculated skewness value is 1.13, so it shows presence of positive skewness among 6-12 years girls weight. Calculated kurtosis value is 0.28, it is having lower height than normal distribution, so it shows presence of platykurtic among 6-12 years girls weight. Study observations of skewness (1.13) and kurtosis (0.28) values indicating that the weight distribution is highly skewed to right with a less peak than normal distribution.

Table 23: Weight(kg) Mean, SD and percentiles for girls

Age	Mean	Median	SD	Skewness	Kurtosis
6	16.78	17.00	2.15	0.84	0.71
7	19.32	19.71	2.36	1.63	3.96
8	20.14	20.62	4.19	1.88	4.06
9	22.09	22.63	4.23	1.24	3.10
10	25.04	25.13	5.41	1.12	1.68
11	26.11	26.18	4.29	0.25	0.31
12	30.93	31.00	5.86	0.49	1.44

Table 23 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years girls weight. Each age wise skewness values are above "0", so girls weight is positively skewed for all ages. Similarly each age wise kurtosis values tells, 6^{th}, 10^{th}, 11^{th} and 12^{th} year old girls weights are platykurtic and 7^{th} ,8^{th} and 9^{th} year old girls weights are leptokurtic. So the 6-12 years girls weight data shows presence of skewness as well as kurtosis.

Normality of girls weight is assessed using graphical method of Histogram with normal curve. Figure 18 and figure 19 of histogram with normal curve shows, 6-12 years girls weight is not normally distributed and it is skewed to right side.

Normal Q-Q plot and Detrended Q-Q plot graphically helps to find the normality of the data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Figure 20 and figure 21 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution.

4.2.3 Model selection and results

The model BCPE($x=age^{\lambda}$, $df(\mu)=4$, $df(\sigma)=3$, $\nu=1$, $\tau=2$) taken as a starting point to construct the weight-for-age reference curves. Improvement of the fitness of the models was investigated by studying changes in global deviance at varying levels of the age-transformation power λ Table 24 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power $\lambda=0.30$. This smallest deviance value of λ value was taken for model fitting.

Table 24 Global deviance (GD) for models within the class BCPE(x=age $^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for weight-for-age for girls

Power(λ)	Global Deviance(GD)
0.10	13716.86
0.20	13728.29
0.30	**13708.25**
0.40	13718.25
0.50	13725.26
0.60	13724.31
0.70	13768.37
0.80	13772.46
0.90	13780.57
1.00	13772.71

After choosing the age-transformation power λ=0.30, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=3 . So the selected final model is BCPE(x=age $^{0.3}$, df(μ)=4, df(σ)=3, ν=1, τ=2).

4.2.4 Goodness-of-fit assessment fitted model for 6-12 years girls

Goodness-of –fit for the selected model of BEPE ($x=age^{0.30}$, $df(\mu)=4$ $df(\sigma)=3$, $\nu=1$, $\tau=2$) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q test.

The worm plot for fitted model shown in figure22 (overall) and in figure23 (age wise) do not indicate any upward or downward shifts except11th & 12th year. This may be due to some extreme values in that age groups.There is no evidence to show that worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 25: Q-test for z-scores form the model BCPE(0.30, 4,3,1,2) for weight-for-age for girls

Age	Z1	Z2	Z3	Z4
6 years	-0.367	-0.218	0.918	0.670
7 years	1.303	0.027	1.029	1.278
8 years	-0.693	-0.363	1.052	1.732
9 years	-0.225	-0.886	1.789	-1.782
10 years	-0.320	2.417	1.098	-1.910
11 years	0.435	0.095	-1.979	**-2.142**
12 years	-0.012	-1.214	**-2.282**	1.330
TOTAL Q stats	2.656	8.288	53.194	47.987
Degrees of freedom for Q stats	2.000	5.000	6.000	6.000
P-value for Q stats	0.26	0.14	0.06	0.10

Note: Absolute values of z1, z2, z3 or z4 larger than 2 indicate that , they are misfit for calculating mean, variance, skewness and kurtosis.

In table 25 the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3, and z4. Absolute deviations greater than 2 noted in the 12^{th} year Z3=-2.282 and 11^{th} year z4=-2.142, however overall p-value for the Q–test is not significant (0.26, 0.14, 0.06, 0.10). There is no evidence to show that worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 26: Final model Skewness and kurtosis for 6-12 years girls

****

Summary of the Quantile Residuals	
mean	= 0.0009166542
variance	= 1.000305
coef. of skewness	= 0.03233467
coef. of kurtosis	= 3.112088
Filliben correlation coefficient	= 0.9985959

****

Table 26 shows after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.0009166542 against 0, variance =1.000305 against 1, skewness =-0.03 against 0, kurtosis=3.11 against 3. It was shown graphically in figure 24.

Figure 24 shows the residual distribution of weight-for-age in females: quantile (standardised) residuals plotted against fitted values and against age, the density estimate with rug plot, and the quantile–quantile plot. The distribution is normal. A straight 1:1 line (plot on RHS bottom) indicates a good fit of the GAMLSS model.

4.2.5 LMS values and percentiles for 6-12 years girls

Table 27 shows the 3rd, 10th , 25th ,50th ,75th , 90th and 97th predicted percentile values of weight for 6-12 years girls with their respective lamda,-mu- sigma values.

Less than 3rd percentile is underweight. Less than 13.0 kg among 6 year old girls are considered underweight, less than 14.3 kg among 7 year old girls are considered underweight, less than 15.0 kg among 8 year old girls are considered underweight, less than 16.0 kg among 9 year old girls are considered underweight, less than 18.0 kg among 10 year old girls are considered underweight, less than 20.7 kg among 11 year old girls are considered underweight and less than 24.3 kg among 12 year old girls are considered underweight . Figure 25A shows the age related smoothened percentile reference chart for standard values and Figure 25B shows the WHO standard percentile curve.

Table 27: LMS values and percentiles for 6-12 years girls

Age	L	M	S	SD	Percentiles(weight in kg)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	16.0	0.0076	2.1	13.0	13.8	14.8	16.0	17.4	19.0	20.8
7 years	1	17.9	0.0075	2.9	14.3	15.3	16.4	17.9	19.7	21.6	23.9
8 years	1	19.1	0.0076	3.3	15.0	16.1	17.4	19.1	21.2	23.5	26.4
9 years	1	20.8	0.0076	3.6	16.0	17.3	18.8	20.8	23.3	26.1	29.6
10 years	1	23.7	0.0071	5.0	18.0	19.5	21.3	23.7	26.7	30.1	34.5
11 years	1	27.7	0.0062	4.8	20.9	22.7	24.8	27.7	31.3	35.5	40.9
12 years	1	32.3	0.0053	5.3	24.3	26.4	28.9	32.3	36.5	41.4	47.8

4.2.6 LMS values and Z-score for 6-12 years Girls

The Z-score system expresses the anthropometric value as a number of standard deviations below or above the reference median value or we can say Z-scores or SD scores are used to describe mathematically how far a measurement is from the median (average). Because z-scores have a direct relationship with percentiles, a conversion can occur in either direction using a standard normal distribution table. Therefore, for every z-score there is a corresponding percentile value and similarly for every percentile value there is a corresponding z-score value. Any desired percentile or *z* score can be calculated from the smoothened L, M, and S parameters. Its advantages are that it permits calculation of *z* scores as well as percentiles and allows calculation of any desired percentile. Accurate estimation of percentiles and Z-scores from the LMS method relies on the assumption that after transformation and smoothing, the variables of interest are normally distributed.

Table 28 shows 6-12 year old girls standard predicted z scores -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD weight values and their respective lamda-mu-sigma values. Less than -2SD is underweight. Less than 11.7 kg among 6 year old girls are considered underweight, less than 12.7 kg among 7 year old girls are considered underweight, less than 13.3 kg among 8 year old girls are considered underweight, less than 14.1 kg among 9 year old girls are considered underweight, less than 15.7 kg among 10 year old girls are considered underweight, less than 18.2 kg among 11 year old girls are considered underweight and less than 21.2 kg among 12 year old girls are considered underweight. Figure 26 shows the age related Z-score reference chart

Table28: LMS values and Z score for 6-12 years Girls

Age	L	M	S	SD	Z score(weight in kg)						
					-3	-2	-1	0	1	2	3
6 years	1	16.0	0.0076	2.1	11.7	12.9	14.3	16.0	18.2	21.2	25.3
7 years	1	17.9	0.0075	2.9	12.7	14.1	15.8	17.9	20.7	24.4	29.9
8 years	1	19.1	0.0076	3.3	13.3	14.8	16.7	19.1	22.4	27.0	34.1
9 years	1	20.8	0.0076	3.6	14.1	15.8	18.0	20.8	24.7	30.4	39.6
10 years	1	23.7	0.0071	5.0	15.7	17.7	20.3	23.7	28.4	35.6	47.7
11 years	1	27.7	0.0062	4.8	18.2	20.6	23.7	27.7	33.4	42.2	57.3
12 years	1	32.3	0.0053	5.3	21.2	24	27.6	32.3	39.0	49.3	66.9

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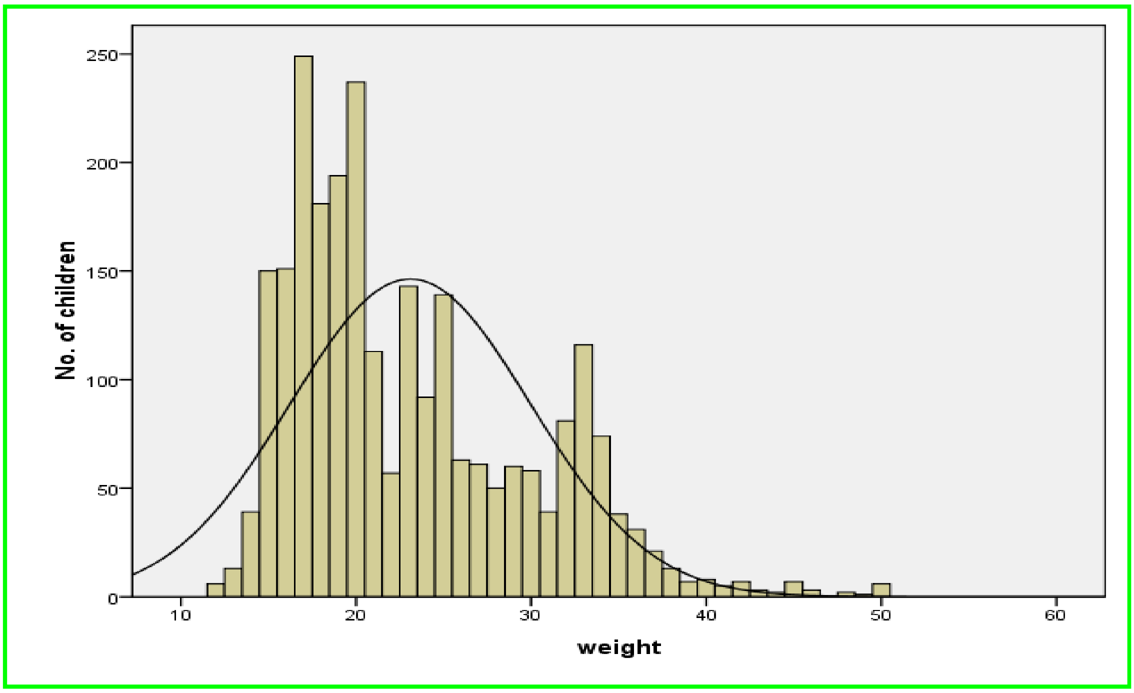


Figure 18: Histogram with normal curve shows the positively skewed distribution for 6-12 years old girls (mean =23.2 median= 22.0 skewness=1.13 kurtosis=0.28)

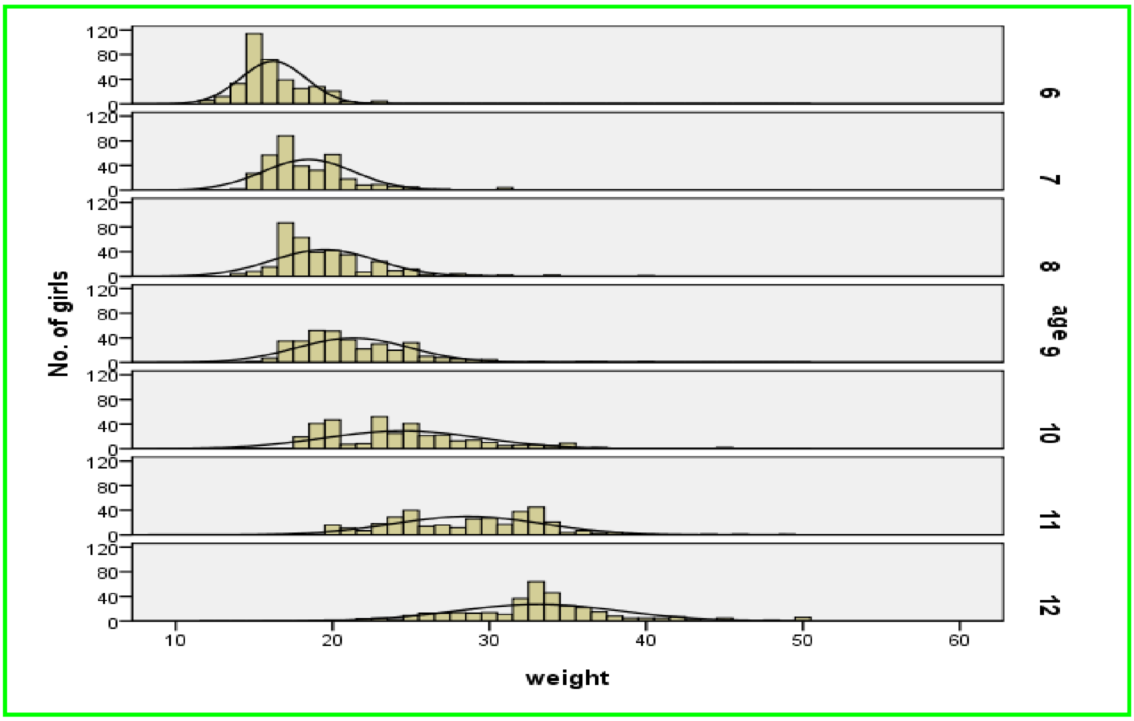
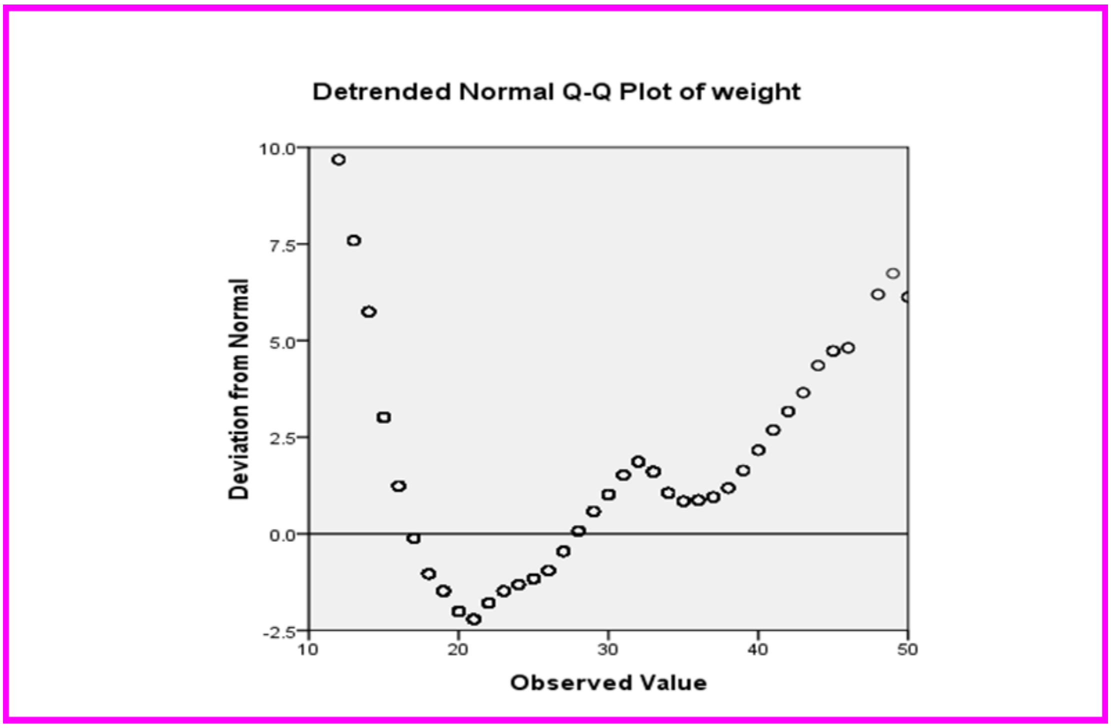


Figure 19: Histogram with normal curve assess the each age wise normality of weight distribution among 6-12 years girls



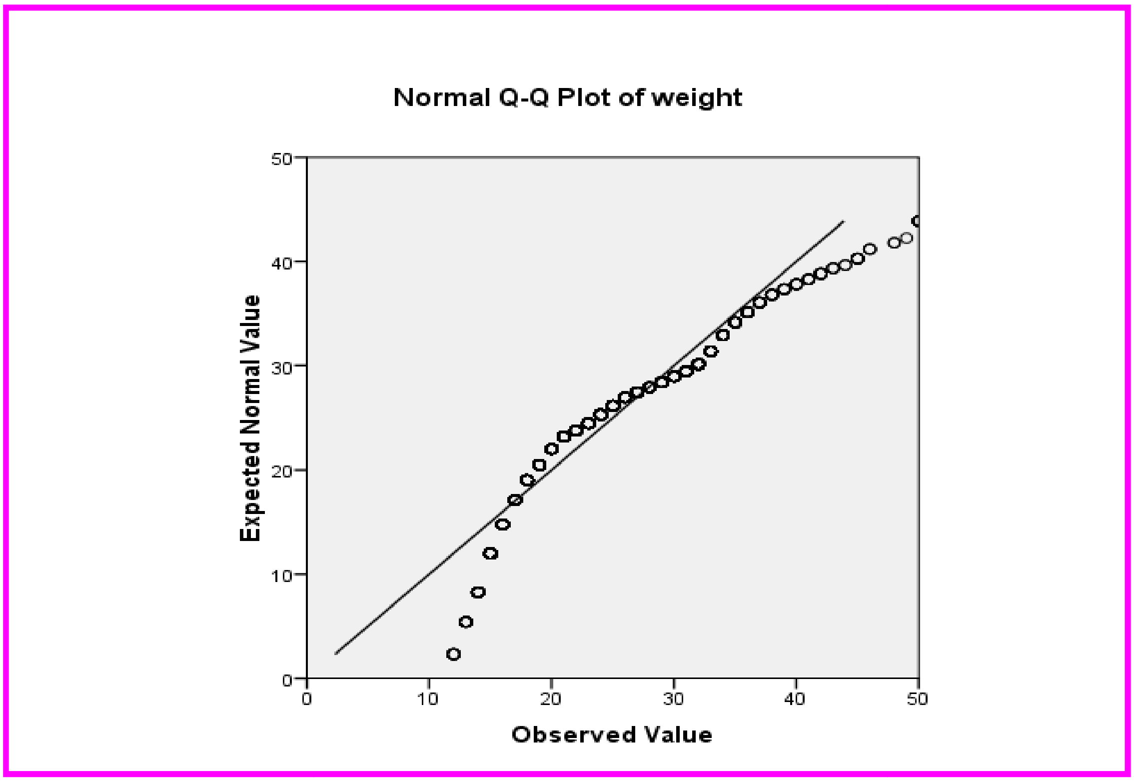


Figure 20: Normal Q-Q plot and detrended normal Q-Q plot assess the normality of weight among 6-12 years girls

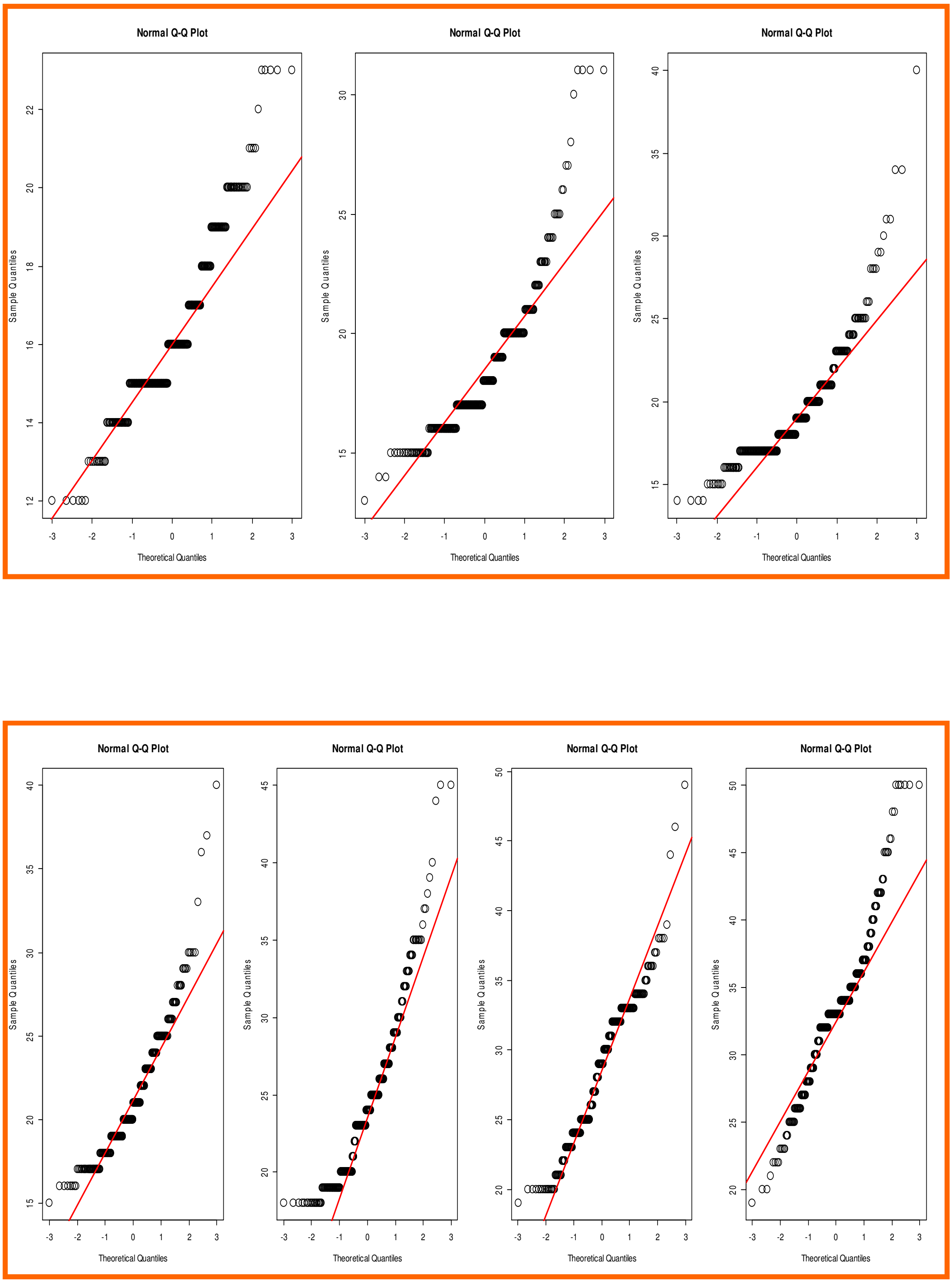


Figure 21: Normal Q-Q plot assess the each agewise normality of Weight among 6-12 years girls

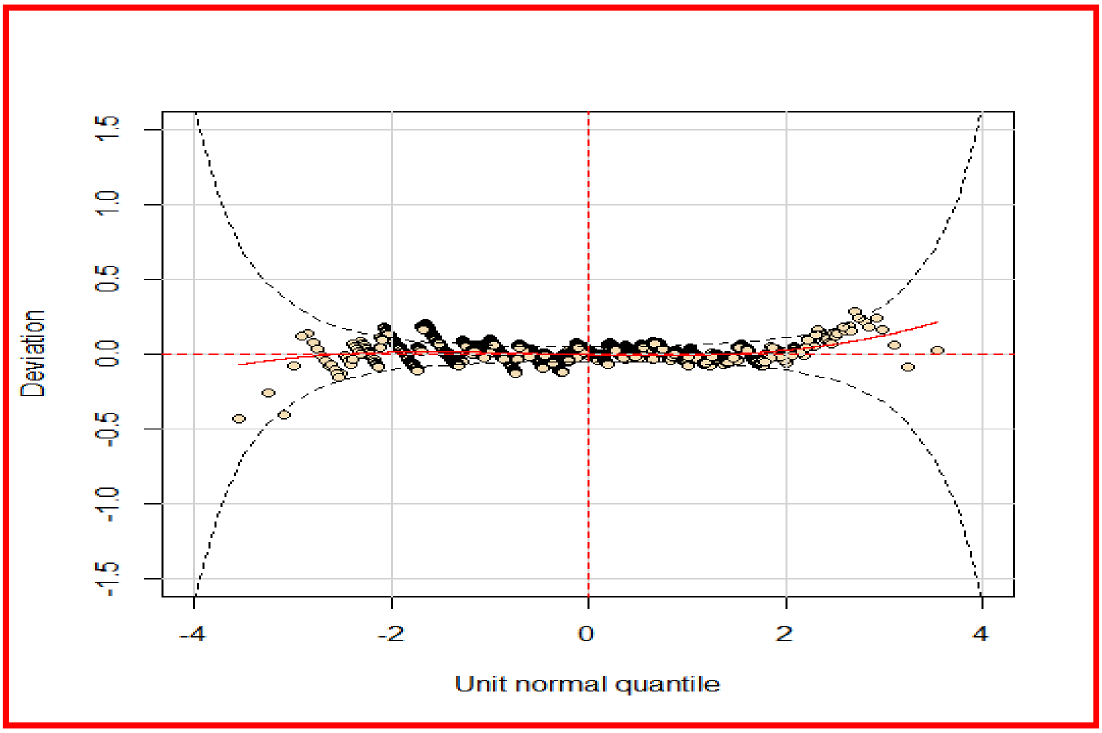


Figure 22: Worm plot assess the normality of fitted weight-for-age data for 6-12 years girls

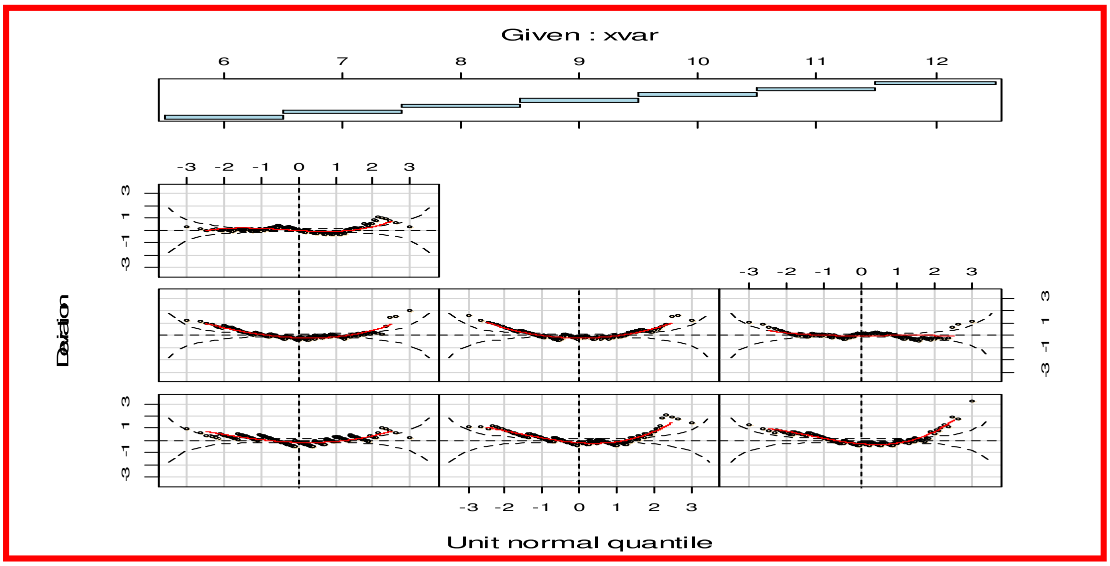


Figure 23: Worm plots of Z scores model of df(μ)=4 df(σ)=3, ν=1, τ=2 with age transformation x=age$^{0.30}$ for 6-12 years weight-for-age of girls

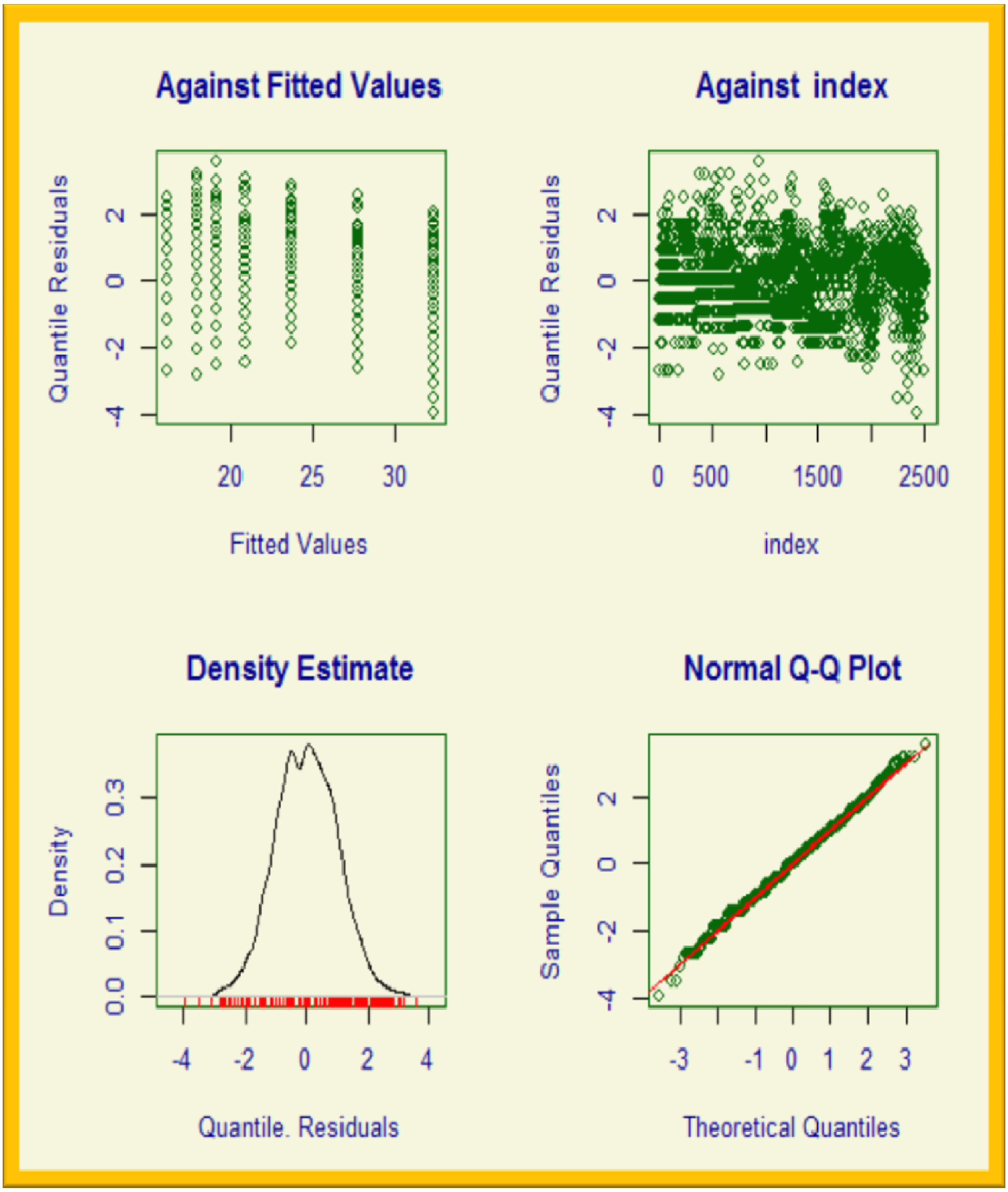


Figure 24 :Residual analysis of fitted model BCPE(x=age$^{0.30}$ df(μ)=4 df(σ)=3, ν=1, τ=2) for 6-12 years weight-for-age of girls

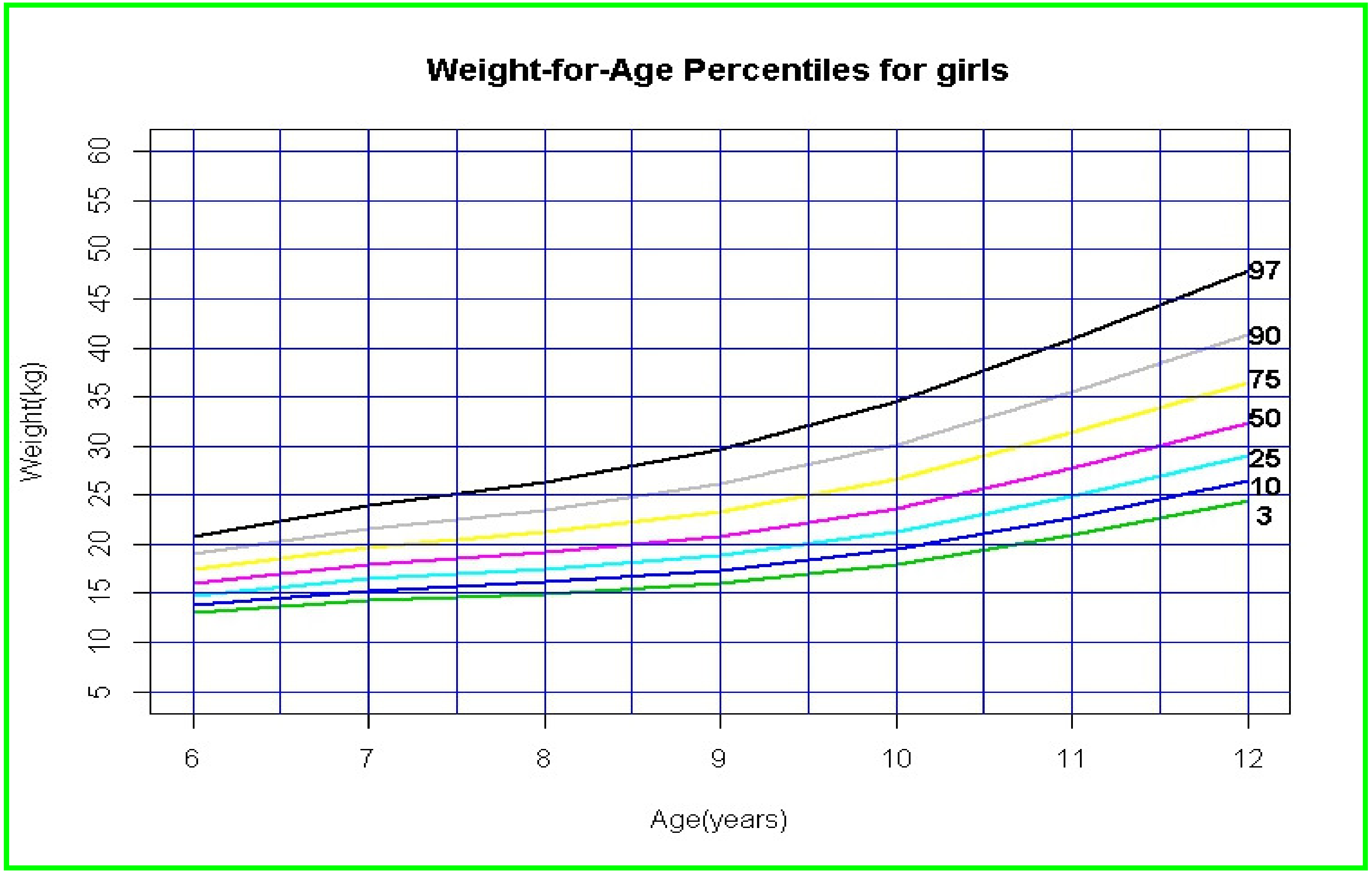


Figure25A:Weight-for-age smoothened percentiles for girls from 6 to 12 years

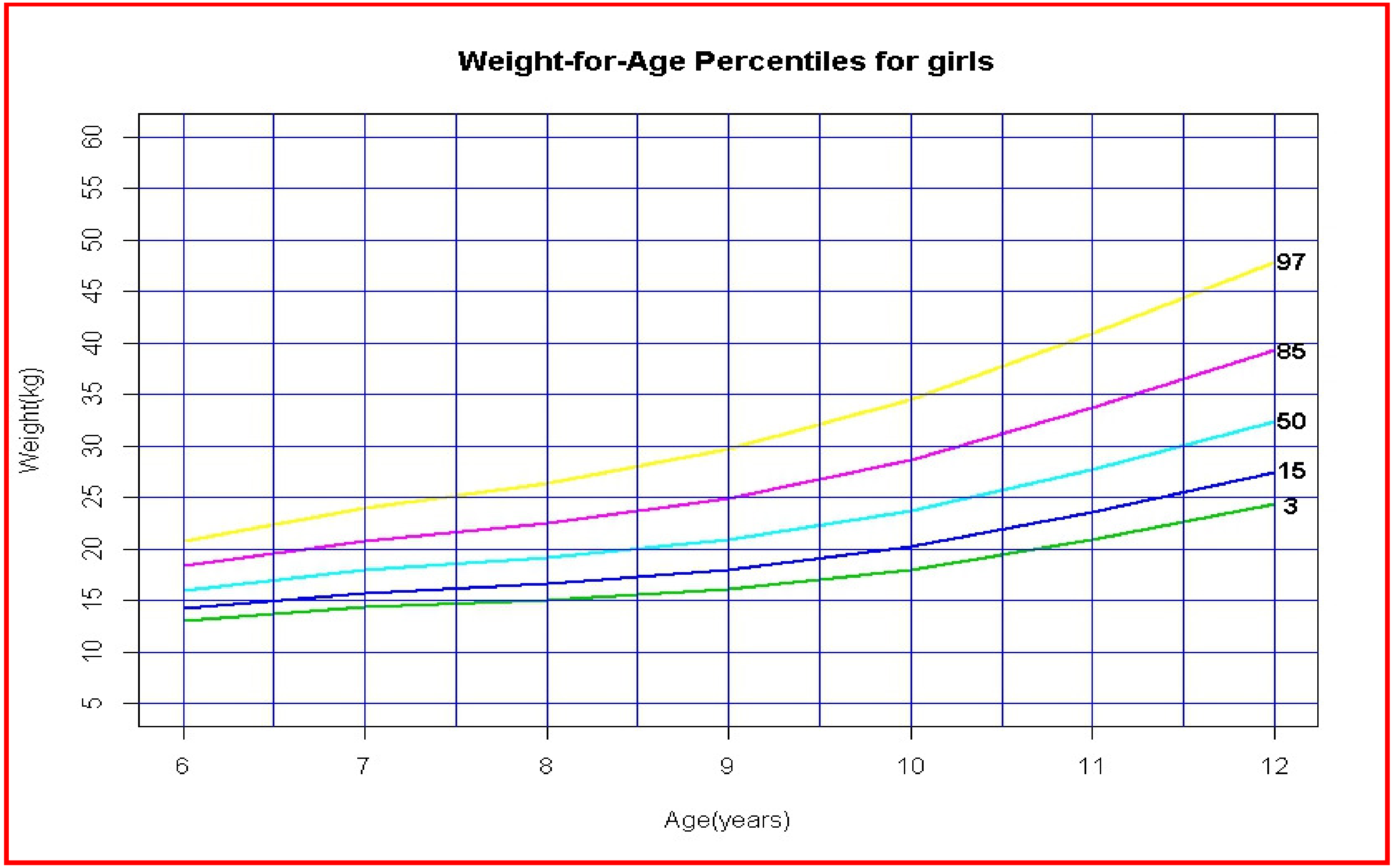


Figure25B: WHO standards weight-for age percentiles for girls from 6 to 12 years

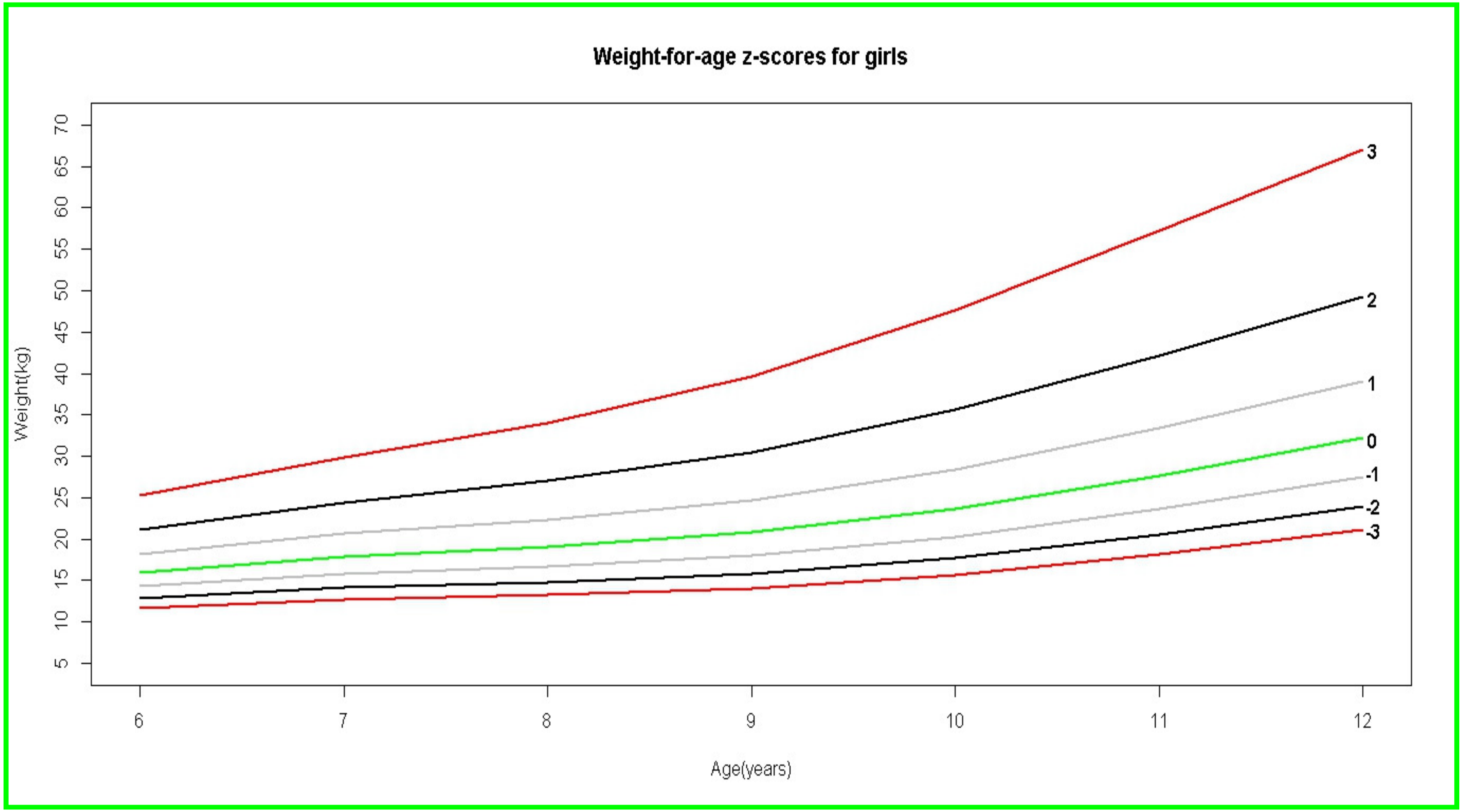


Figure26: Weight-for age Z scores for girls from 6 to 12 years

4.3 Construction of Height-for-age reference chart for boys

4.3.1 Sample size and mean height

There were 2520 height observations for boys. Cross-sectional sample sizes, mean height and standard deviation for each age group are shown in Tables 29.

Table 29 : Cross-sectional sample sizes for height-for-age for boys

Age (years)	No. of boys	Height(cm)	
		Mean	SD
6 years	360	111.12	5.77
7 years	360	116.42	5.20
8 years	360	120.32	6.21
9 years	360	124.65	7.27
10 years	360	131.15	6.28
11 years	360	135.56	6.80
12 years	360	140.17	5.24

Each age group wise 360 boys were taken for the study. Mean height of boys shows there is a gradual increase for each age.

4.3.2 Normality checking

Normality of height distribution was checked using graphical and mathematical methods. Graphically it was tested using Histogram & normal Q-Q plot (Figure 27-30) and mathematically it was tested using Kolmogorov-Smirnov normality test (z=3.95 p=0.001), skewness(0.05) & kurtosis(-0.86).

Kolmogorov-Smirnov normality test is mathematical method of finding normality of distribution for larger sample size data. Calculated KS test value is Z=3.95 and it is statistically significant, it indicates that the 6-12 years boys height is not distributed normally.

In this study, calculated skewness value is 0.05, so it shows presence of mild positive skewness among 6-12 years boys height. Calculated kurtosis value is -0.86, so it shows presence of platykurtic among 6-12 years boys height.

Observed height distribution of 6-12 years boys data skewness (1.14) and kurtosis (1.57) values indicating that the height variable is skewed to right with a less peak when comparing normal distribution.

Table30: Height(cm) Mean and SD for 6-12 boys

Age	Mean	Median	SD	Skewness	Kurtosis
6 years	111.12	112.00	5.77	-0.38	-0.86
7 years	116.42	115.00	5.20	0.67	1.01
8 years	120.32	120.00	6.21	0.40	0.33
9 years	124.65	125.00	7.27	-0.16	-0.93
10 years	131.15	131.00	6.28	0.06	-0.37
11 years	135.56	135.00	6.80	0.01	3.09
12 years	140.17	140.00	5.24	-0.52	3.38

Table 30 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years boys height. 6^{th}, 9^{th} and 12^{th} year boys height values are below “0” , so boys are have negative skewed values and 7^{th}, 8^{th}, 10^{th} and 11^{th} year boys height values are above “0”, so these boys are having positively skewed values. Similarly each age wise kurtosis values tells, 6^{th} , 7^{th} , 8^{th} , 9^{th} and 10^{th} year old boys heights are platykurtic and 11^{th} and 12^{th} year old boys heights are leptokurtic. So the 6-12 years boys height data shows presence of skewness as well as kurtosis.

Normality of boys height is assessed using graphical method of histogram with normal curve. Figure 27 and figure 28 of histogram with normal curve shows, 6-12 years boys height is not normally distributed and it is skewed to right side.

Normal Q-Q plot and Detrended Q-Q plot graphically helps to find the normality of the data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Figure 29 and figure 30 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution.

4.3.3 Model selection and results

The model BCPE($x=age^{\lambda}$, $df(\mu)=4$, $df(\sigma)=3$, $\nu=1$, $\tau=2$) served as a starting point to construct the height-for-age reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 31 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power $\lambda=0.10$. This smallest deviance value of λ value was taken for model fitting.

Table 31: Global deviance (GD) for models within the class BCPE(x=age$^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for height-for-age for boys

Power(λ)	**Global Deviance(GD)**
0.10	**16236.77**
0.20	16240.32
0.30	16250.36
0.40	16244.40
0.50	16242.44
0.60	16243.48
0.70	16260.53
0.80	16254.58
0.90	16256.64
1.00	16251.70

After choosing the age-transformation power λ=0.10, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penaltyequal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=3 . So the final selected model is BCPE(x=age$^{0.1}$, df(μ)=3, df(σ)=3, ν=1, τ=2).

4.3.4 Goodness-of-fit assessment fitted model for 6-12 years boys

Goodness-of-fit for the selected model BEPE(x=age $^{0.10}$, df(μ)=3 df(σ)=3, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure31(overall) and in figure32(age wise) do not indicate any upward or downward shifts except 6th &7th years. This may be due to some extreme values in that age group.There is no evidence to show that the worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 32: Q-test for z-scores form the model BCPE(0.10, 4,3,1,2)

for height-for-age for boys

Age	**Z1**	**Z2**	**Z3**	**Z4**
6 years	-0.367	-0.218	0.918	**-2.042**
7 years	1.303	0.027	1.929	**2.078**
8 years	-0.693	-0.363	1.992	1.732
9 years	-0.225	-0.886	1.789	-1.782
10 years	-0.320	2.417	1.098	-1.100
11 years	0.435	0.095	-1.979	1.042
12 years	-0.012	-1.214	-1.882	1.330
TOTAL Q stats	2.656	8.288	9.394	8.987
Degrees of freedom for Q stats	2.000	5.000	6.000	6.000
P-value for Q stats	0.265	0.141	0.100	0.120

Note: Absolute values of z1,z2,z3 or z4 larger than 2 indicate that, they are misfit for mean, variance, skewness and kurtosis respectively.

In table 33 the Q-test was performed to assess the overall significance of the deviations of z1 ,z2, z3, and z4. Absolute deviations greater than 2 noted in the 6th year z4=-2.042 and 7th year z4=2.078, however overall p-value for the Q –test is not significant(0.26,0.14,0.10, 0.12). So it is not suggest any significance departure of the fitted model z-scores from normality at the 5% level of significance.

Table 33: Final model Skewness and kurtosis for 6-12 years boys

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Summary of the Quantile Residuals		
mean	=	0.0002096831
variance	=	1.000444
coef. of skewness	=	-0.01173433
coef. of kurtosis	=	2.970131
Filliben correlation coefficient	=	0.999347

****

Table 33 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.00 (against 0), variance =1.00 (against 1), skewness =-0.01 (against 0), kurtosis=2.97 (against 3). It was shown in figure 33.

Figure 33 shows the residual distribution of weight-for-age in females: Quantile (standardized) residuals plotted against fitted values and against age, the density estimate with rug plot, and the Quantile–Quantile plot. The distribution is normal. A straight 1:1 line (plot on RHS bottom) indicates a good fit of the GAMLSS model.

4.3.5 LMS values and percentiles for 6-12 years boys

Table 34 shows the 3rd, 10th, 25th, 50th,75th, 90th and 97th predicted percentile values of height for 6-12 years boys with their respective lamda-mu-sigma values.

Less than 3rd percentile is stunted. Less than 100.8 cm among 6 year old boys are considered stunted, less than 104.8 cm among 7 year old boys are considered stunted, less than 108.4 cm among 8 year old boys are considered stunted, less than 112.6 cm among 9 year old boys are considered stunted, less than 118.2 cm among 10 year old boys are considered stunted, less than 123.7 cm among 11 year old boys are considered stunted and less than 129.3 cm among 12 year old boys are considered stunted. Figure 34A shows the age related smoothened percentile reference chart for standard values and Figure 34B shows the WHO standard percentile curve.

Table34: LMS values and percentiles for 6-12 years boys

Age	L	M	S	SD	Percentiles(height in cm)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	111.3	0.00045	5.8	100.8	104.2	107.6	111.3	115	118.3	121.7
7 years	1	116.1	0.00044	5.2	104.8	108.5	112.2	116.1	119.9	123.5	127.1
8 years	1	120.4	0.00043	6.2	108.4	112.3	116.2	120.4	124.5	128.3	132.1
9 years	1	125.2	0.00042	7.3	112.6	116.8	120.8	125.2	129.5	133.5	137.5
10 years	1	130.8	0.00038	6.3	118.2	122.3	126.4	130.8	135.1	139.1	143.1
11 years	1	135.7	0.00034	6.8	123.7	127.7	131.5	135.7	139.8	143.6	147.4
12 years	1	140.2	0.00029	5.2	129.3	132.9	136.4	140.2	144	147.5	151

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4.3.6 LMS values and Z-score for 6-12 years boys

Table 35 shows 6-12 year old boys' standard predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD height values and their respective lamda-mu-sigma values. Less than -2SD is stunted. Less than 94.0 cm among 6 year old boys stunted are considered stunted, less than 12.7 kg among 7 year old boys are considered stunted, less than 13.3 cm among 8 year old boys are considered stunted, less than 14.1 cm among 9 year old boys are considered stunted, less than 15.7 cm among 10 year old boys are considered stunted, less than 18.2 cm among 11 year old boys are considered stunted and less than 21.2 cm among 12 year old boys are considered stunted. Figure 35 shows the age related Z-score reference chart.

Table 35: LMS values and Z score for 6-12 years boys

Age	L	M	S	SD	Z score(height in cm)						
					-3	-2	-1	0	1	2	3
6 years	1	111.3	0.00045	5.8	94.0	100.1	105.8	111.3	116.8	122.4	128.1
7 years	1	116.1	0.00044	5.2	97.7	104.1	110.2	116.1	121.9	127.8	133.9
8 years	1	120.4	0.00043	6.2	100.8	107.6	114.1	120.4	126.5	132.9	139.3
9 years	1	125.2	0.00042	7.3	104.7	111.8	118.7	125.2	131.6	138.3	145.1
10 years	1	130.8	0.00038	6.3	110.2	117.4	124.2	130.8	137.2	143.9	150.7
11 years	1	135.7	0.00034	6.8	116.2	122.9	129.5	135.7	141.9	148.2	154.7
12 years	1	139.7	0.00060	5.7	119.2	123.8	131.2	139.7	144.1	152.7	161.8

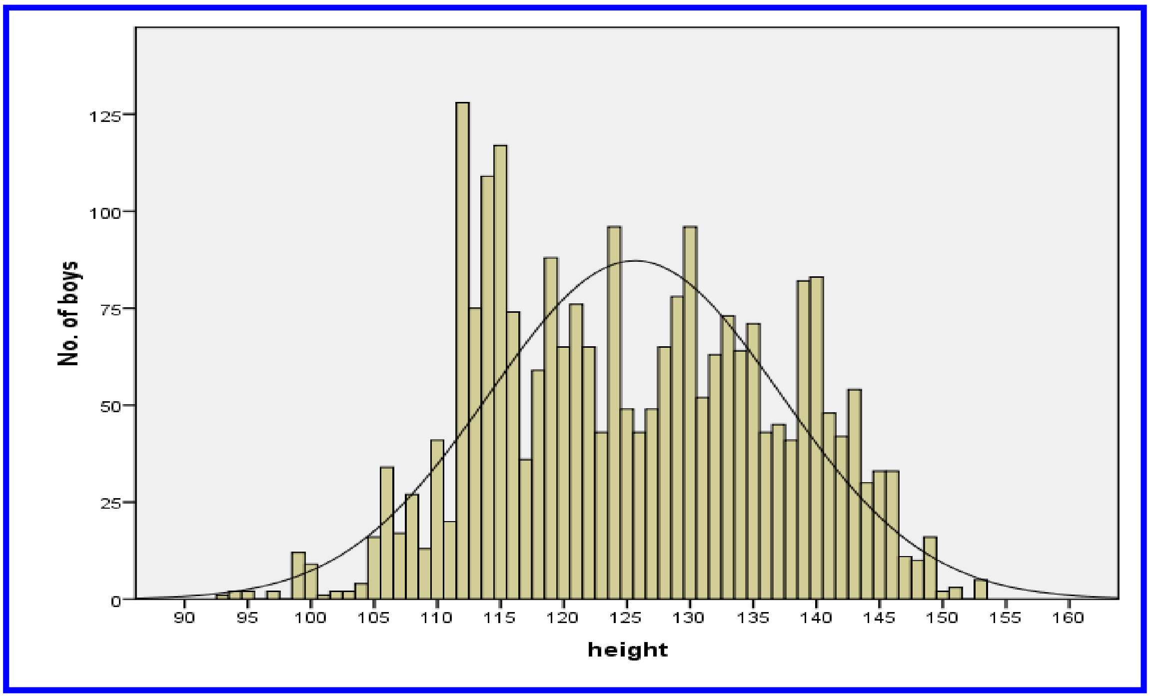


Figure 27: Histogram with normal curve shows the positively skewed distribution for 6-12 years boys height (Mean =125.6 median= 125.0 skewness=0.05 kurtosis=0.86)

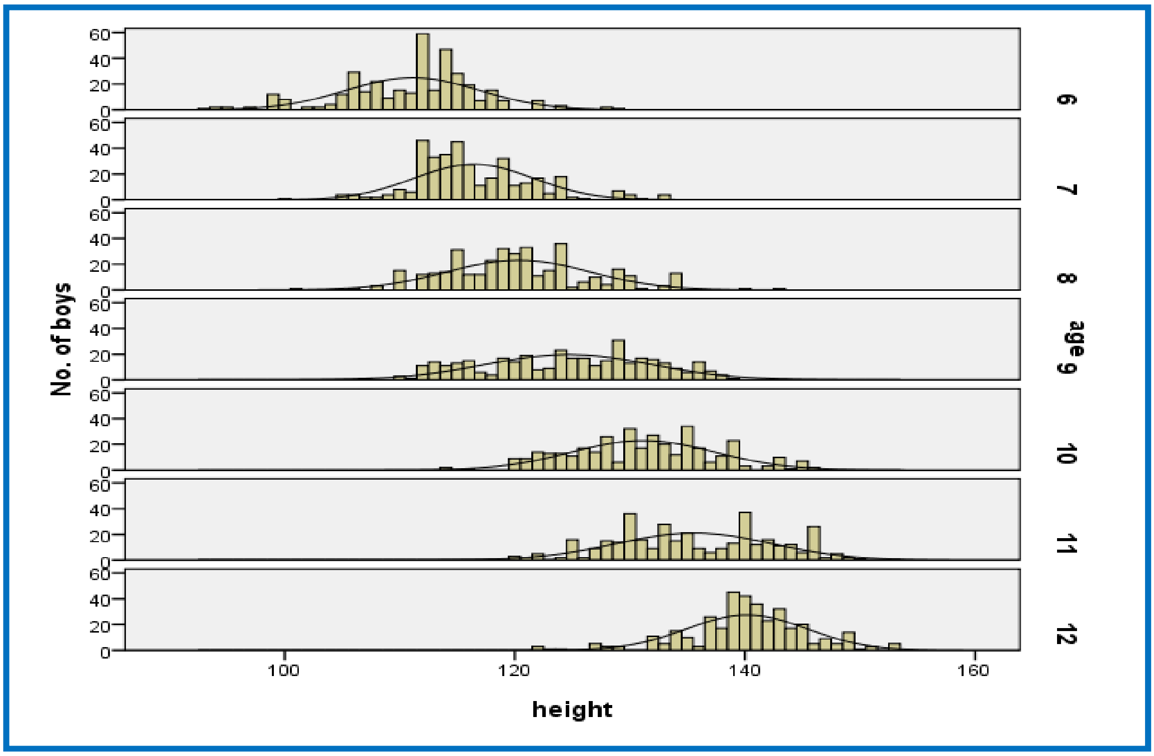
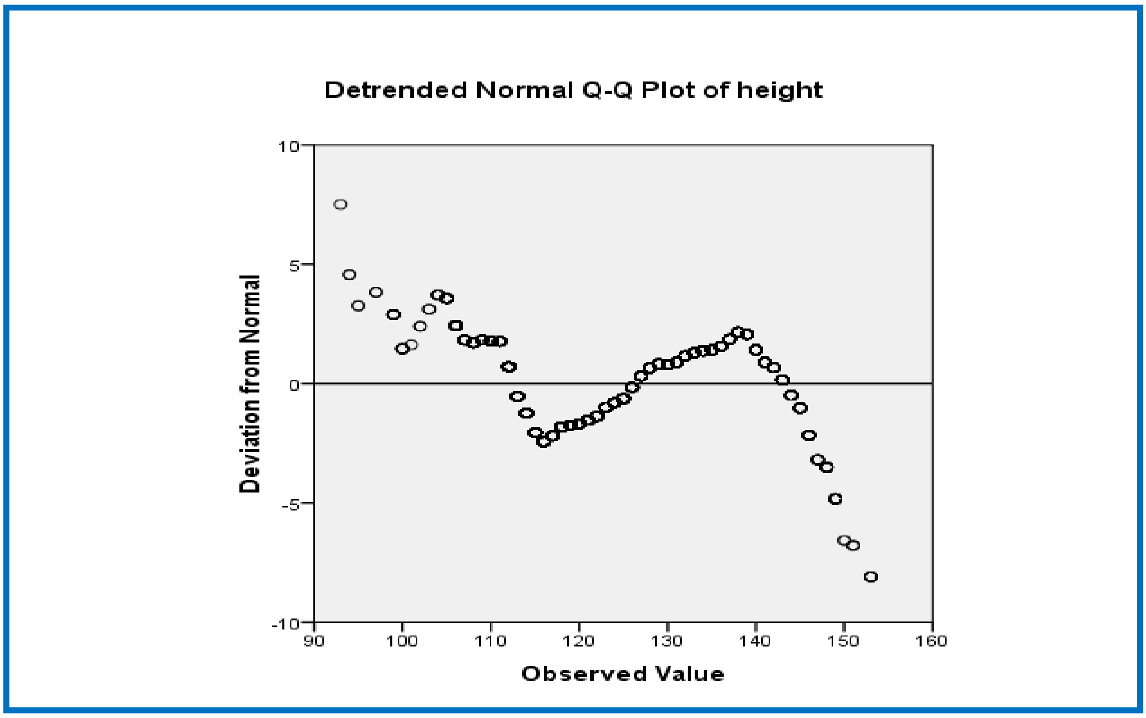


Figure 28: Histogram with normal curve assess the normality of height of 6-12 years boys



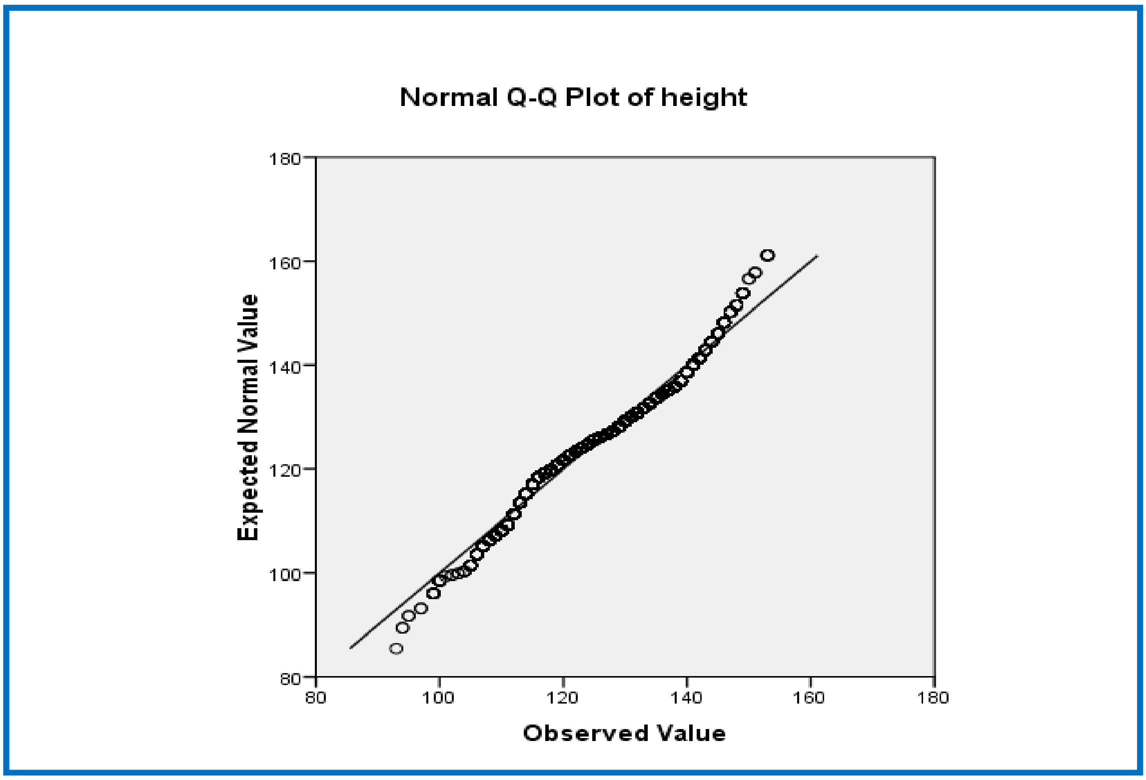
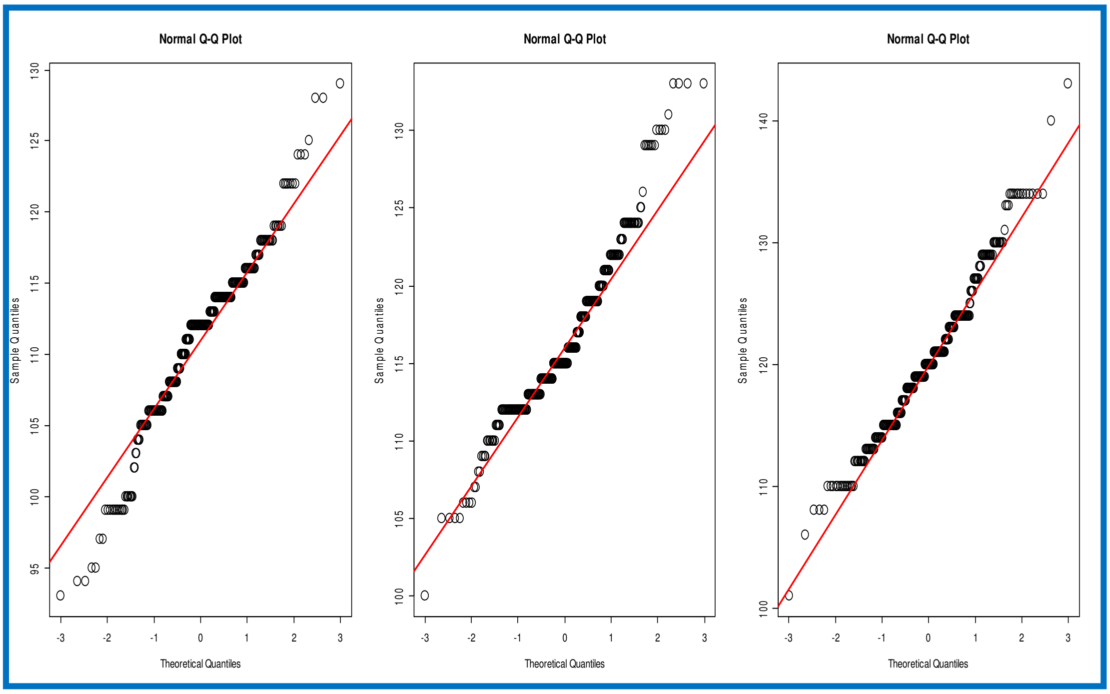


Figure29: Normal Q-Q plot and detrended normal Q-Q plot assess the normality of Height among 6-12 years boys



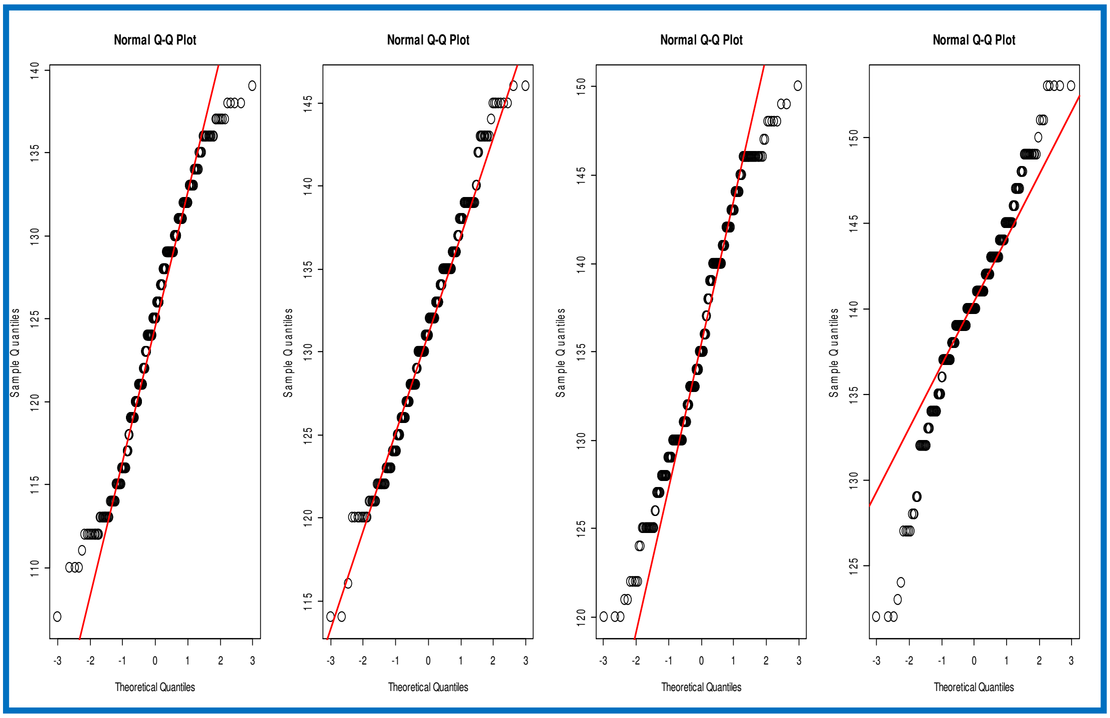


Figure30: Normal Q-Q plot assess the each agewise normality of

Height among 6-12 years boys

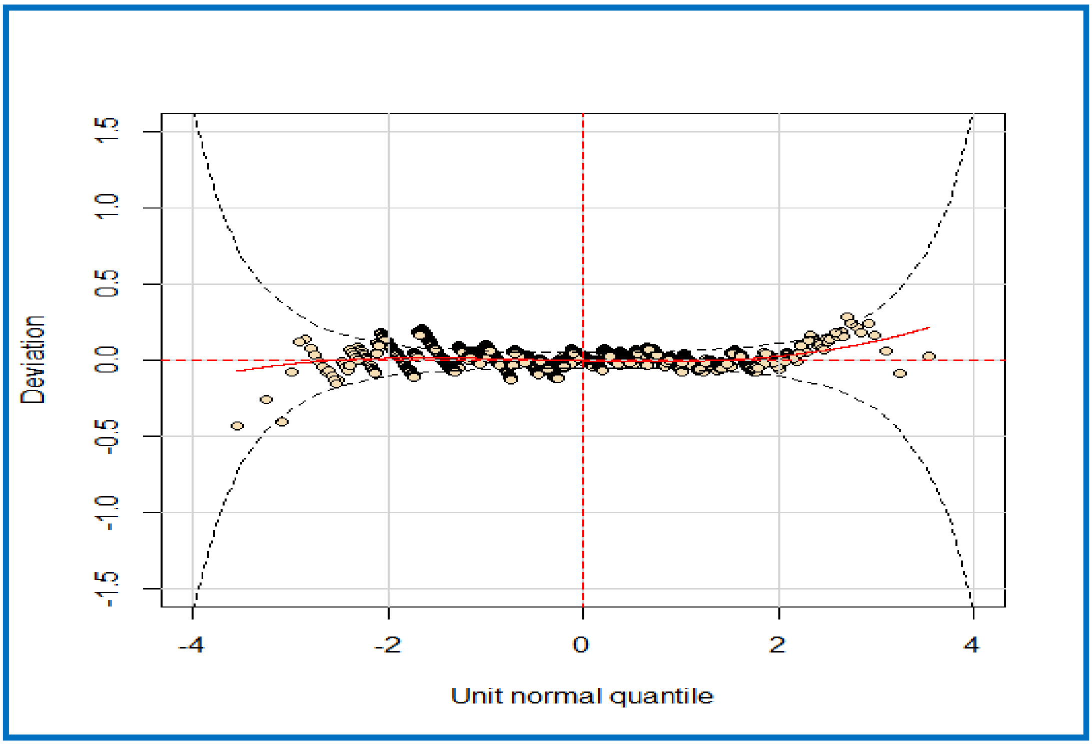


Figure31: Worm plot assess the normality of fitted height-for-age data for 6-12 years boys

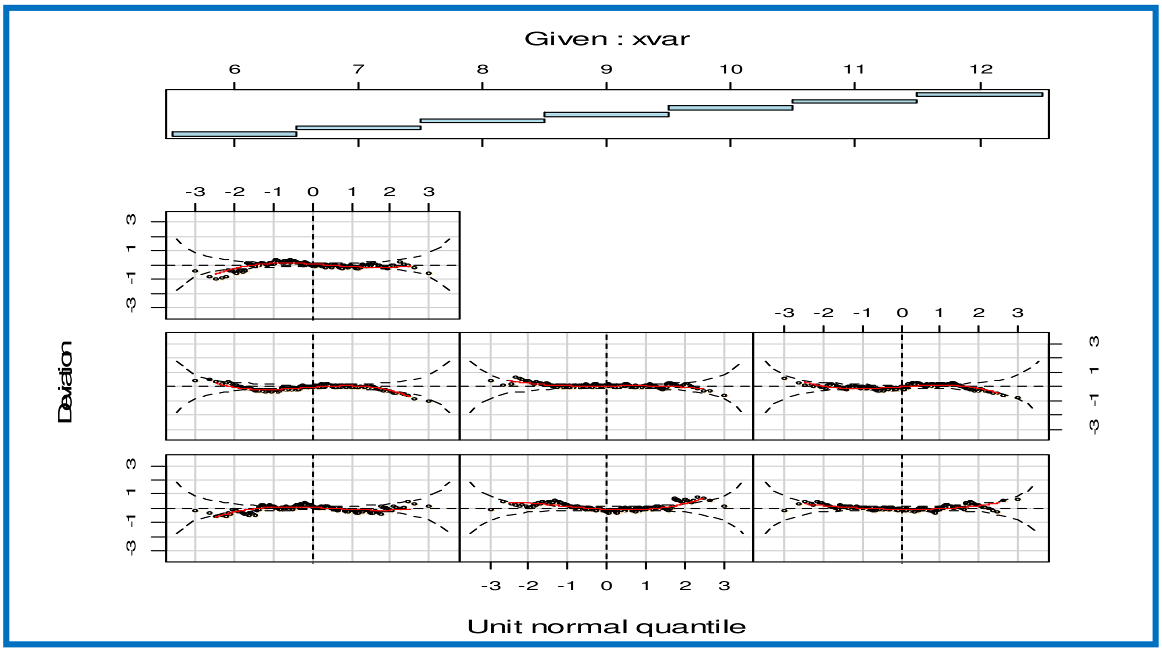


Figure32: Worm plots of Z scores model of df(μ)=3 df(σ)=3, ν=1, τ=2 with age transformation x=age$^{0.10}$ for 6-12 years height-for-age of boys

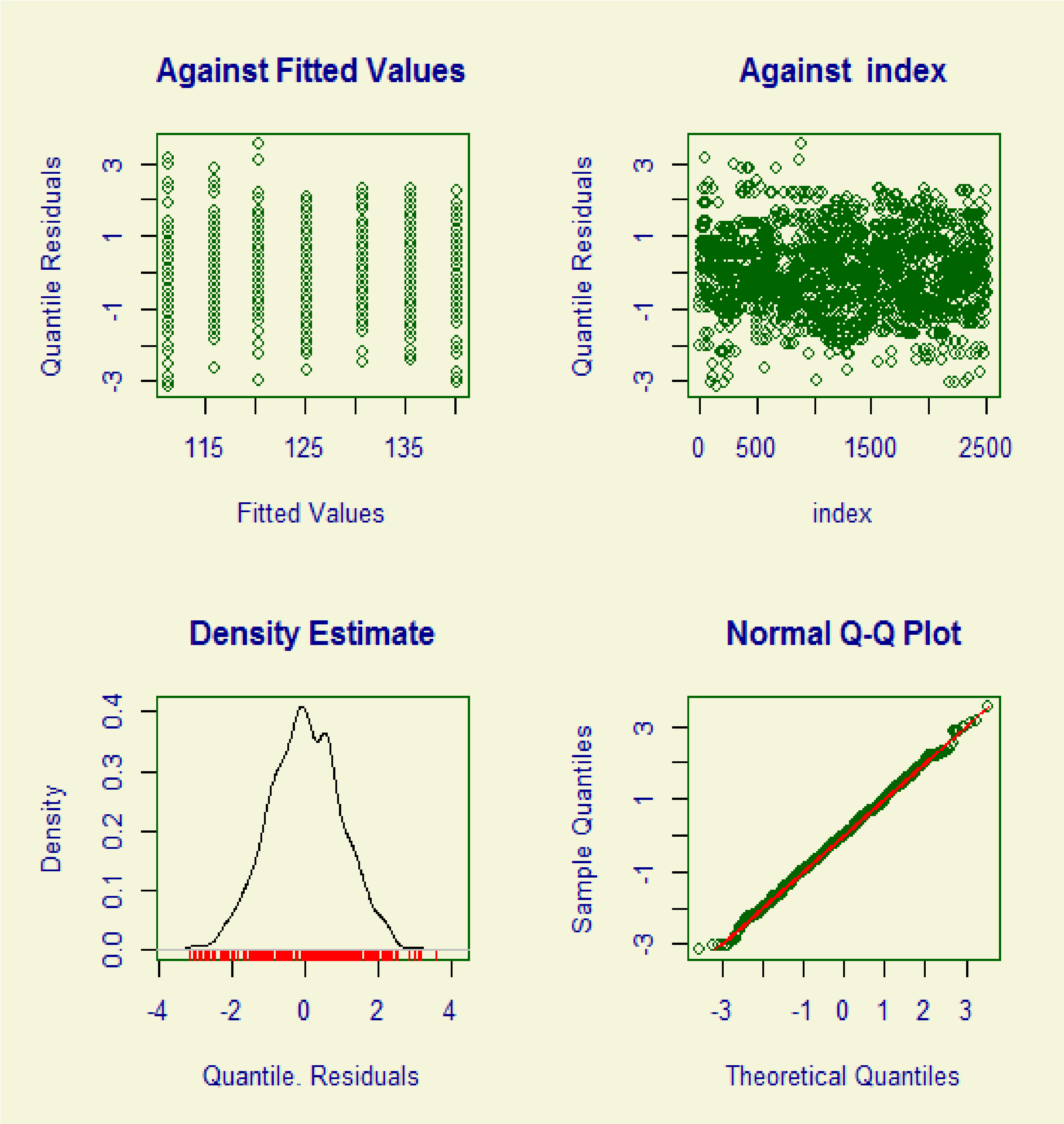


Figure 33 :Residual analysis of fitted model BCPE(x=age$^{0.10}$ df(μ)=3 df(σ)=3, ν=1, τ=2) for 6-12 years height-for age of boys

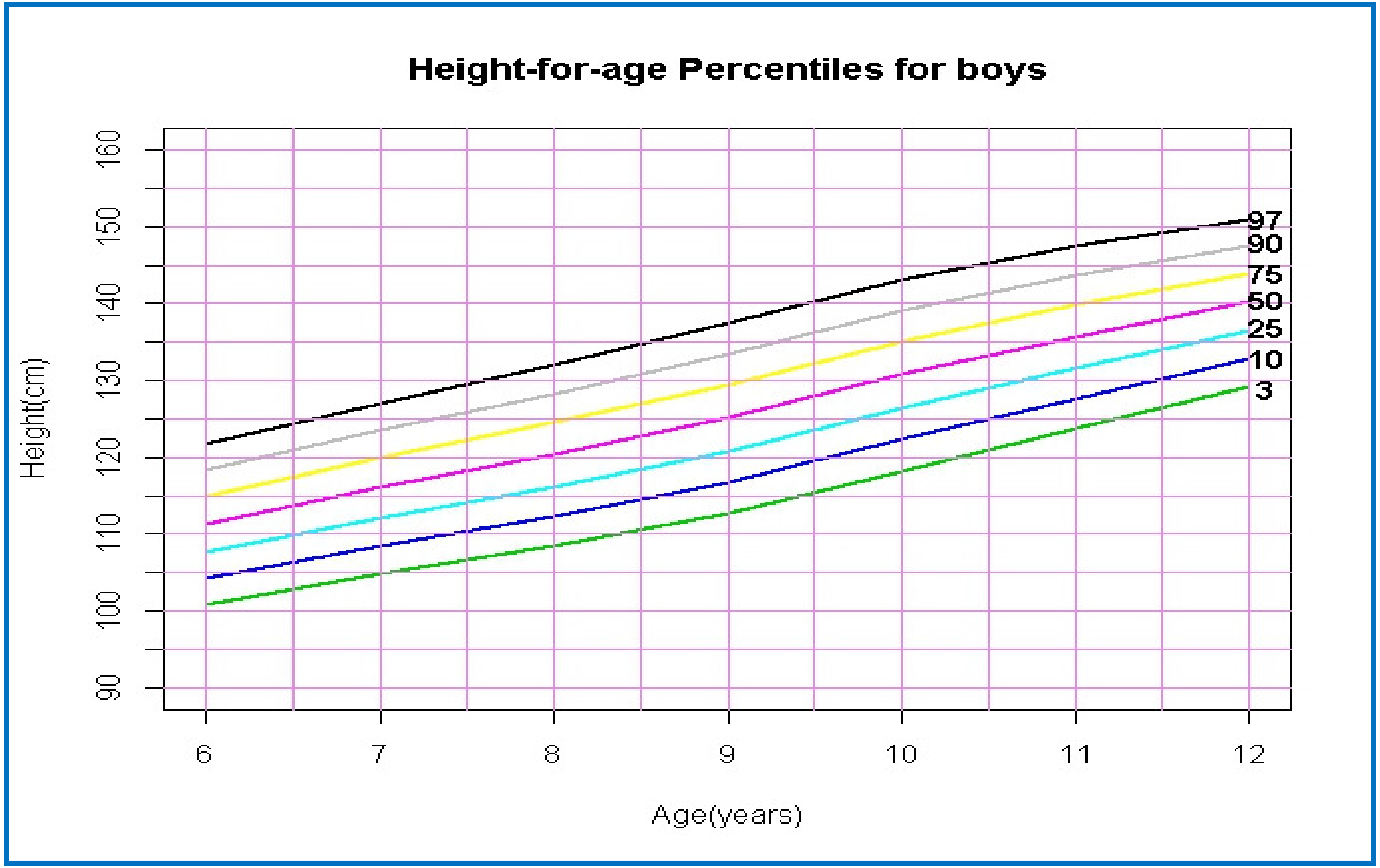


Figure 34A: Height-for- age smoothened percentiles for boys from 6 to 12 years

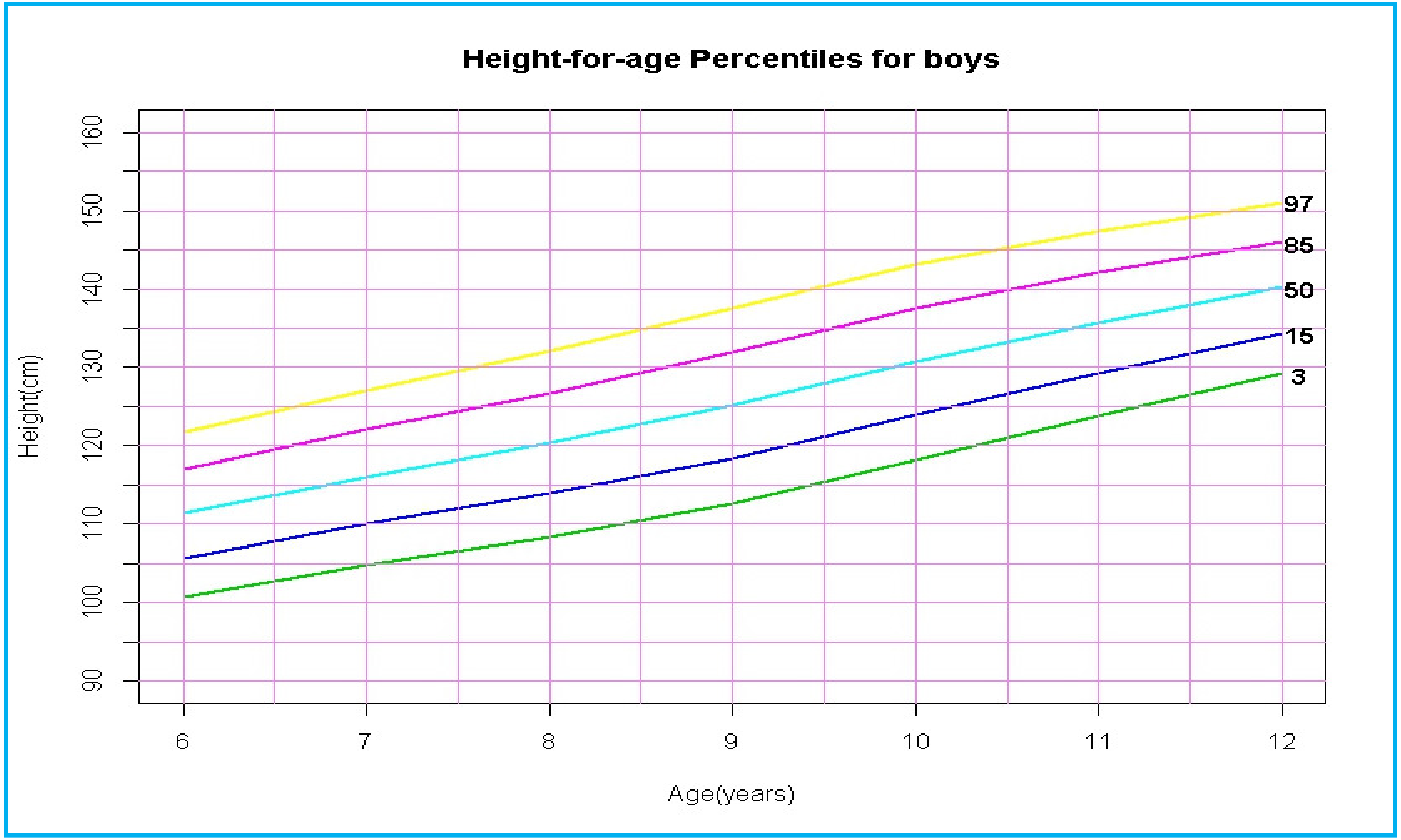


Figure 34B: WHO standards Height-for- age percentiles for boys from 6 to 12 years

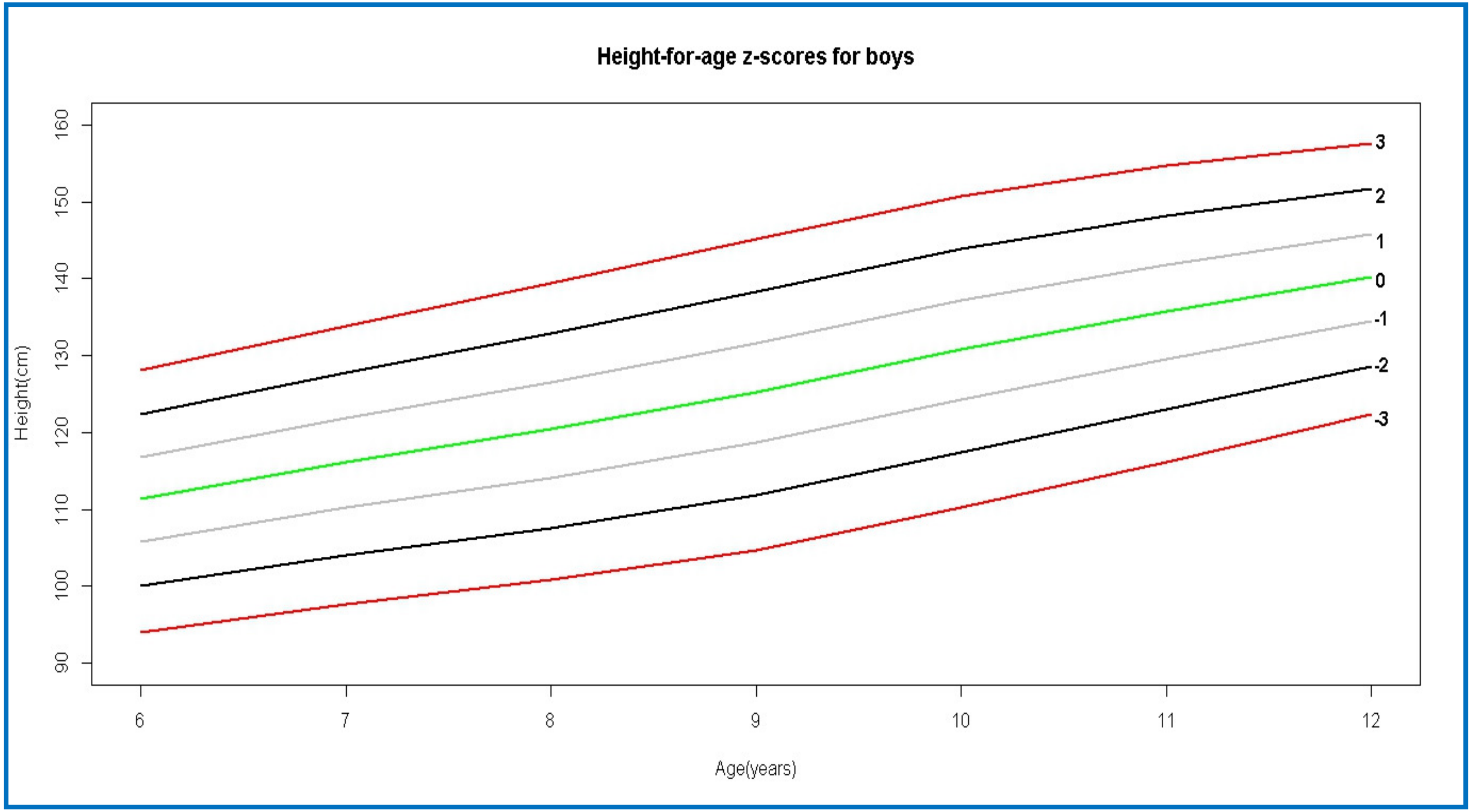


Figure35: Height-for- age Z scores for boys from 6 to 12 years

4.4 Construction of Height-for-age reference chart for girls

4.4.1 Sample size and mean height

There were 2520 height observations for girls. Cross-sectional sample sizes, mean height and standard deviation for each age group are shown in Tables 36.

Table 36 :Cross-sectional sample sizes for height-for-age for girls

Age (years)	No. of girls	Height(cm)	
		Mean	SD
6 years	210	109.58	5.71
7 years	210	114.38	4.95
8 years	210	118.78	5.92
9 years	210	123.16	6.18
10 years	210	129.35	6.09
11 years	210	137.57	5.95
12 years	210	142.31	4.65

Each age group wise 360 girls were taken for the study. Mean height of girls shows there is a gradual increase for each age.

4.4.2 Normality checking

Normality of height distribution was checked using graphical and mathematical methods. Graphically it was tested using Histogram & normal Q-Q plot (Figures 36-39) and mathematically it was tested using Kolmogorov-Smirnov Test (z=4.44 p=0.001), skewness (0.13) & kurtosis (-0.95).

Calculated Kolmogorov-Smirnov normality test value is Z=4.44 and it is statistically significant, it indicates that the 6-12 years girls weight is not distributed normally. In this study, calculated skewness value is 0.13, so it shows presence of positive skewness among 6-12 years girls height. Calculated kurtosis value is -0.95, it is having lower height than normal distribution, so it shows presence of platykurtic among 6-12 years girls height. Skewness (0.13) and kurtosis (-0.95) values indicates, the height distribution is skewed to right with a less peak than normal distribution.

Table37: Height(cm) Mean, SD and percentiles for girls

Age	Mean	Median	SD	Skewness	Kurtosis
6 years	109.58	111.00	5.71	-0.54	-0.04
7 years	114.38	113.50	4.95	1.14	2.39
8 years	118.78	119.00	5.92	0.65	0.92
9 years	123.16	124.00	6.18	-0.09	-0.31
10 years	129.35	130.00	6.09	0.29	2.96
11 years	137.57	138.00	5.95	-0.18	-0.23
12 years	142.31	143.00	4.65	-0.97	2.30

Table 37 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years girls height. 6^{th}, 9^{th}, 10^{th} and 12^{th} year girls height values are below “0” , so girls have negative skewed values and 7^{th}, 8^{th} and 11^{th} year girls height values are above “0”, so these girls are having positively skewed values. Similarly each age wise kurtosis values tells, 6^{th}, 9^{th} and 11^{th} year old girls heights are platykurtic and 7^{th} ,8^{th}

,10th and 12th year old girls heights are leptokurtic. So the 6-12 years girls height data shows presence of skewness as well as kurtosis.

Normality of girls height is assessed using graphical method of histogram with normal curve. Figure 36 and figure 37 of histogram with normal curve shows, 6-12 years girls height is not normally distributed and it is skewed to right side.

Normal Q-Q plot and Detrended Q-Q plot graphically helps to find the normality of the data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Figure 38 and figure 39 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution.

4.4.3 Model selection and results

The model BCPE($x=age^{\lambda}$, $df(\mu)=4$, $df(\sigma)=3$, $\nu=1$, $\tau=2$) served as a starting point to construct the height-for-age reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 38 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power $\lambda=0.70$. This smallest deviance value of λ value was taken for model fitting.

Table 38: Global deviance (GD) for models within the class BCPE(x=age$^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for height-for-age for girls

Power(λ)	Global Deviance(GD)
0.10	15843.61
0.20	15845.83
0.30	15844.62
0.40	15855.40
0.50	15855.17
0.60	15845.93
0.70	**15830.68**
0.80	15833.42
0.90	15845.15
1.00	15875.88

After choosing the age-transformation power λ=0.70, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=3 . So the final selected model is BCPE(x=age $^{0.7}$, df(μ)=3, df(σ)=3, ν=1, τ=2).

4.4.4 Goodness-of-fit assessment fitted model for 6-12 years girls

Goodness-of –fit for the selected model BEPE(x=age $^{0.70}$, df(μ)=3 df(σ)=3, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure40(overall) and in figure41(age wise) do not indicate any upward or downward shifts except 11th & 12th years. This may be due to some extreme values in that age group.There is no evidence of worms shows midfit and all theworms are within 95% confidence interval.

Table 39: Q-test for z-scores form the model BCPE(0.70, 3,3,1,2) for height-for-age for girls

Age	Z1	Z2	Z3	Z4
6 years	-0.868	1.022	-1.997	**-2.512**
7 years	1.121	-1.949	1.890	1.501
8 years	0.790	0.566	1.781	0.285
9 years	-1.231	1.006	-0.331	-1.728
10 years	-1.807	0.173	-1.022	1.957
11 years	1.823	1.791	-0.927	-1.578
12 years	-1.012	-1.408	-1.788	1.770
TOTAL Q stats	14.788	21.332	19.421	18.769
Degrees of freedom for Q stats	2.000	5.000	6.000	6.000
P-value for Q stats	0.22	0.23	0.11	0.09

Note: Absolute values of z1, z2, z3 or z4 larger than 2 indicate that, they are misfit for clculating mean, variance, skewness and kurtosis.

In table 39 the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3, and z4. Absolute deviations greater than 2 noted in the 6^{th} year z4=-2.512, however overall p-value for the Q –test is not significant (0.22, 0.23, 0.11, 0.09). There is no evidence to show that worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 40: Final model Skewness and kurtosis for 6-12 years girls

****

Summary of the Quantile Residuals

mean	=	-0.00280402
variance	=	1.003765
coef. of skewness	=	-0.0666277
coef. of kurtosis	=	3.298689
Filliben correlation coefficient	=	0.9977052

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Table 40 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.00 (against 0), variance =1.00 (against 1), skewness =-0.06 (against 0), kurtosis=3.09 (against 3.00). Figure 42 shows the residual distribution of weight-for-age in males: Quantile (standardized) residuals plotted against fitted values and against age, the density estimate with rug plot, and the Q–Q plot. The distribution is normal. A straight 1:1 line (plot on RHS bottom) indicates a good fit of the GAMLSS model.

4.4.5 LMS values and percentiles for 6-12 years girls

Table 41 shows the 3rd, 10th , 25th ,50th ,75th , 90th and 97th predicted percentile values of height for 6-12 years girls with their respective lamda,-mu- sigma values.

Less than 3rd percentile is stunted. Less than 99.2 cm among 6 year old girls are considered stunted, less than 102.9 cm among 7 year old girls are considered stunted, less than 107.0 cm among 8 year old girls are considered stunted, less than 111.9 cm among 9 year old girls are considered stunted, less than 118.4 cm among 10 year old girls are considered stunted, less than 126.1 cm among 11 year old girls are considered stunted and less than 133.1 cm among 12 year old girls are considered stunted. Figure 43A shows the age related smoothened percentile reference chart for standard values and Figure 43B shows the WHO standard percentile curve.

Table41: LMS values and percentiles for 6-12 years girls

Age	L	M	S	SD	Percentiles(height in cm)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	111.3	0.00045	5.8	99.2	103.1	106.6	110.0	113.3	116.7	120.4
7 years	1	116.1	0.00044	5.2	102.9	106.9	110.5	114.0	117.4	120.9	124.6
8 years	1	120.4	0.00043	6.2	107.0	111.2	114.9	119.5	122.1	125.7	129.6
9 years	1	125.2	0.00042	7.3	111.9	116.1	119.9	124.6	127.3	131.0	135.0
10 years	1	130.8	0.00038	6.3	118.4	122.6	126.4	131.0	133.6	137.3	141.3
11 years	1	135.7	0.00034	6.8	126.1	130.0	133.6	137.1	140.5	144.0	147.7
12 years	1	129.7	0.00600	5.7	133.1	136.6	139.8	142.9	146.0	149.1	152.5

4.4.6 LMS values and Z-score for 6-12 years girls

Table 42 shows 6-12 year old girls' standard predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD height values and their respective lamda-mu-sigma values. Less than -2SD is stunted. Less than 90.8 cm among 6 year old boys stunted are considered stunted, less than 94.4 kg among 7 year old boys are considered stunted, less than 98.1 cm among 8 year old boys are considered stunted, less than 102.7 cm among 9 year old boys are considered stunted, less than 109.4 cm among 10 year old boys are considered stunted, less than 117.6 cm among 11 year old boys are considered stunted and less than 125.6 cm among 12 year old boys are considered stunted. Figure 44 shows the age related Z-score reference chart.

Table 42: LMS values and Z score for 6-12 years girls

Age	L	M	S	SD	Z score(height in cm)						
					-3	-2	-1	0	1	2	3
6 years	1	110.0	0.0076	5.7	90.8	98.3	104.8	110.0	115.1	121.1	127.9
7 years	1	114.0	0.0075	5.0	94.4	102.1	108.7	114.0	119.2	125.4	132.4
8 years	1	118.5	0.0076	5.9	98.1	106.1	113.0	118.5	124.0	130.4	137.6
9 years	1	123.6	0.0076	6.2	102.7	111.0	118.0	123.6	129.2	135.8	143.3
10 years	1	130.0	0.0071	6.1	109.4	117.5	124.4	130.0	135.5	142.1	149.5
11 years	1	137.1	0.0062	6.0	117.6	125.2	131.8	137.1	142.3	148.5	155.5
12 years	1	142.9	0.0053	4.7	125.6	132.3	138.2	142.9	147.6	153.2	159.6

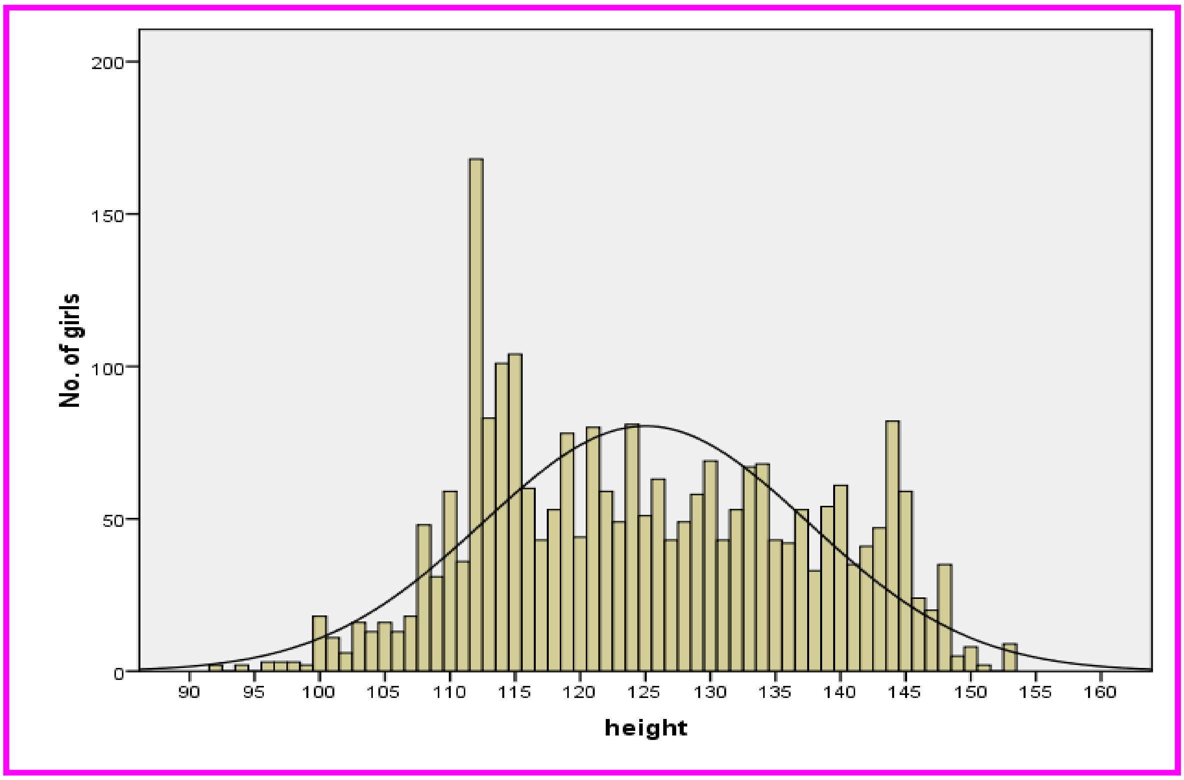


Figure36 : Histogram with normal curve shows the height of 6-12 years children are distributed positively skewed (Mean =125.0 median= 124.0 skewness=0.13 kurtosis=-0.94)

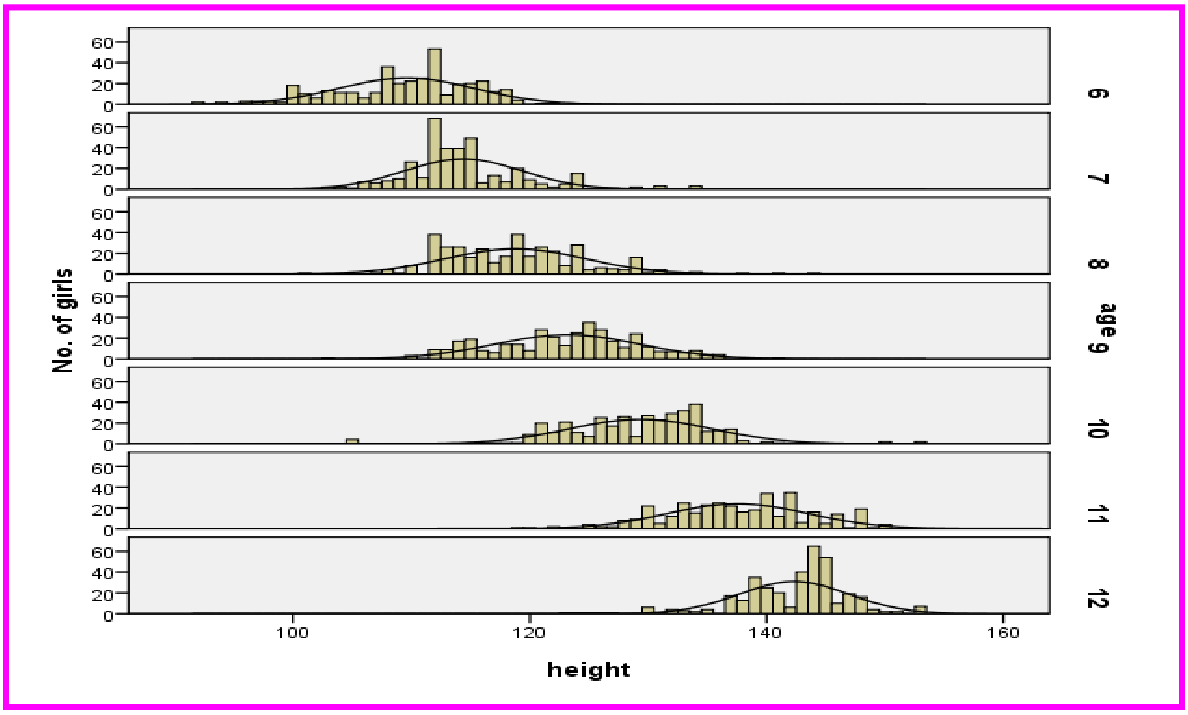
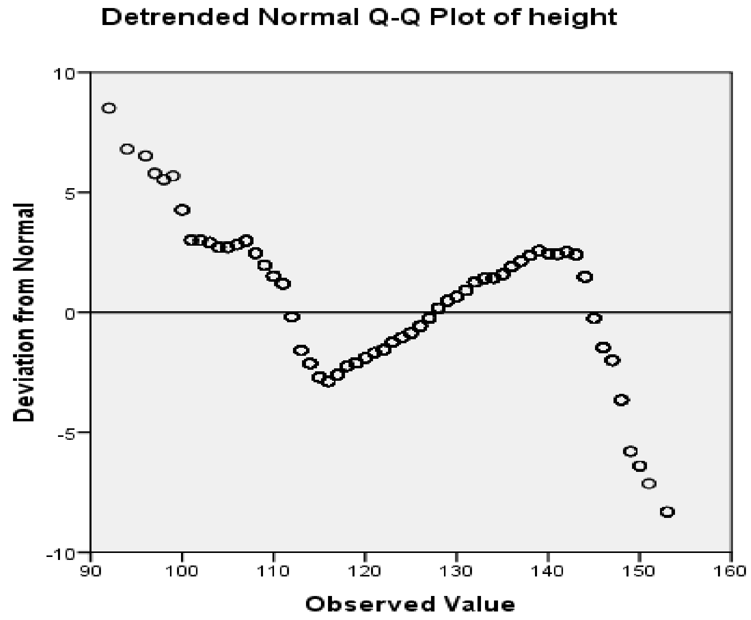


Figure 37: Histogram with normal curve assess the normality of height of 6-12 years girls



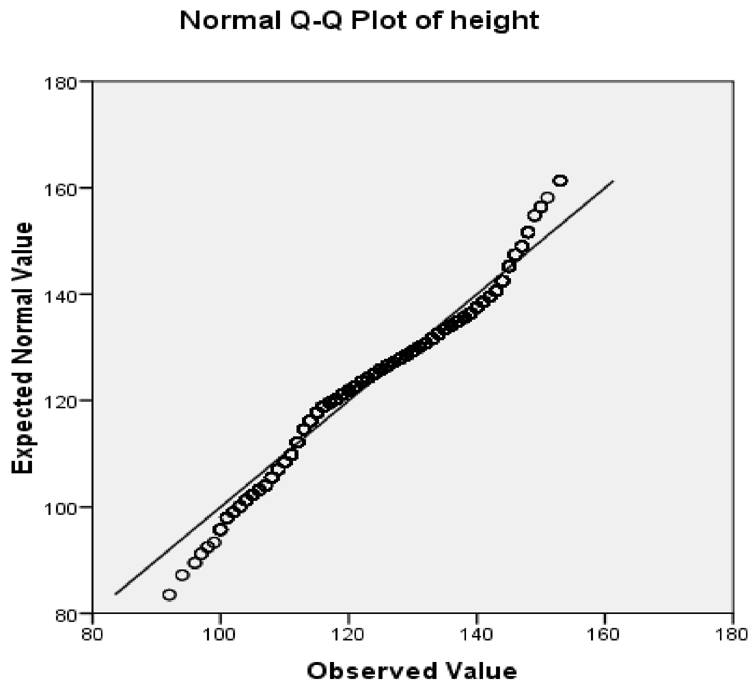


Figure38: Normal Q-Q plot and detrended normal Q-Q plot assess the normality of Height among 6-12 years girls

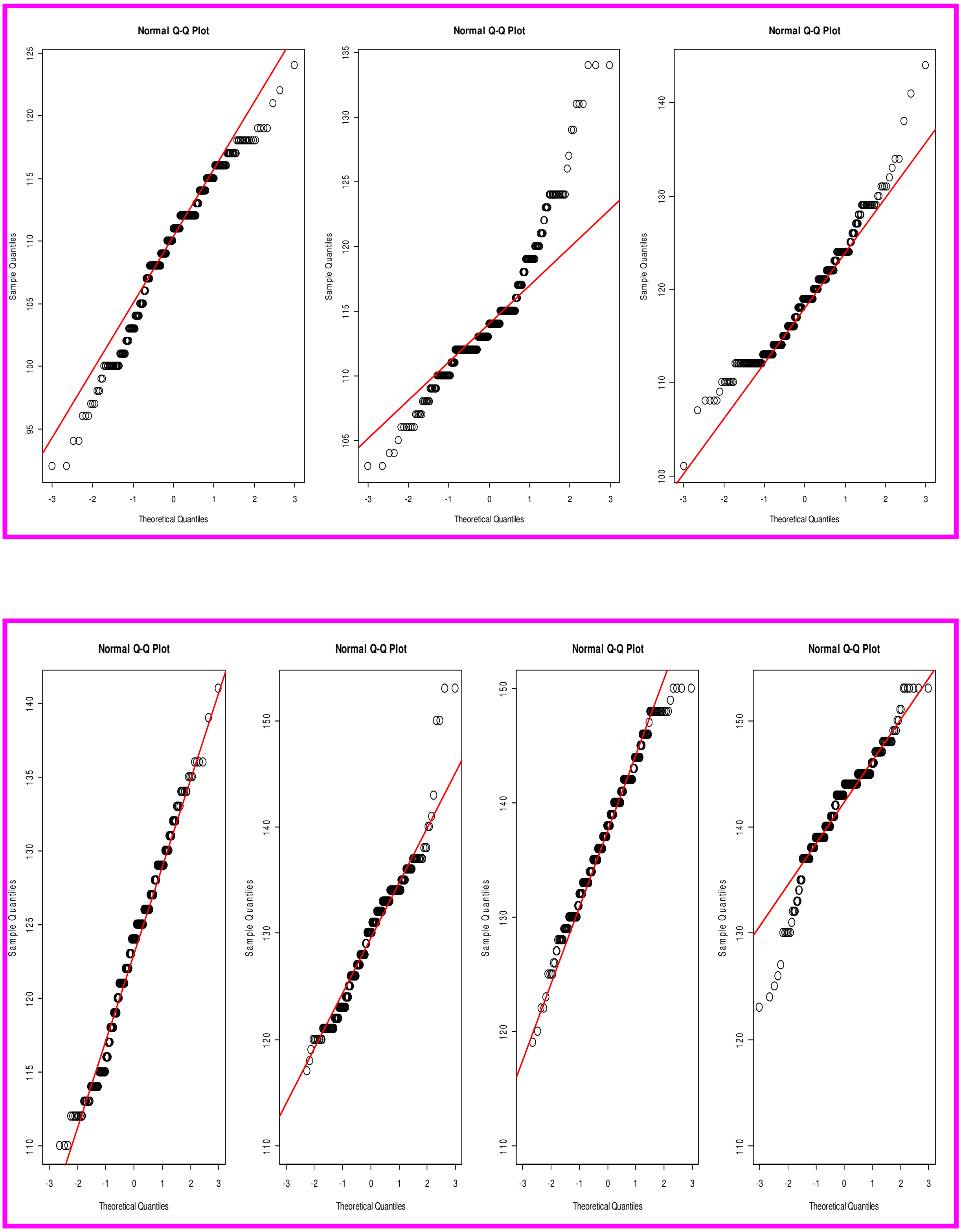


Figure39: Normal Q-Q plot assess the each agewise normality of Height among 6-12 years girls

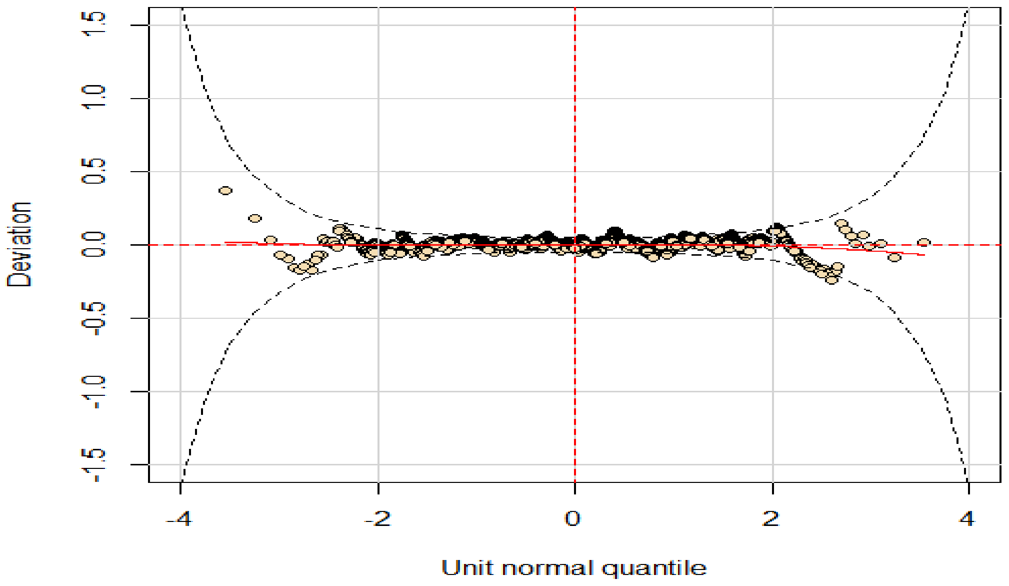


Figure 40: Worm plot assess the normality of fitted height-for-age data for 6-12 years girls

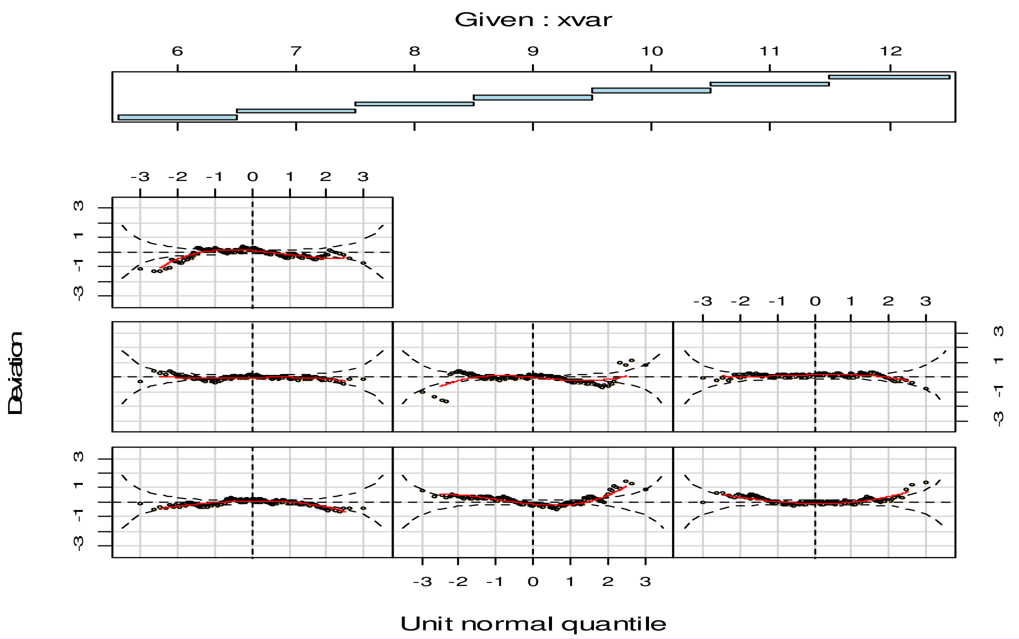


Figure 41: Worm plots of Z scores model of df(μ)=3 df(σ)=3, ν=1, τ=2 with age transformation $x = age^{0.70}$ for 6-12 years height-for-age of girls

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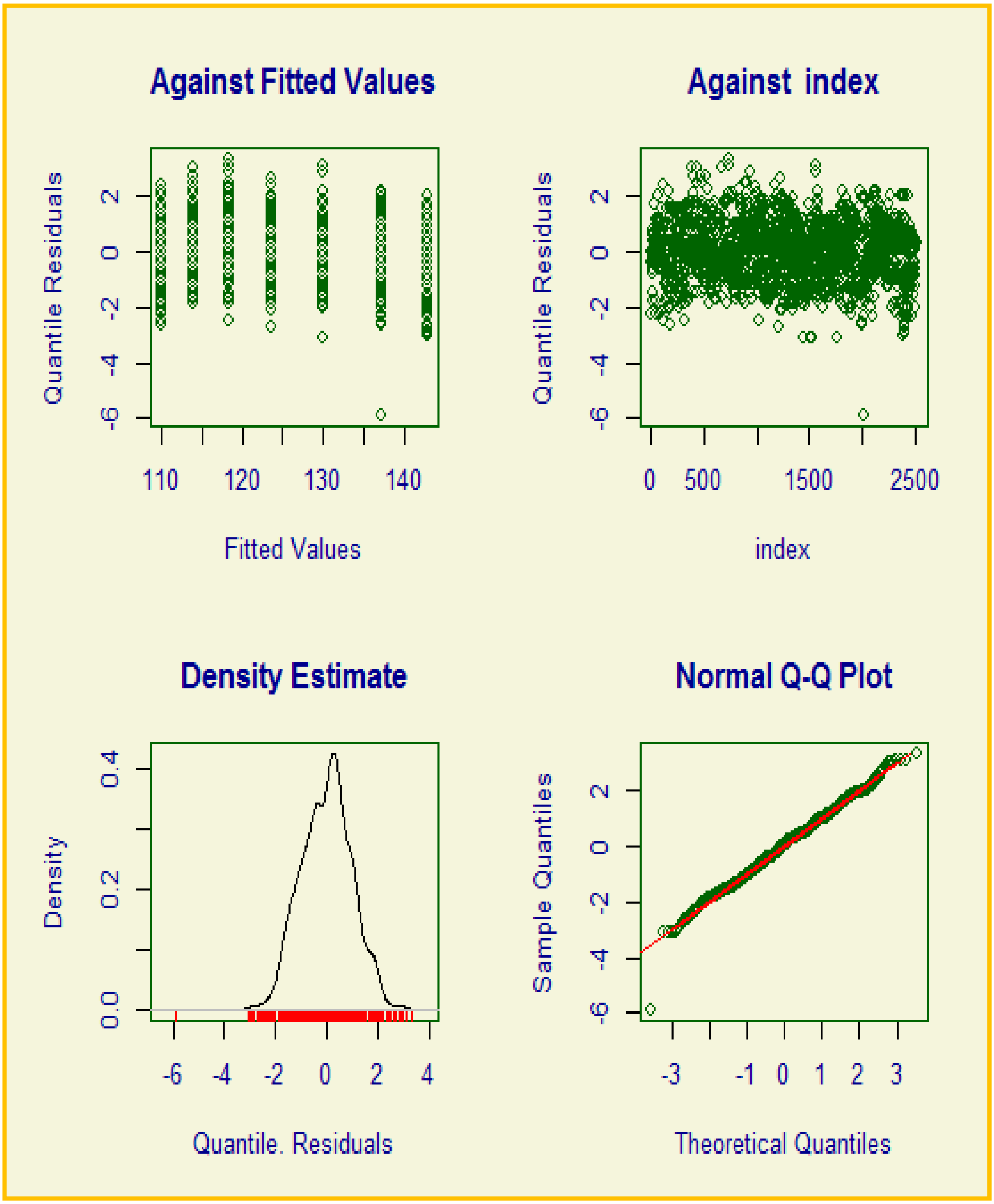


Figure 42: Residual analysis of fitted model BCPE(x=age$^{0.70}$ df(μ)=3 df(σ)=3, ν=1, τ=2) for 6-12 years height-for age of girls

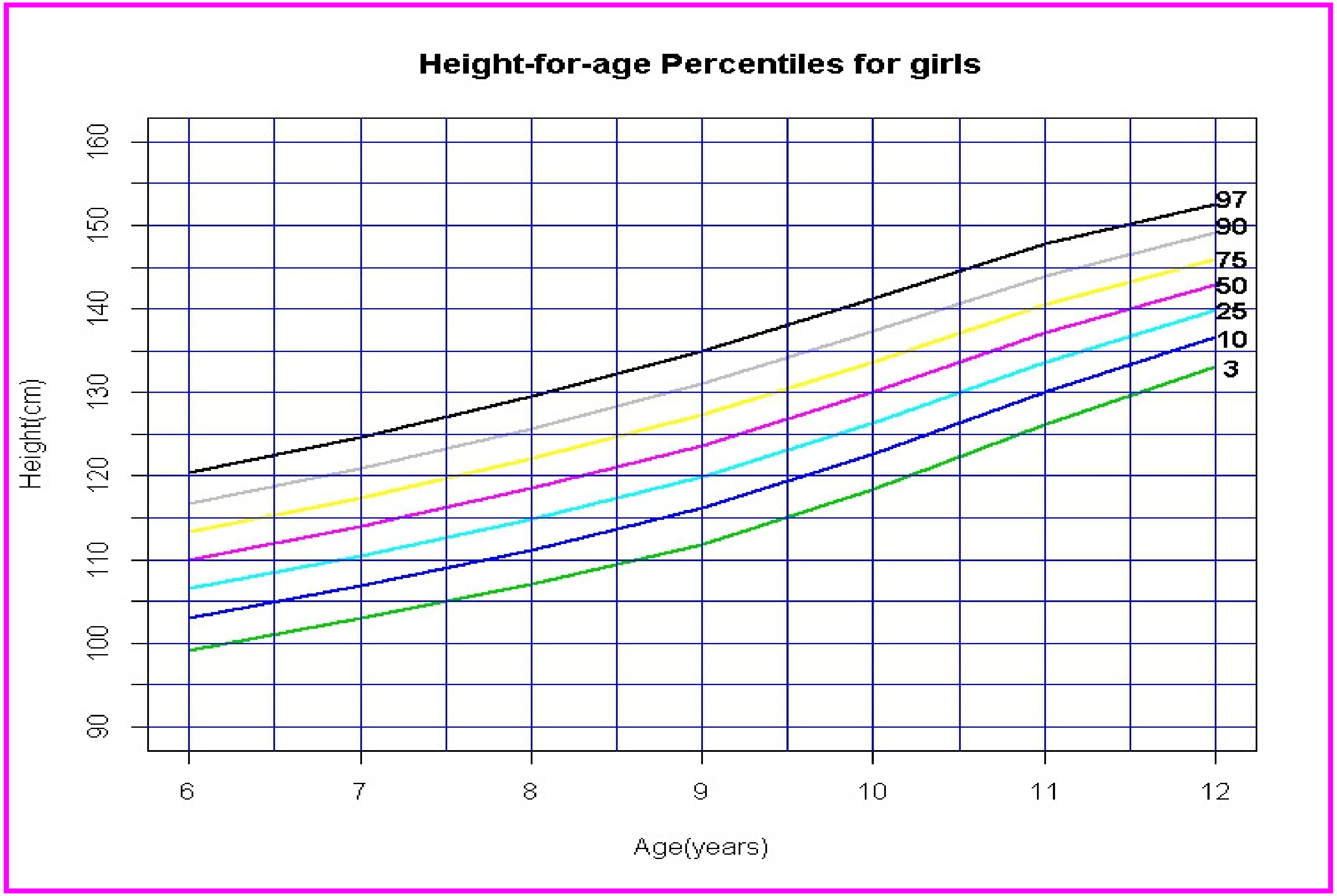


Figure 43A: Height-for-age smoothened percentiles for girls from 6 to 12 years

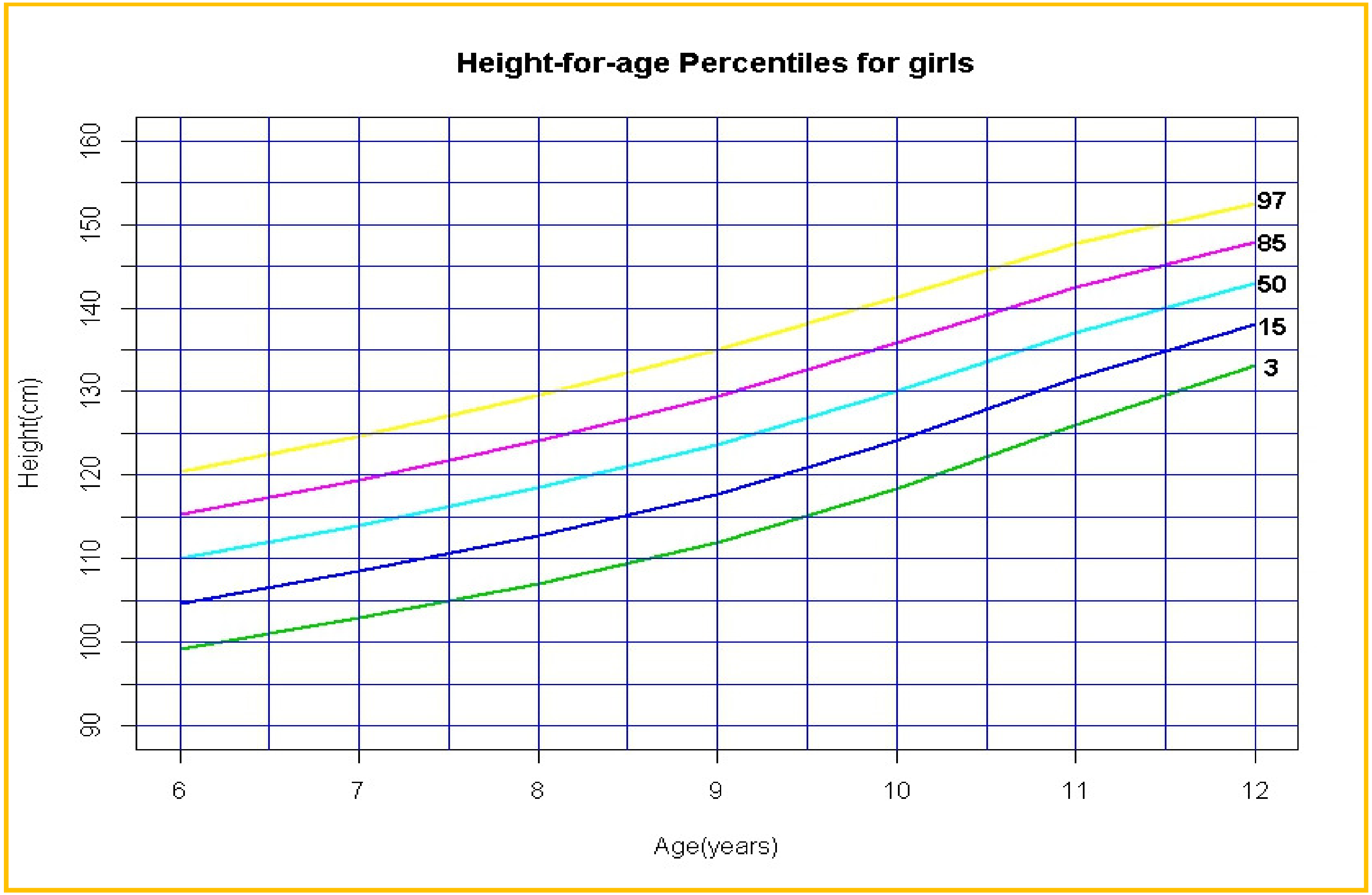


Figure 43B: WHO standards Height-for-age percentiles for girls from 6 to 12 years

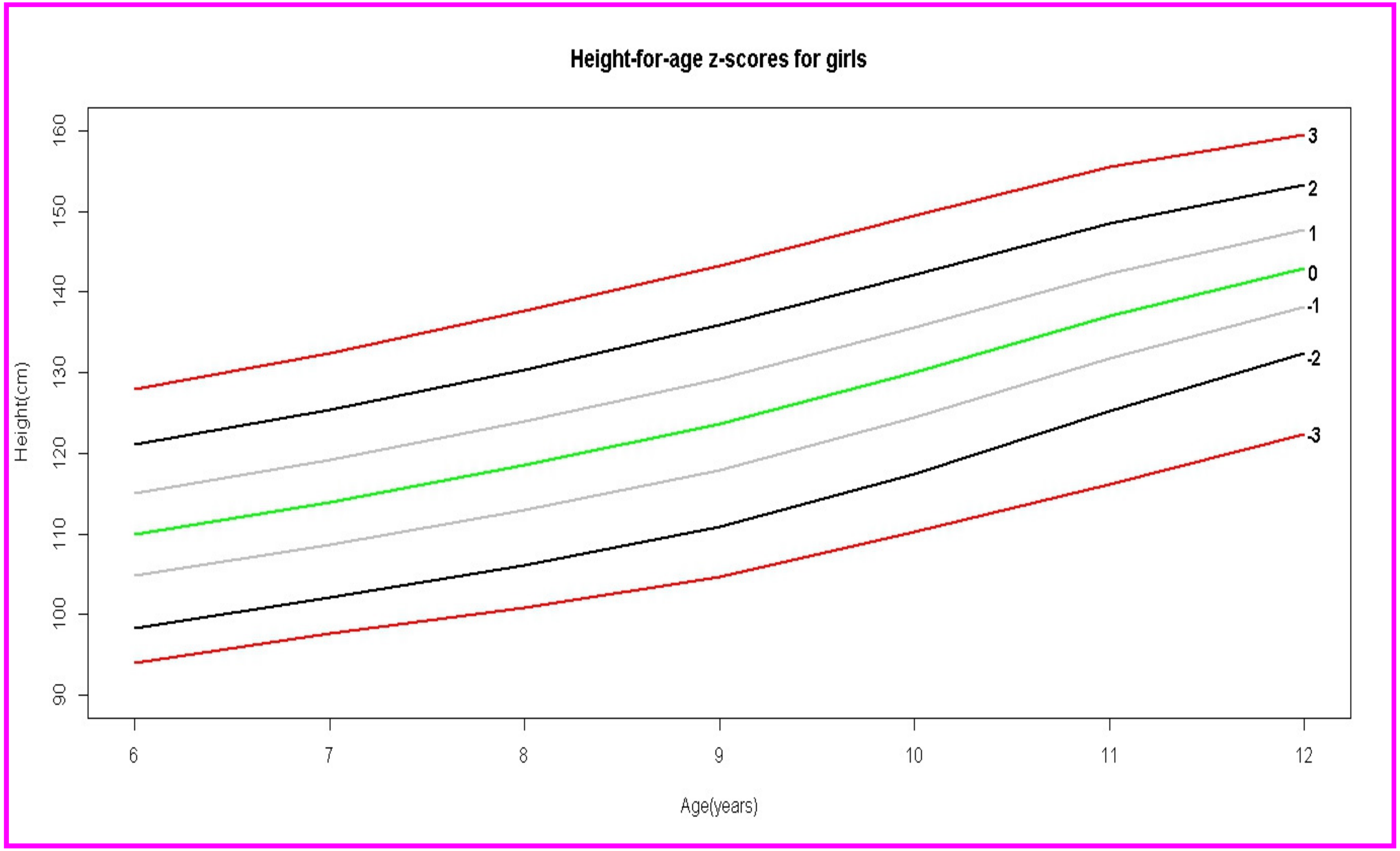


Figure44: Height-for-age Z scores for girls from 6 to 12 years

4.5 Construction of Weight-for-Height reference chart for boys

4.5.1 Sample size and mean weight and height

There were 2520 height observations for boys. Cross-sectional sample sizes, mean height and standard deviation for each age group are shown in Tables 43.

Table 43: Cross-sectional sample sizes for weight-for-height for boys

Age (years)	Sample size	Height(cm)		Weight(kg)	
		Mean	SD	Mean	SD
6 years	320	111.12	5.77	17.34	2.33
7 years	320	116.42	5.20	19.71	2.31
8 years	320	120.32	6.21	20.62	3.70
9 years	320	124.65	7.27	22.23	4.21
10 years	320	131.15	6.28	25.13	5.49
11 years	320	135.56	6.80	26.18	4.29
12 years	320	140.17	5.24	31.06	5.75

Each age group wise 360 girls were taken for the study. Mean height and weight of girls shows there is a gradual increase for each age.

4.5.2 Model selection and results

The model BCPE(x=age$^{\lambda}$, df(μ)=4, df(σ)=3, ν=1, τ=2) served as a starting point to construct the height-for-age reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 44 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power λ=0.80. This smallest deviance value of λ value was taken for model fitting.

Table 44: Global deviance (GD) for models within the class BCPE(x=age$^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for weight-for-height for boys

Power(λ)	Global Deviance(GD)
0.10	10813.35
0.20	10811.46
0.30	10823.33
0.40	10845.76
0.50	10789.34
0.60	10789.56
0.70	10787.38
0.80	**10783.36**
0.90	10793.39
1.00	10797.33

After choosing the age-transformation power λ=0.80, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=3 . So the final selected model is BCPE(x=age$^{0.8}$, df(μ)=3, df(σ)=4, ν=1, τ=2).

4.5.3 Goodness-of-fit assessment fitted model for 6-12 years boys

Goodness-of –fit for the selected model BEPE(x=age $^{0.80}$, df(μ)=3 df(σ)=4, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure45 (overall) and in figure46 (age wise) do not indicate any upward or downward shifts except 8th year. This may be due to some extreme values in that age group.There is no evidence of worms shows midfit and all the worms are within 95% confidence interval.

Table 45: Q-test for z-scores form the model BCPE(0.80, 3,4,1,2)

for height-for-age for boys

Age	Z1	Z2	Z3	Z4
6 years	-0.571	0.648	0.901	-1.887
7 years	1.561	-0.486	-0.502	-1.265
8 years	-1.126	0.729	1.216	**-2.665**
9 years	-0.065	-1.993	0.375	0.586
10 years	1.332	1.039	1.995	1.284
11 years	-1.473	-0.756	-1.669	0.707
12 years	1.469	0.560	-1.965	1.232
TOTAL Q stats	5.085	8.412	8.301	9.288
Degrees of freedom for Q stats	2.000	5.000	6.000	6.000
P-value for Q stats	0.08	0.13	0.14	0.16

Note: Absolute values of z1,z2,z3 or z4 larger than 2 indicate misfit of , respectively, mean, variance, skewness and kurtosis

In table 45 the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3, and z4. Absolute deviations greater than 2 noted in the 8th year z4=-2.665, however overall p-value for the Q –test is not significant (0.08, 0.13, 0.14, 0.16). So it is not suggest any significance departure of the fitted model z-scores from normality at the 5% level of significance

Table 46: Final model Skewness and kurtosis for 6-12 years boys

```
*******************************************************************
Summary of the Quantile Residuals
mean                              = 0.0008135526
variance                          = 1.000871
coef. of skewness                 = 0.01513449
coef. of kurtosis                 = 3.062236
Filliben correlation coefficient  = 0.9992233
*******************************************************************
```

Table 46 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.00 (against 0), variance =1.00 (against 1), skewness =0.02 (against 0), kurtosis=3.06(against 3.00). It was shown in figure 47.

4.5.4 LMS values and percentiles for 6-12 years Boys

Table 47 shows the 3rd, 10th, 25th, 50th, 75th, 90th and 97th predicted percentile values of height for 6-12 years boys with their respective lamda,-mu- sigma values.

Less than 3rd percentile is wasted. Less than 12.3 kg among 100 cm height boys are considered wasted, less than 14 kg among 110 cm height boys are considered wasted, less than 15.8 kg among 120 cm height boys are considered wasted, less than 18.8 kg among 130 cm height boys are considered wasted, less than 21.6 kg among 140 cm height boys are considered wasted, less than 23.7 kg among 150 cm height boys are considered wasted and less than 25.3 kg among 160 cm height boys are considered wasted. Figure 48A shows the age related smoothened percentile reference chart for standard values and Figure 48B shows the WHO standard percentile curve.

Table47: LMS values and percentiles for 6-12 years Boys

Height(cm)	L	M	S	SD	Percentiles(weight in kg)						
					3rd	10th	25th	50th	75th	90th	97th
100	1	14.8	0.0055	1.5	12.3	13	13.8	14.8	15.9	17.1	18.4
110	1	17.0	0.0059	2.1	14.0	14.9	15.8	17.0	18.4	19.8	21.4
120	1	19.5	0.0063	2.1	15.8	16.9	18.0	19.5	21.1	22.9	24.9
130	1	23.8	0.0072	3.2	18.8	20.2	21.8	23.8	26.2	28.7	31.7
140	1	28.9	0.0048	4.8	21.6	23.5	25.8	28.9	32.6	36.8	42.1
150	1	34.0	0.0044	7.2	23.7	26.3	29.5	34.0	39.8	46.7	56.1
160	1	39.3	0.0040	7.4	25.3	28.7	33.0	39.3	48.2	59.6	76.8

. **4.5.5 LMS values and Z-score for 6-12 years Boys**

Table 48 shows 6-12 year old boys' predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD weight-for-height values and their respective lamda-mu-sigma values. Less than -2SD is wasted. Less than 12.6 kg among 100 cm height boys are considered wasted, less than 14.1 kg among 110 cm height boys are considered wasted, less than 15.9 kg among 120 cm height boys are considered wasted, less than 18.8 kg among 130 cm height boys are considered wasted, less than 21.7 kg among 140 cm height boys are considered wasted, less than 23.7 kg among 150 cm height boys are considered wasted and less than 26.4 kg among 160 cm height boys are considered wasted. Figure Figure 49 shows the weight-for-height percentile curve.

Table 48: LMS values and Z score for 6-12 years Boys

Height (cm)	Age	L	M	S	SD	Z score(weight in kg)						
						-3	-2	-1	0	1	2	3
100	6 years	1	14.9	0.0054	1.5	12.6	13.2	13.8	14.9	16.0	17.1	18.3
110	7 years	1	17.1	0.0051	2.1	14.1	14.9	15.8	17.1	18.4	19.8	21.4
120	8 years	1	19.5	0.0077	2.1	15.9	16.9	18.0	19.5	21.1	22.9	24.9
130	9 years	1	24.9	0.0096	3.2	18.8	20.3	21.8	24.9	26.2	28.7	31.3
140	10 years	1	28.9	0.0091	4.8	21.7	23.5	25.8	28.9	32.7	36.8	42.1
150	11 years	1	35.5	0.0073	7.2	23.7	26.3	29.6	35.5	39.8	45.8	57.1
160	12 years	1	39.7	0.0075	7.4	26.4	28.7	34.0	39.7	48.2	60.6	77.8

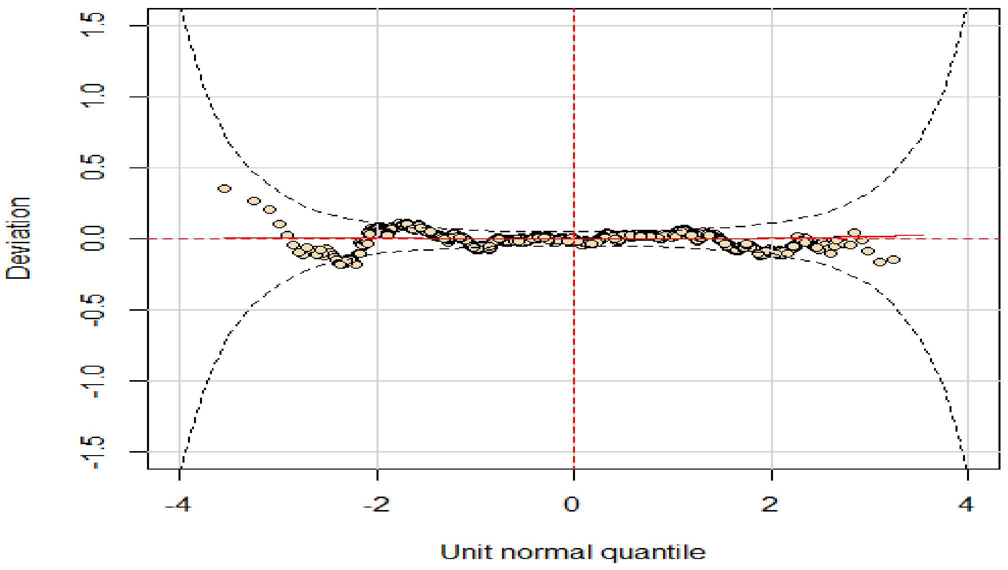


Figure45: Worm plot assess the normality of fitted weight-for-height data

lfor 6-12 years boys

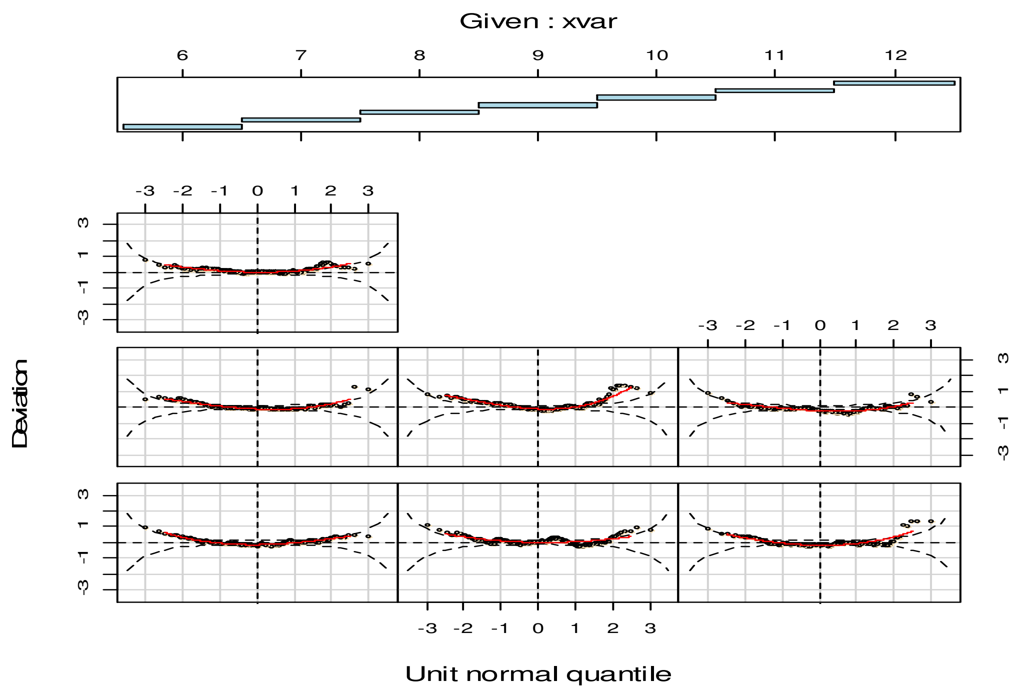


Figure 46: Worm plots of Z scores model of df(μ)=4 df(σ)=3, ν=1, τ=2 with age transformation $x=age^{0.80}$ for 6-12 years weight-for-height of boys

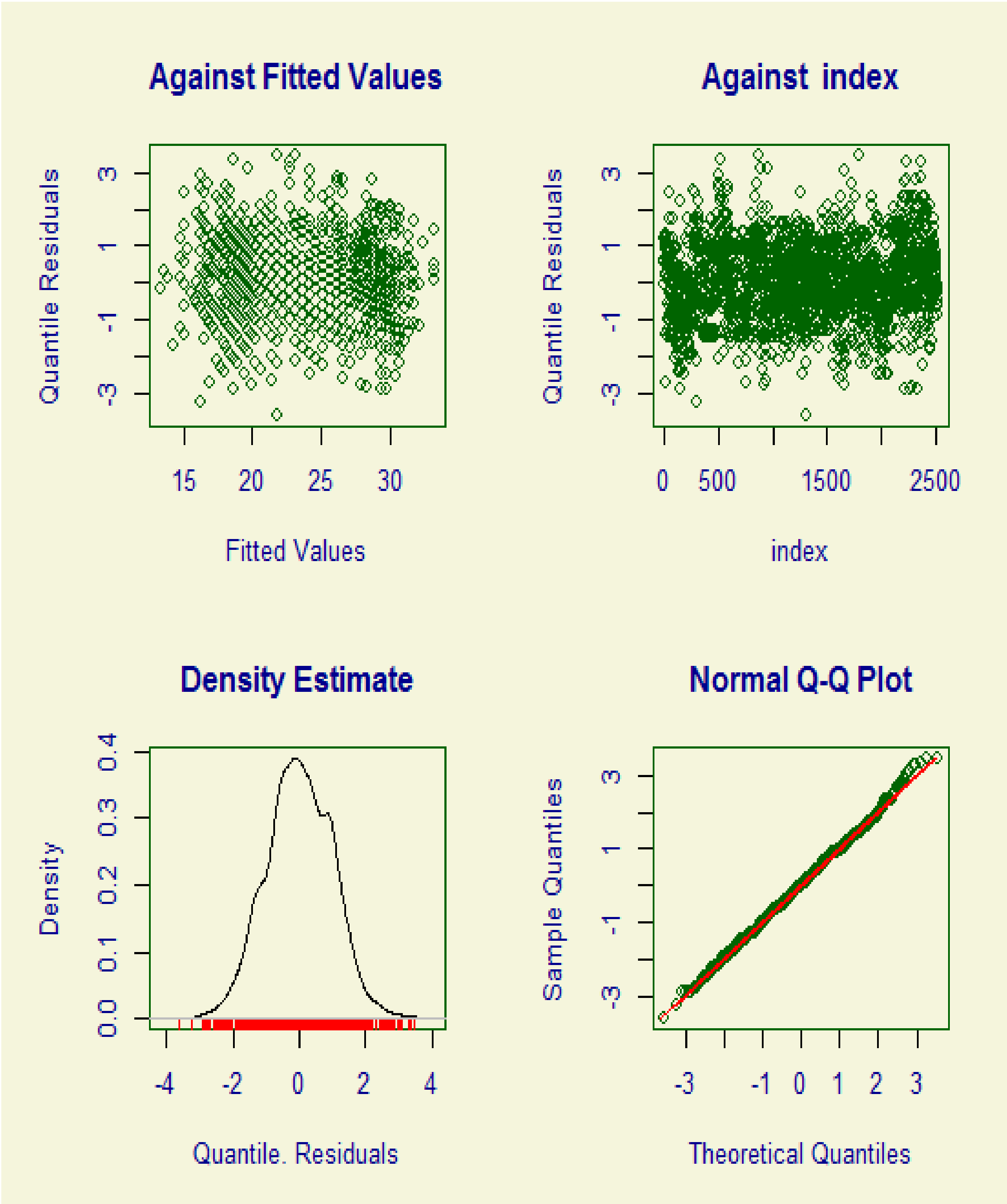


Figure 47 :Residual analysis of fitted model BCPE(x=age$^{0.80}$ df(μ)=3 df(σ)=4, ν=1, τ=2) for 6-12 years weight-for height of boys.

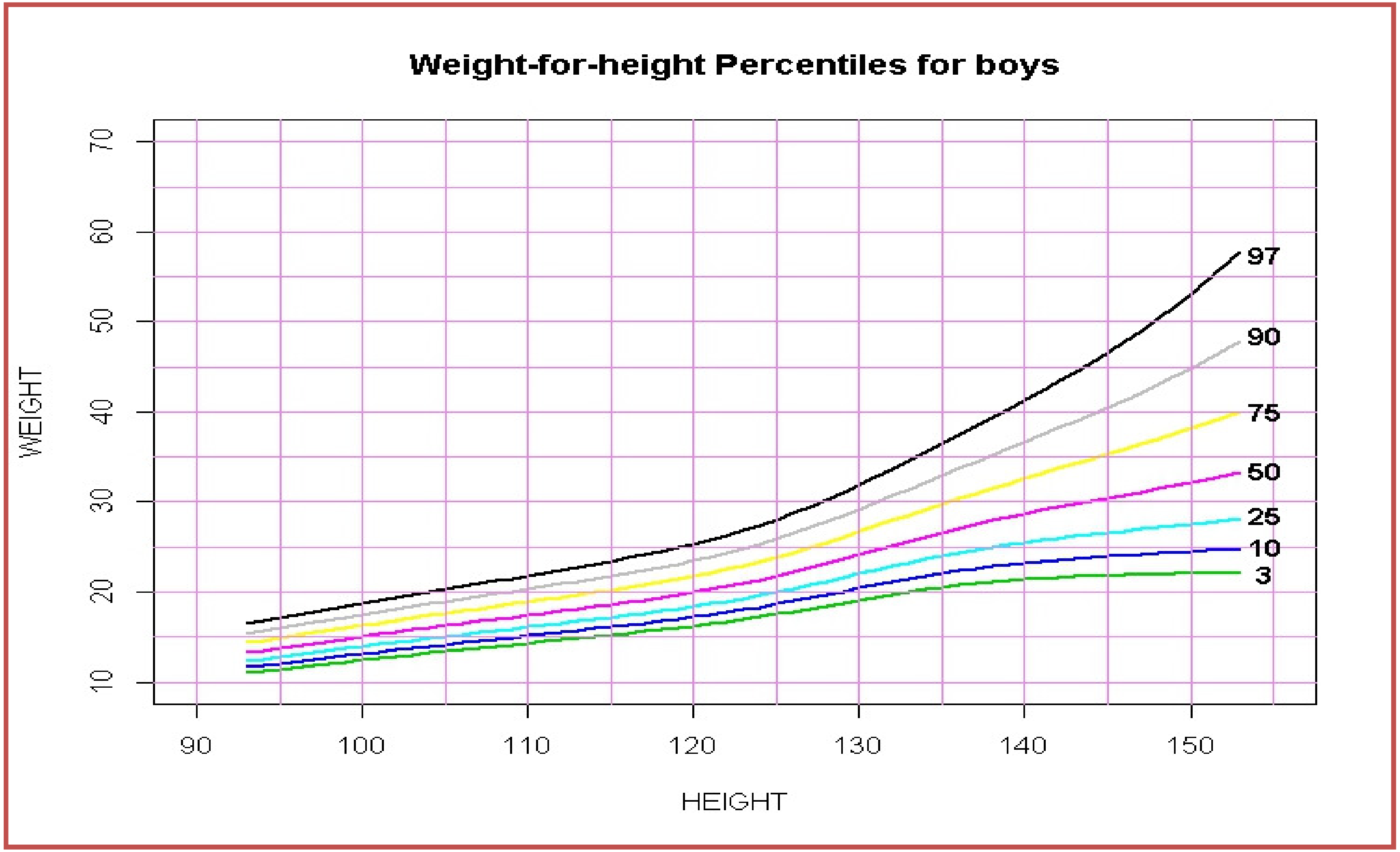


Figure48A: Weight-for-height smoothened percentiles for boys from 6 to 12 years

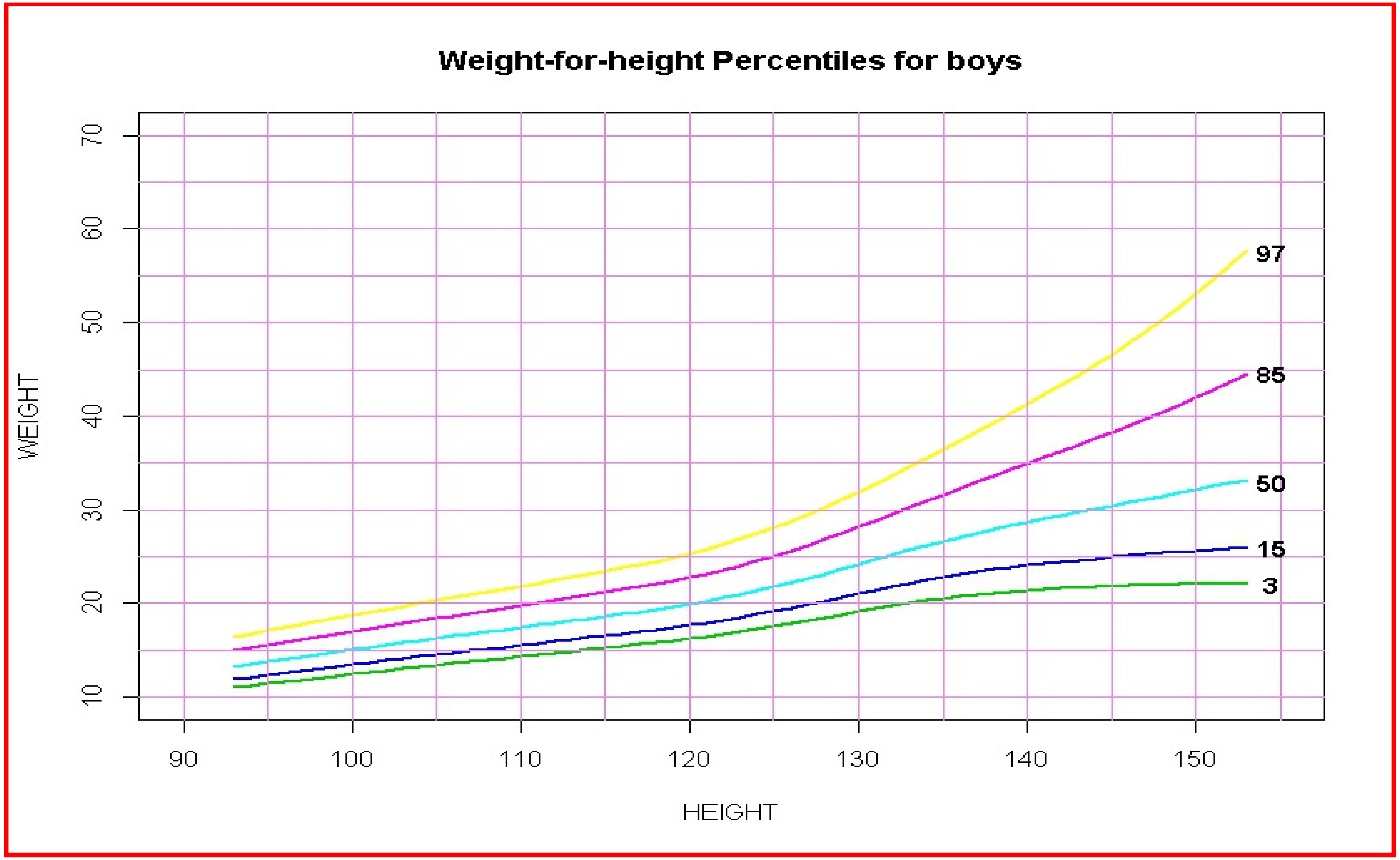


Figure48B: WHO standard weight-for-height percentiles for boys from 6 to 12 years

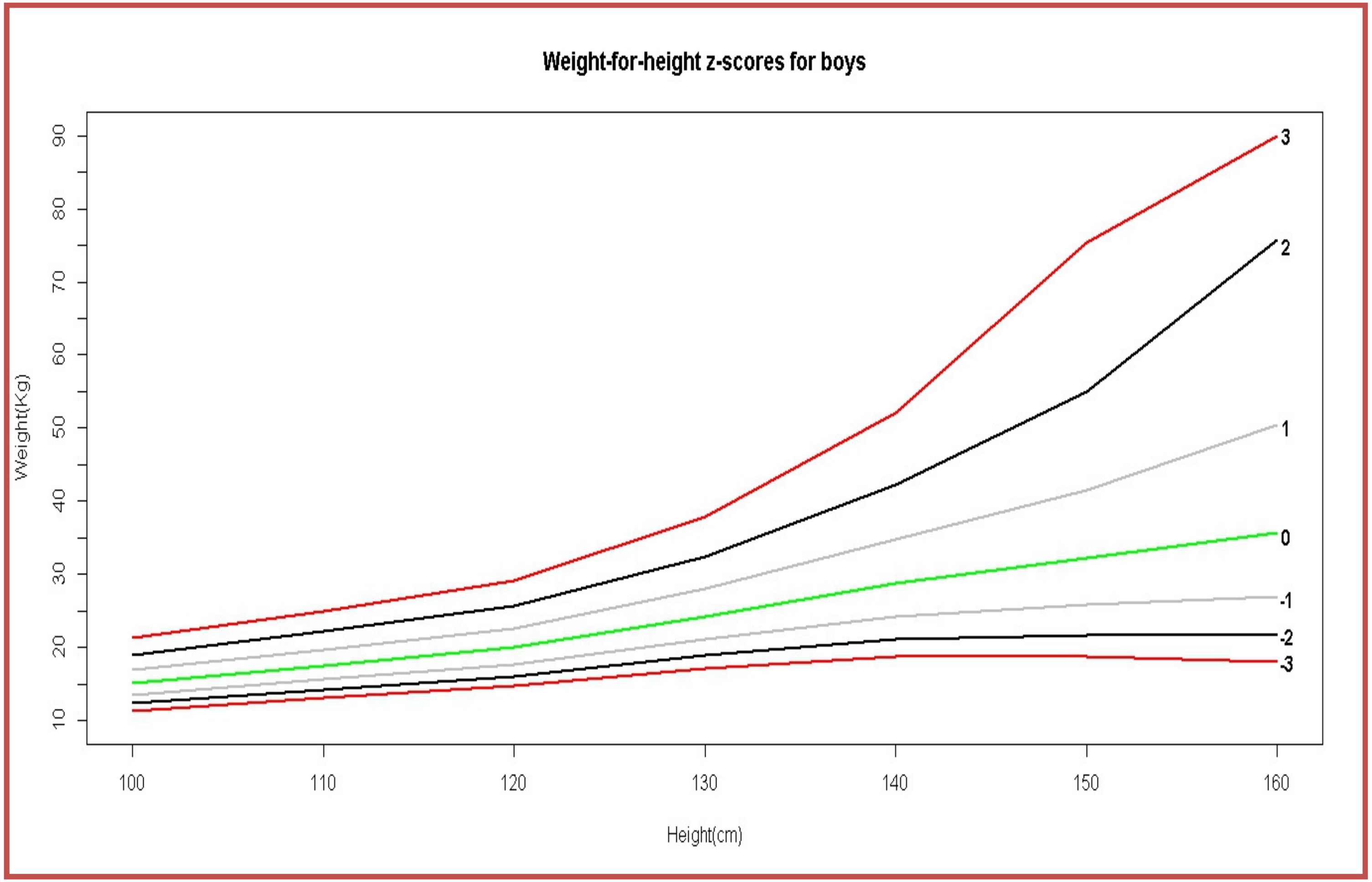


Figure49: Weight-for-height Z scores for boys from 6 to 12 years

4.6 Construction of Weight-for-Height reference chart for girls

4.6.1 Sample size and mean weight and height

There were 2520 weight and height observations for girls. Cross-sectional sample sizes, mean weight, height and standard deviation for each age group are shown in Tables 49.

Table 49: Cross-sectional sample sizes for weight-for-height for girls

Age (years)	Sample size	Height(cm)		Weight(kg)	
		Mean	SD	Mean	SD
6 years	360	109.58	5.71	16.22	2.07
7 years	360	114.38	4.95	18.45	2.89
8 years	360	118.78	5.92	19.49	3.32
9 years	360	123.16	6.18	21.32	3.61
10 years	360	129.35	6.09	24.46	4.98
11 years	360	137.57	5.95	28.63	4.81
12 years	360	142.31	4.65	33.11	5.27

Each age group wise 360 girls were taken for the study. Mean height and weight of girls shows there is a gradual increase for each age.

4.6.2 Model selection and results

The model BCPE($x=age^{\lambda}$, $df(\mu)=4$, $df(\sigma)=3$, $\nu=1$, $\tau=2$) served as a starting point to construct the height-for-age reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 50 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power λ=0.70. This smallest deviance value of λ value was taken for model fitting.

Table 50: Global deviance (GD) for models within the class BCPE(x=age$^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for weight-for-height for girls

Power(λ)	**Global Deviance(GD)**
0.10	10671.52
0.20	10618.54
0.30	10644.62
0.40	10642.54
0.50	10651.61
0.60	10641.76
0.70	**10601.72**
0.80	10611.71
0.90	10621.61
1.00	10613.75

After choosing the age-transformation power λ=0.70, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=3 . So the final selected model is BCPE(x=age$^{0.7}$, df(μ)=3, df(σ)=4, ν=1, τ=2).

4.6.3 Goodness-of-fit assessment fitted model for 6-12 years girls

Goodness-of-fit for the selected model BEPE(x=age $^{0.70}$, df(μ)=3 df(σ)=4, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure 50 (overall) and in figure 51 (age wise) do not indicate any upward or downward shifts except 6th & 12th years. This may be due to some extreme values in that age group.There is no evidence of worms shows midfit and all the worms are within 95% confidence interval.

Table 51: Q-test for z-scores form the model BCPE(0.70, 3,4,1,2)

for height-for-age for girls

Age	**Z1**	**Z2**	**Z3**	**Z4**
6 years	-0.488	-1.146	0.764	**-2.950**
7 years	1.819	1.980	1.024	-0.486
8 years	-0.643	-0.692	1.596	0.406
9 years	0.263	-1.777	1.514	-0.721
10 years	0.277	-0.640	1.668	-0.878
11 years	-1.112	1.942	1.993	0.489
12 years	0.231	-1.909	**2.464**	1.528
TOTAL Q stats	5.285	8.462	8.412	9.988
Degrees of freedom for Q stats	2.000	5.000	6.000	6.000
P-value for Q stats	0.07	0.13	0.13	0.14

Note: Absolute values of z1,z2,z3 or z4 larger than 2 indicate misfit of , respectively, mean, variance, skewness and kurtosis

In table 51 the Q-test was performed to assess the overall significance of the deviations of z1,z2,z3, and z4. Absolute deviations greater than 2 noted in the12th year z3=2.464 & 6th year z4=-2.950, however overall p-value for the Q –test is not significant(0.07,0.13,0.13, 0.14). So it does not suggest any significance departure of the fitted model z-scores from normality at the 5% level of significance

Table 52: Final model Skewness and kurtosis for 6-12 years girls

****

Summary of the Quantile Residuals

Mean	= 0.01813698
Variance	= 1.00037
coef. of skewness	= 0.05057914
coef. of kurtosis	= 2.985026
Filliben correlation coefficient	= 0.9985216

****

Table 52 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean=0.02 (against 0), variance =1.00 (against 1), skewness =0.05 (against 0), kurtosis=2.98 (against 3.00). It was shown in figure 52.

4.6.4 LMS values and percentiles for 6-12 years Girls

Table 53 shows the 3rd, 10th, 25th, 50th, 75th, 90th and 97th predicted percentile values of weight–for-height for 6-12 years girls with their respective lamda,-mu- sigma values.

Less than 3rd percentile is wasted. Less than 12.2 kg among 100 cm height girls are considered wasted, less than 14 kg among 110 cm height girls are considered wasted, less than 15.9 kg among 120 cm height girls are considered wasted, less than 19 kg among 130 cm height girls are considered wasted, less than 22 kg among 140 cm height girls are considered wasted, less than 24.1 kg among 150 cm height girls are considered wasted and less than 25.5 kg among 160 cm height girls are considered wasted. Figure 53A shows the age related smoothened percentile reference chart for standard values and Figure 53B shows the WHO standard percentile curve.

Table53: LMS values and percentiles for 6-12 years Girls

Height(cm)	L	M	S	SD	Percentiles(weight in kg)						
					3rd	10th	25th	50th	75th	90th	97th
100	1	14.8	0.0052	1.5	12.2	12.8	13.5	14.8	15.4	16.4	17.5
110	1	16.8	0.0057	2.0	14	14.9	15.8	16.8	18.2	19.5	21.0
120	1	19.4	0.0073	2.1	15.9	16.9	18.1	19.4	21.2	23.0	24.9
130	1	24.0	0.0075	3.2	19	20.4	22.1	24.0	26.6	29.1	32.2
140	1	28.8	0.0068	5.2	22	24.1	26.5	28.8	33.6	37.9	43.2
150	1	34.1	0.0064	7.5	24.1	27	30.4	34.1	41.3	48.5	58.2
160	1	39.5	0.0041	7.3	25.5	29.3	34	39.5	50.2	62.3	80.2

4.6.5 LMS values and Z-score for 6-12 years Girls

Table 54 shows 6-12 year old girls' predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD weight-for-height values and their respective lamda-mu-sigma values. Less than -2SD is wasted. Less than 12.4 kg among 100 cm height girls are considered wasted, less than 14.2 kg among 110 cm height girls are considered wasted, less than 15.9 kg among 120 cm height girls are considered wasted, less than 19.3 kg among 130 cm height girls are considered wasted, less than 22.3 kg among 140 cm height girls are considered wasted, less than 24.4 kg among 150 cm height girls are considered wasted and less than 25.5 kg among 160 cm height girls are considered wasted. Figure 54 shows the weight-for-height percentile curve.

Table54: LMS values and Z score for 6-12 years Girls

Height(cm)	L	M	S	SD	Z score(weight in kg)						
					-3	-2	-1	0	1	2	3
100	1	14.8	0.0054	1.5	12.4	12.8	13.6	14.8	15.4	16.4	17.5
110	1	16.8	0.0051	2.1	14.2	14.9	15.8	16.6	18.7	19.9	22.0
120	1	19.4	0.0077	2.1	15.9	16.9	18.3	19.4	21.2	23.0	24.9
130	1	24.0	0.0096	3.2	19.3	20.5	22.1	24.0	26.6	29.1	32.4
140	1	28.8	0.0091	4.8	22.3	24.1	26.5	28.8	33.6	37.9	44.2
150	1	36.1	0.0073	7.2	24.4	27.2	30.4	36.1	41.3	48.5	58.2
160	1	40.5	0.0075	7.4	25.5	29.3	34.3	40.5	50.2	62.3	79.2

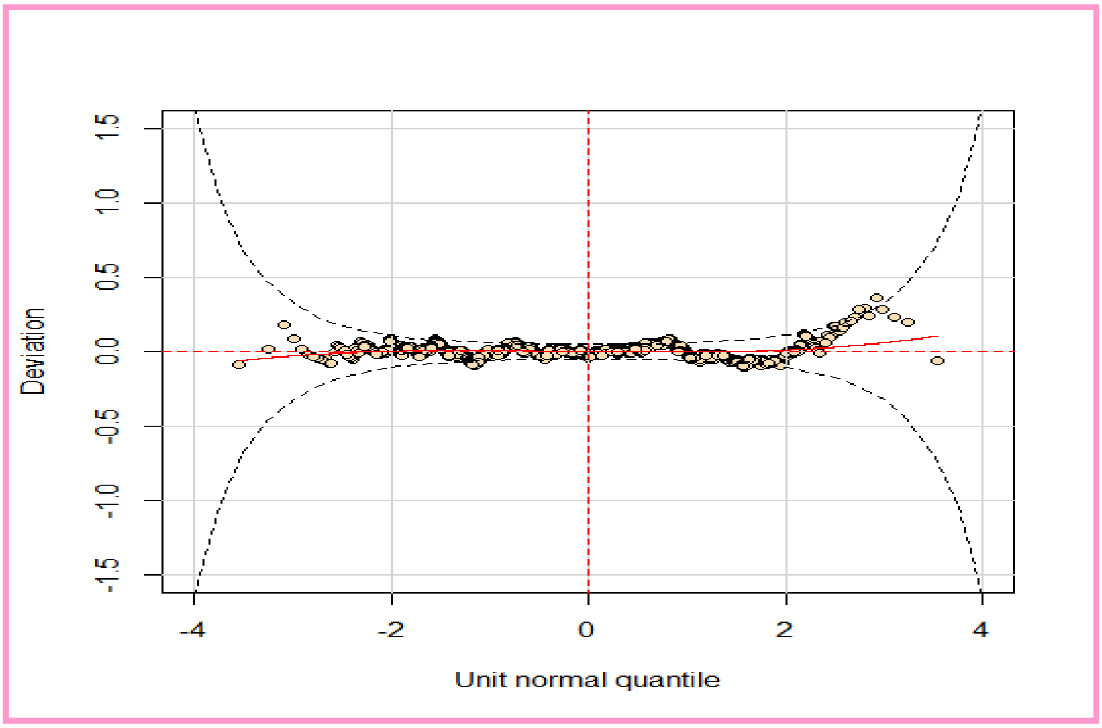


Figure 50: Worm plot assess the normality of fitted weight-for-height data for 6-12 years girls

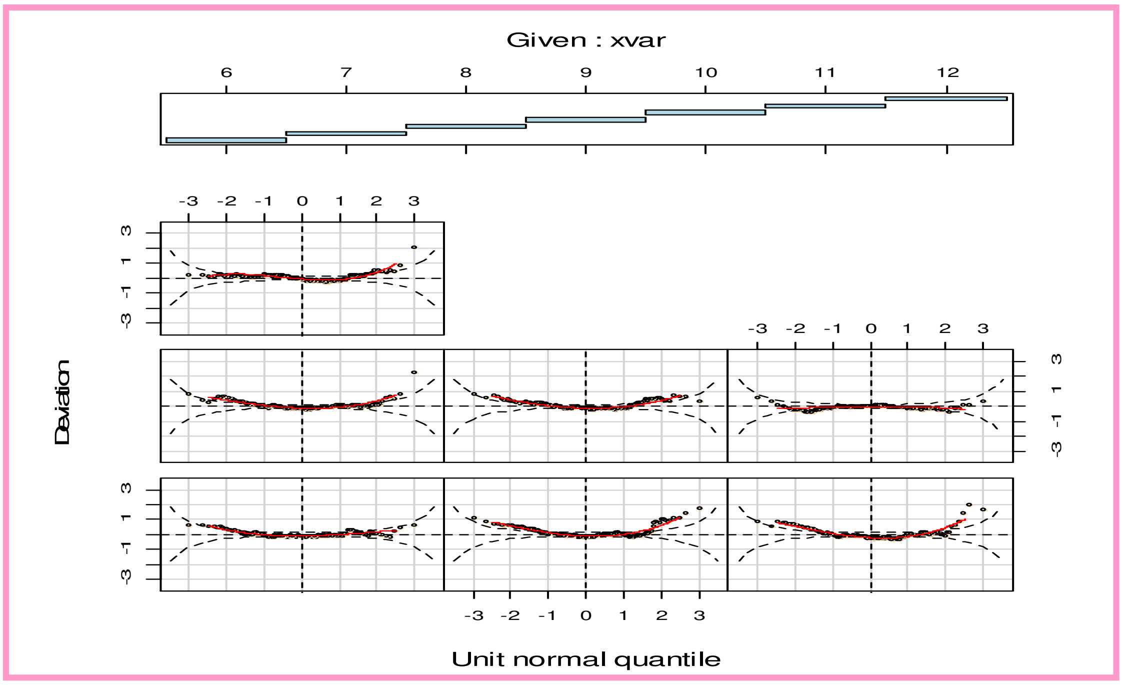


Figure 51: Worm plots of Z scores model of df(μ)=4 df(σ)=3, ν=1, τ=2with age transformation x=age$^{0.70}$ for 6-12 years weight-for-height of girls

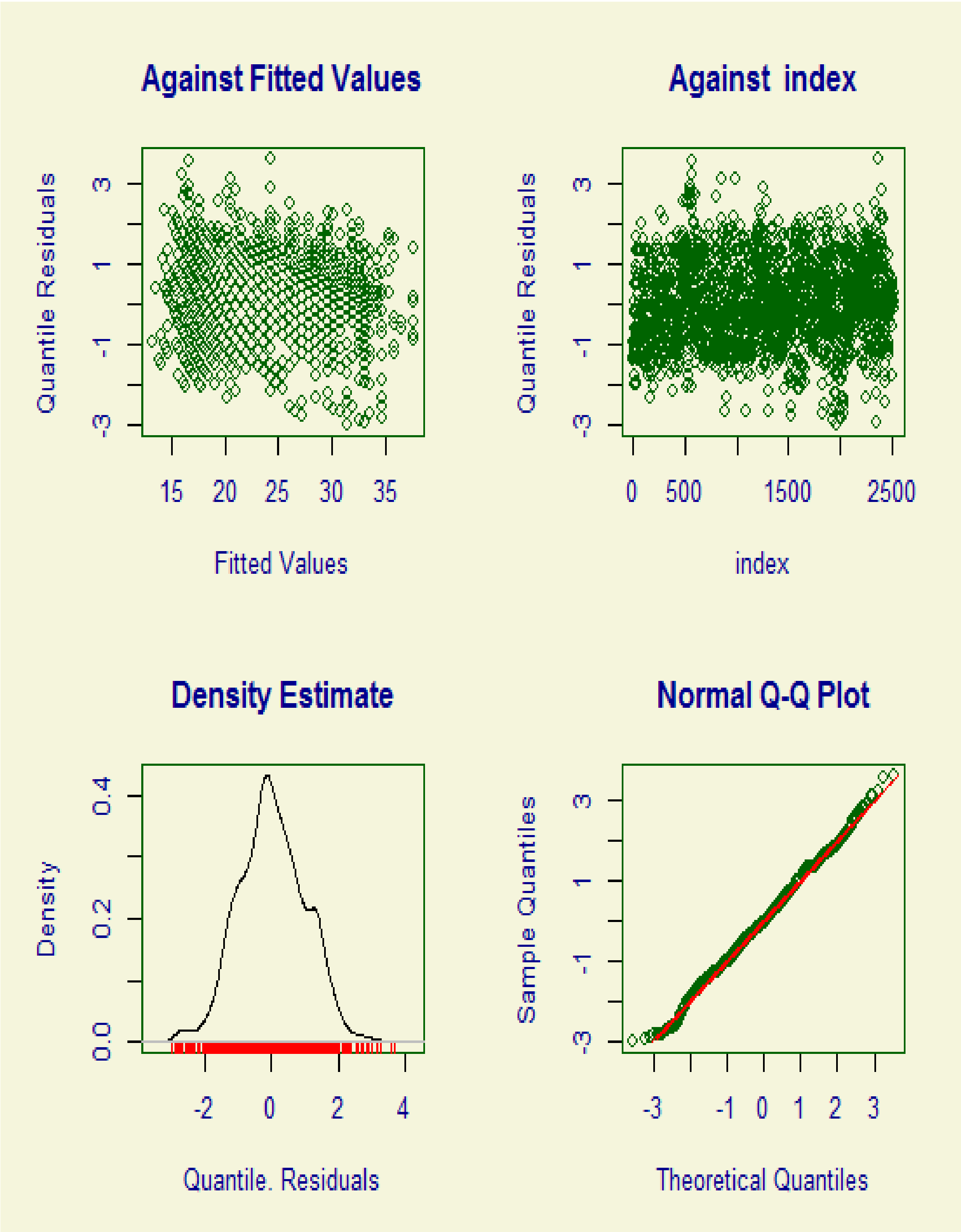


Figure 52 :Residual analysis of fitted model BCPE(x=age$^{0.70}$ df(μ)=3 df(σ)=4, ν=1, τ=2) for 6-12 years weight-for height of girls

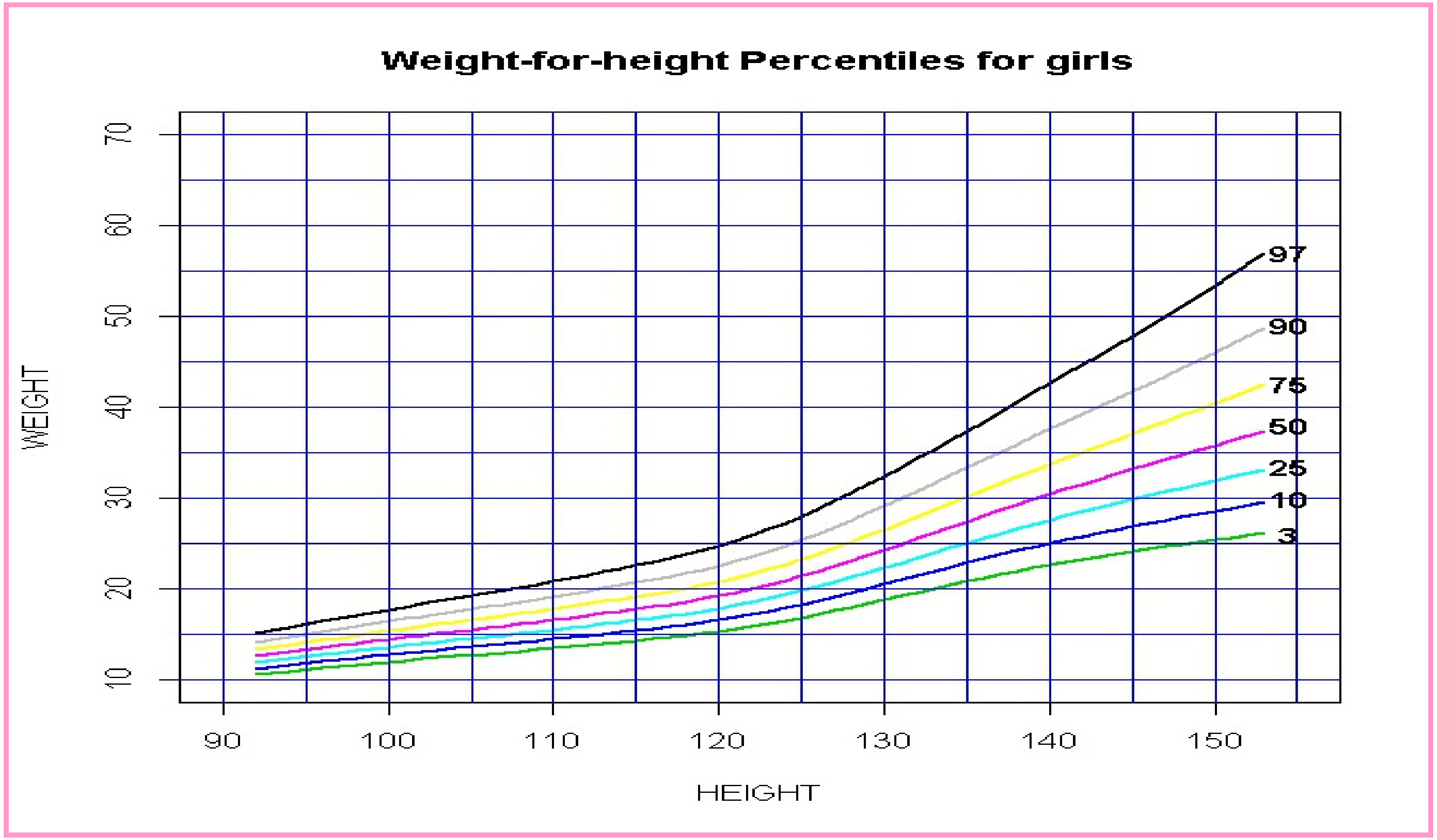


Figure 53A: Weight-for- height smoothened percentiles for girls from 6 to 12 years

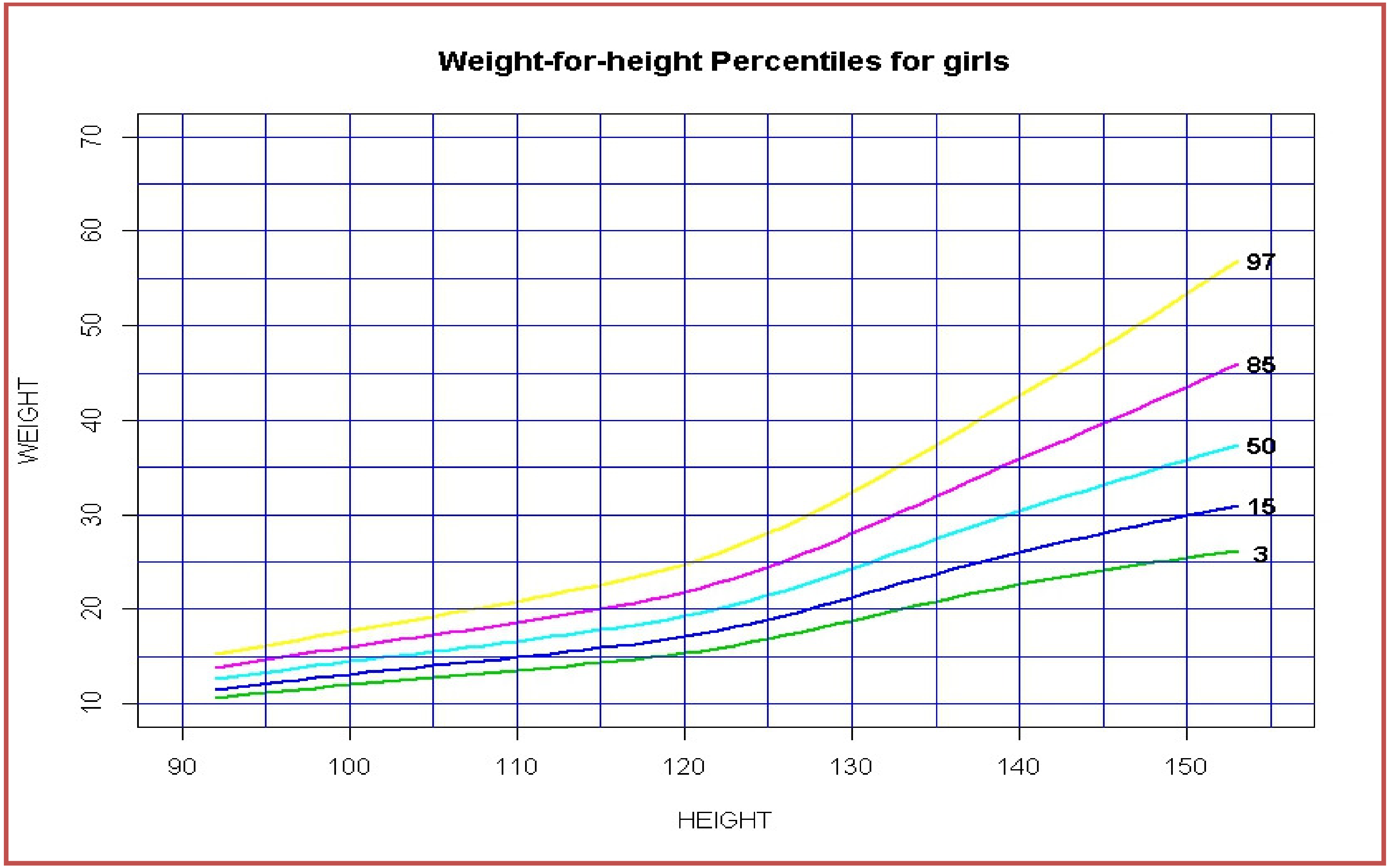


Figure 53B: WHO standard Weight-for- height percentiles for girls from 6 to 12 years

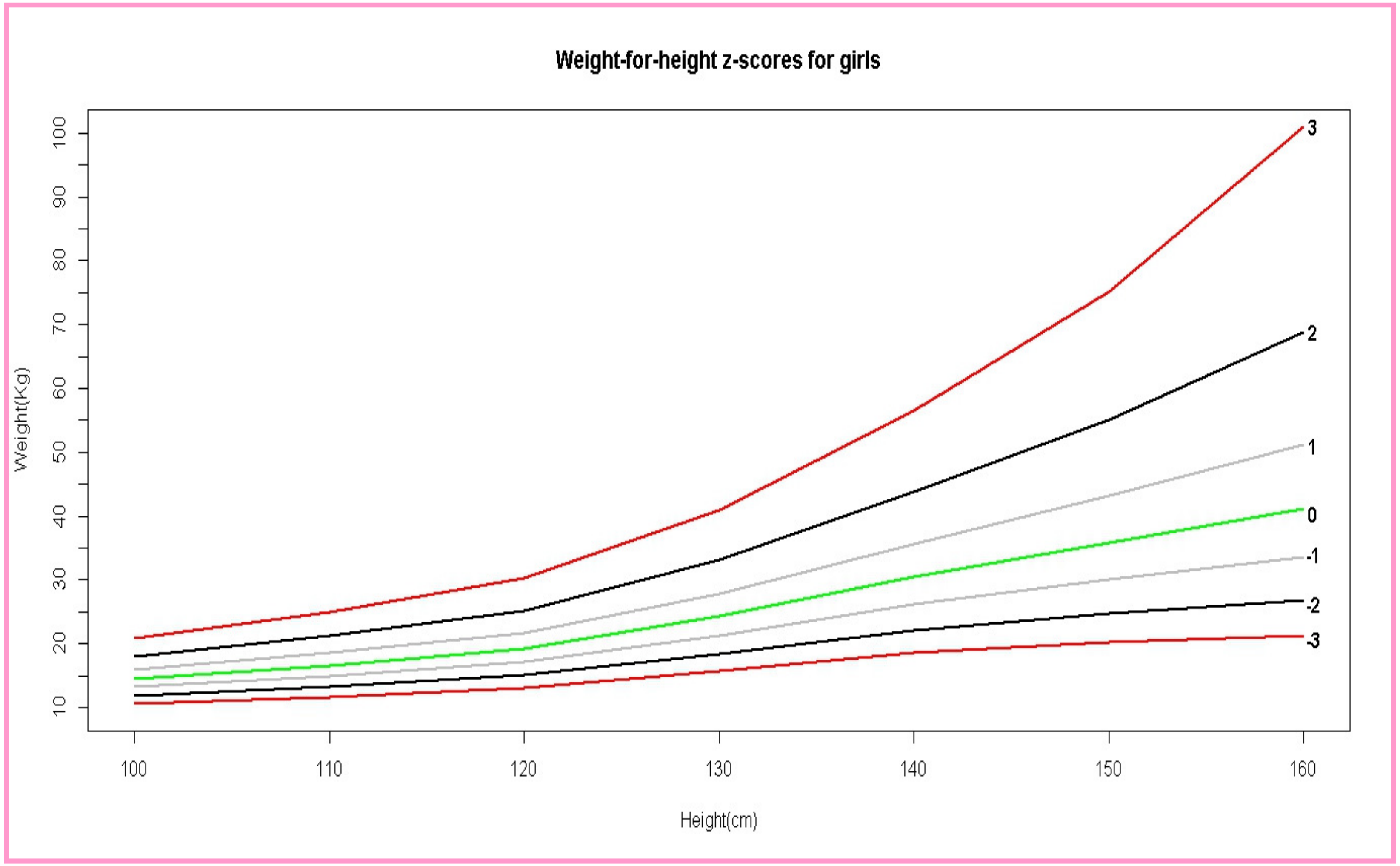


Figure54: Weight-for- height Z scores for girls from 6 to 12 years

4.7 Construction of Body Mass Index reference chart for boys

4.7.1 Sample size and mean body mass index(BMI)

There were 2520 weight observations for boys. Cross-sectional sample size, mean weight and standard deviation for each age group are shown in Tables 55.

Table 55: Cross-sectional sample sizes and BMI-for-age for boys

Age (years)	No. of boys	Weight(kg)	
		Mean	SD
6 years	360	14.06	1.74
7 years	360	14.57	1.76
8 years	360	14.20	1.90
9 years	360	14.23	1.77
10 years	360	14.52	2.35
11 years	360	14.27	2.19
12 years	360	15.82	2.86

Each age group wise 360 boys were taken for the study. Mean body mass index shows there is a gradual increase for each age.

4.7.2 Normality checking

Normality of BMI distribution was checked using graphical and mathematical methods. Graphically it was tested using Histogram & normal Q-Q plot (Figures 55-58) and mathematically it was tested using Kolmogorov-Smirnov normality test (z=3.51 p=0.001), skewness (0.91) & kurtosis (1.65).

Calculated Kolmogorov-Smirnov normality test value is Z=3.51 and it is statistically significant, it indicates that the 6-12 years boys BMI is not distributed normally.

Calculated skewness value is 0.91, so it shows presence of positive skewness among 6-12 years boys BMI. Calculated kurtosis value is 1.95, it is having lower height than normal distribution, so it shows presence of platykurtic among 6-12 years boys BMI. Skewness (0.91) and kurtosis (1.65) values indicates, the BMI distribution is skewed to right with a less peak than normal distribution.

Table 56: Body Mass Index Mean & SD for Boys

Age	Mean	Median	SD	skewness	Kurtosis
6 years	14.06	13.76	1.74	0.57	0.11
7 years	14.57	14.58	1.76	0.46	0.52
8 years	14.20	14.10	1.89	0.81	1.46
9 years	14.23	14.09	1.77	0.68	1.14
10 years	14.52	14.04	2.35	1.15	1.89
11 years	14.27	14.13	2.19	0.56	0.79
12 years	15.82	15.65	2.86	0.50	0.30

Table 56 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years boys height. Each age group of boys shows, body mass index values are above “0”, so boys BMI values are positively skewed. Similarly each age wise kurtosis values are below "3", so BMI values are platykurtic. 6-12 years boys BMI data shows presence of skewness as well as kurtosis.

Normality of boys BMI is assessed using graphical method of histogram with normal curve. Figure 55 and figure 56 of histogram with normal curve shows, 6-12 years boys height is not normally distributed and it is skewed to right side.

Normal Q-Q plot and Detrended Q-Q plot graphically helps to find the normality of the data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Figure 57 and figure 58 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution.

4.7.3 Model selection and results

The model BCPE($x=age^{\lambda}$, $df(\mu)=5$, $df(\sigma)=3$, $\nu=1$, $\tau=2$) served as a starting point to construct the body mass index reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 57 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power $\lambda=0.90$. This smallest deviance value of λ value was taken for model fitting.

Table 57: Global deviance (GD) for models within the class BCPE($x=age^{\lambda}$, df(μ)=4, df(σ)=3,ν=1, τ=2) for BMI-for-age for boys

Power(λ)	Global Deviance(GD)
0.10	12992.43
0.20	12976.52
0.30	12983.64
0.40	12997.23
0.50	12987.11
0.60	12946.25
0.70	12978.26
0.80	12981.42
0.90	**12922.42**
1.00	12985.55

After choosing the age-transformation power λ=0.90, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=3 df(σ)=4 . So the final selected model is BCPE($x=age^{0.9}$, df(μ)=3, df(σ)=4, ν=1, τ=2).

4.7.4 Goodness-of-fit assessment fitted model for 6-12 years boys

Goodness-of-fit for the selected model BEPE($x=age^{0.90}$, df(μ)=3 df(σ)=4, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure59 (overall) and in figure60 (age wise) do not indicate any upward or downward shifts except 9th and 12th year. This may be due to some extreme values in that age groups.There is no evidence to show that worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 58: Q-test for z-scores form the model BCPE(0.90, 3,4,1,2) for body mass index for boys

Age	Z1	Z2	Z3	Z4
6 years	-0.571	0.648	0.901	-1.986
7 years	1.561	-1.481	-0.502	-1.265
8 years	-1.126	0.729	1.215	0.344
9 years	-0.065	1.293	**-2.594**	0.585
10 years	1.331	1.034	0.374	1.284
11 years	-1.473	-0.751	-1.668	0.707
12 years	1.469	0.559	**-2.676**	1.231
TOTAL Q stats	5.601	8.411	9.301	9.287
Degrees of freedom for Q stats	2.0	5.0	6.0	6.0
P-value for Q stats	0.07	0.14	0.16	0.16

Note: Absolute values of z1,z2,z3 or z4 larger than 2 indicate misfit of , respectively, mean, variance skewness and kurtosis

In table 58 the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3, and z4. Absolute deviations greater than 2 noted in the 9th year

Z3=-2.594 and 12th year z3=-2.676, however overall p-value for the Q –test is not significant (0.07, 0.14, 0.16, 0.16). So it is not suggest any significance departure of the fitted model z-scores from normality at the 5% level of significance.

Table 59: Final model Skewness and kurtosis for 6-12 years boys

****

Summary of the Quantile Residuals	
Mean	= 0.0009464369
Variance	= 1.000387
coef. of skewness	= 0.01508327
coef. of kurtosis	= 3.02018
Filliben correlation coefficient	= 0.9993871

****

Table 59 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean =0 (against 0), variance =1 (against 1), skewness =-0.01 (against 0), kurtosis=3.02 (against 3).

Figure 61 shows the residual distribution of weight-for-age in males: Quantile (standardized) residuals plotted against fitted values and against age, the density estimate with rug plot, and the Quantile–Quantile plot. The distribution is normal. A straight 1:1 line (plot on RHS bottom) indicates a good fit of the GAMLSS model.

4.7.5 LMS values and percentiles for 6-12 years boys

Table 60 shows the 3rd, 10th, 25th, 50th, 75th, 90th and 97th predicted percentile values of BMI–for-age for 6-12 years boys with their respective lamda,-mu- sigma values. Body Mass Index (BMI) is the number calculated from weight and height to determine body fatness. Percentiles are used for children because the amount of body fat differs between boys and girls and body fat also changes with age.

The percentiles which fall below the 3rd percentile indicate underweight, the 15th to less than the 85th percentiles indicate normal, while 85th to 97th percentile indicates overweight. The percentile equal to or greater than the 97th percentile indicates obesity. Figure 62A shows the age related smoothened percentile reference chart for standard values and Figure 62B shows the WHO standard percentile curve.

Table60: LMS values and percentiles for 6-12 years boys

Age	L	M	S	SD	Percentiles(BMI)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	13.9	0.0085	1.7	11.3	12.1	12.9	13.9	15.1	16.3	17.7
7 years	1	14.3	0.0085	1.8	11.5	12.3	13.2	14.1	15.5	16.8	18.2
8 years	1	14.1	0.0089	1.9	11.3	12.1	13	14.3	15.4	16.7	18.2
9 years	1	14.1	0.0094	1.8	11.1	12	12.9	14.5	15.4	16.8	18.4
10 years	1	14.1	0.0102	2.4	11	11.8	12.8	14.7	15.6	17.1	18.9
11 years	1	14.3	0.0111	2.2	10.9	11.8	12.9	14.9	16	17.7	19.8
12 years	1	15.2	0.0116	2.9	11.2	12.3	13.6	15.4	17.2	19.4	21.9

4.7.6 LMS values and Z-score for 6-12 years boys

Table 61 shows 6-12 year old boys' predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD body mass index values and their respective lamda-mu-sigma values. . It is the only indicator that includes all the three measurements of weight, height and age. Body Mass Index is the most widely used diagnostic tool for screening and identifying underweight, overweight and obesity in population for both adults and children. WHO suggest a set of thresholds based on single standard deviation spacing. Underweight: <-2SD, Overweight: between +1SD and <+2SD, Obese: >+2SD.Figure 63 shows the age related z-score reference chart.

Table 61: LMS values and Z score for 6-12 years boys

Age	L	M	S	SD	Z score(BMI)						
					-3	-2	-1	0	1	2	3
6 years	1	14.0	0.0085	1.7	10.1	11.2	12.4	14.0	15.8	18	20.7
7 years	1	14.3	0.0085	1.8	10.2	11.4	12.7	14.3	16.2	18.5	21.4
8 years	1	14.6	0.0089	1.9	10	11.2	12.5	14.6	16.1	18.5	21.5
9 years	1	14.6	0.0094	1.8	9.8	11	12.4	14.6	16.1	18.7	22
10 years	1	14.5	0.0102	2.4	9.6	10.8	12.3	14.5	16.4	19.3	23
11 years	1	14.3	0.0111	2.2	9.4	10.7	12.3	14.3	16.9	20.2	24.7
12 years	1	15.9	0.0116	2.9	9.5	11	12.9	15.9	18.3	22.5	28.3

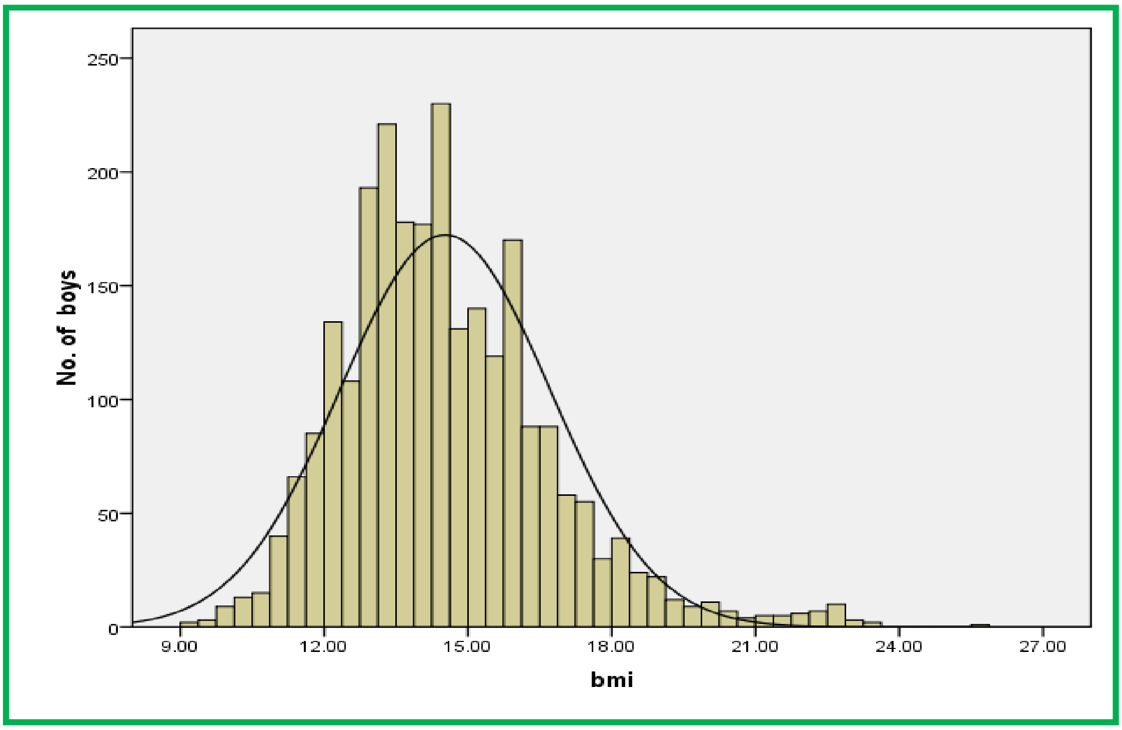


Figure 55: Histogram with normal curve shows the BMI-for-age of 6-12 years children are distributed positively skewed (Mean =14.5 median= 14.3 skewness=0.91 kurtosis=1.65)

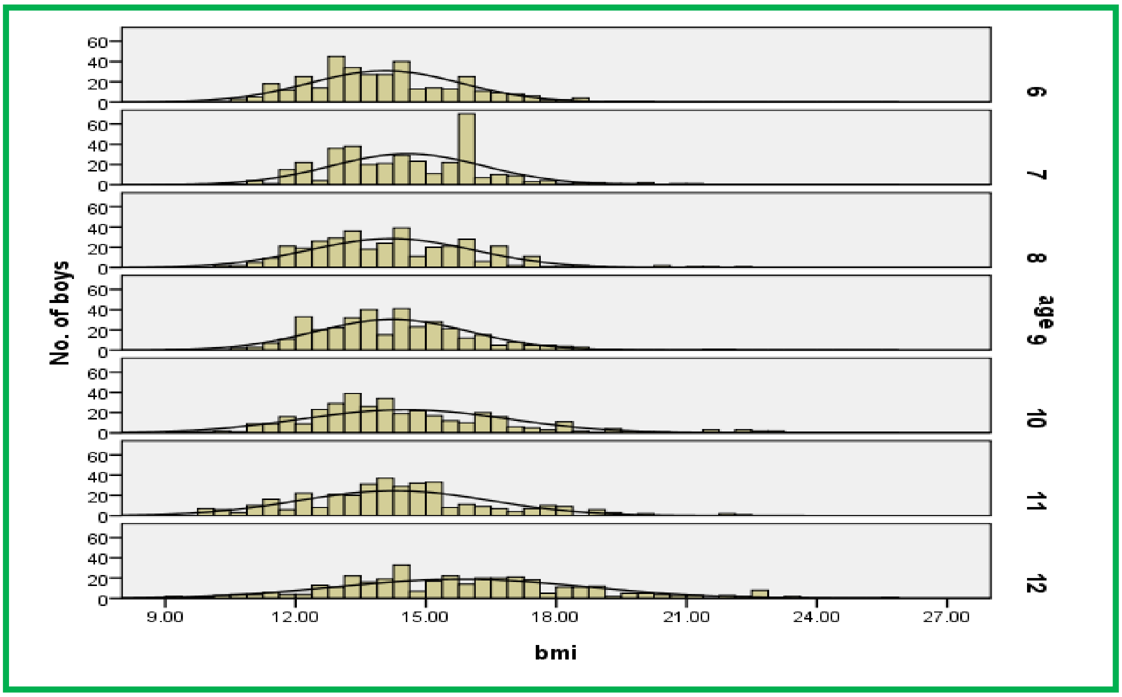
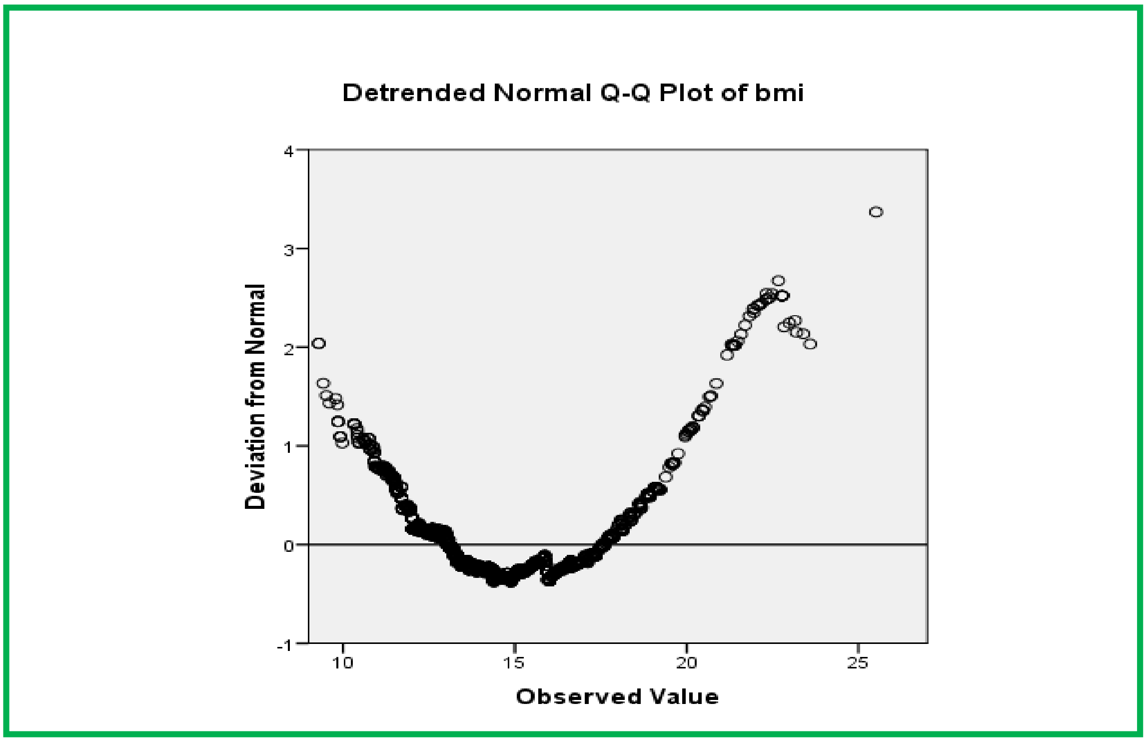


Figure 56: Histogram with normal curve assess the normality of BMI-for-age of 6-12 years boys



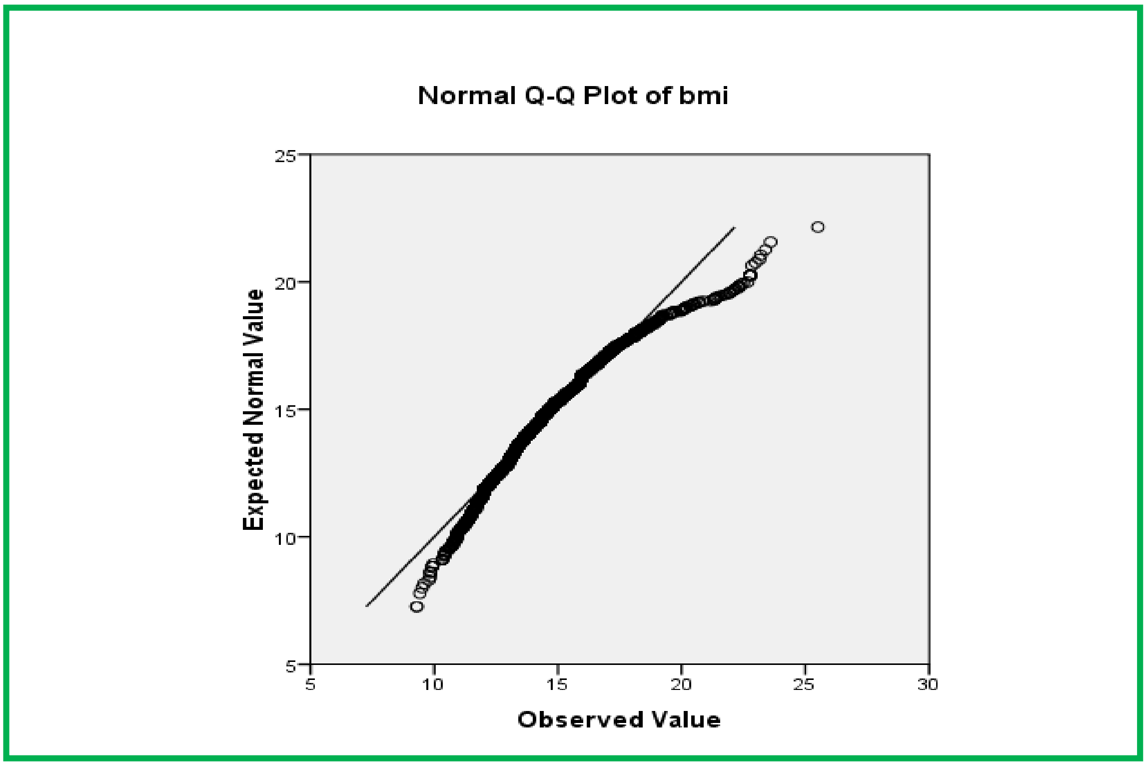


Figure57: Normal Q-Q plot and detrended normal Q-Q plot assess the normality of BMI-for-age among 6-12 years boys

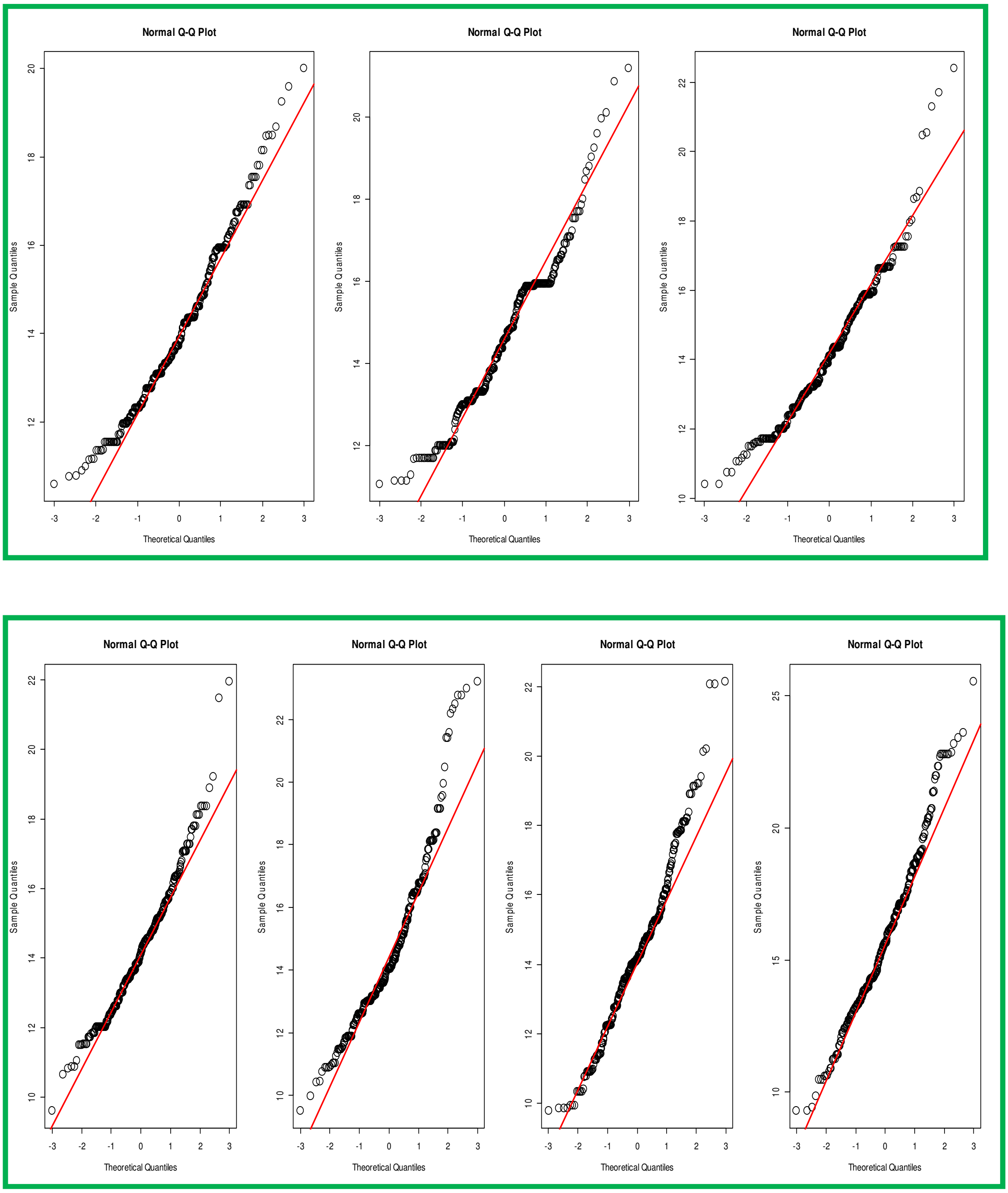


Figure58: Normal Q-Q plot assess the each agewise normality of BMI-for-age among 6-12 years boys

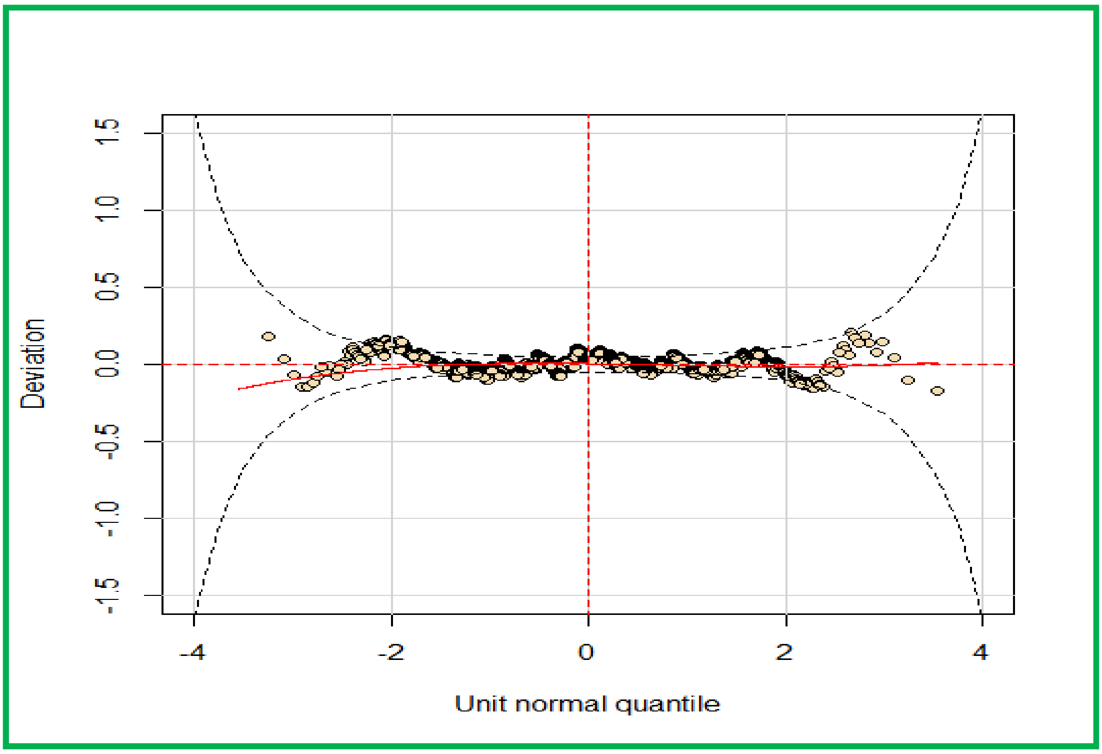


Figure59: Worm plot assesses the normality of fitted BMI-for-age data for 6-12 years boys

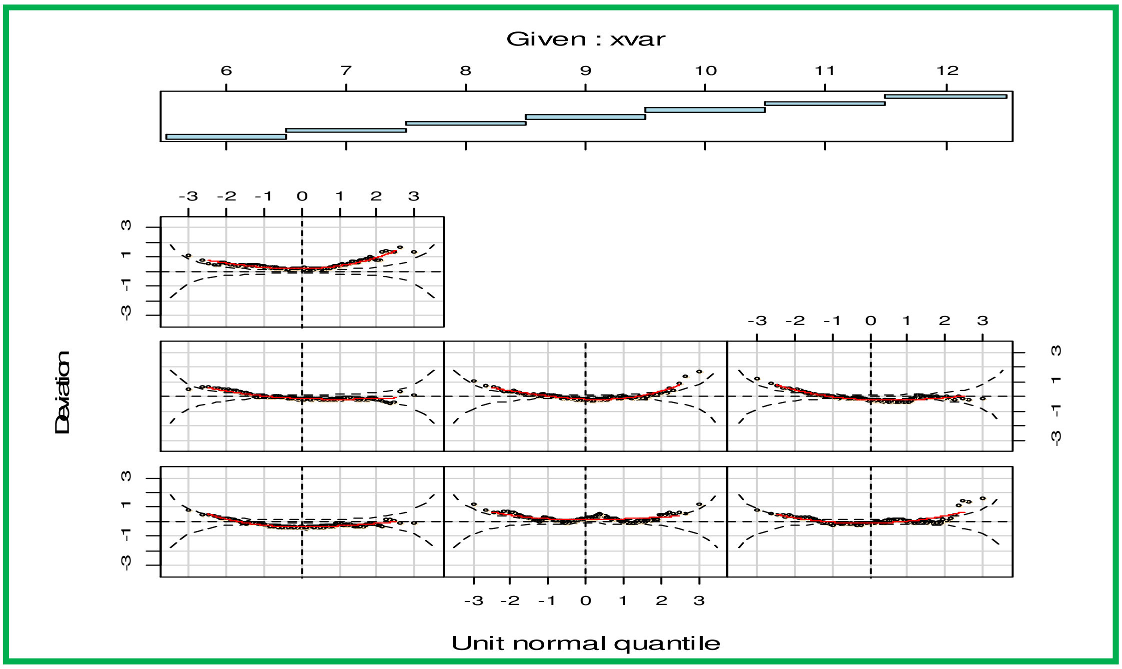


Figure60: Worm plots of Z scores model of df(μ)=3 df(σ)=4, ν=1, τ=2 with age transformation $x=age^{0.90}$ for 6-12 years body mass index of boys

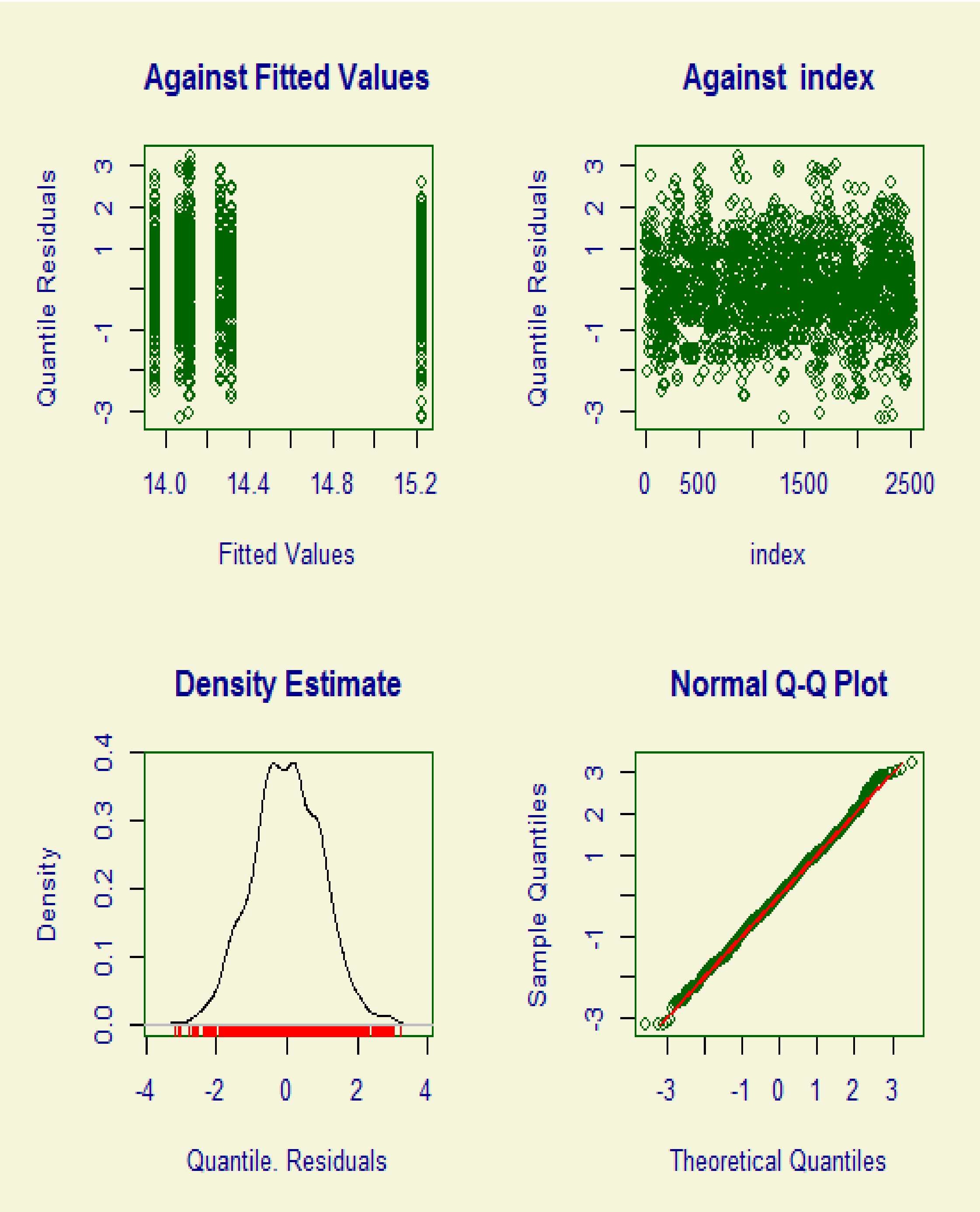


Figure 61 :Normalized residue charts of fitted model BCPE(x=age $^{0.90}$ df(μ)=3 df(σ)=4, ν=1, τ=2) for 6-12 years Body Mass Index of boys

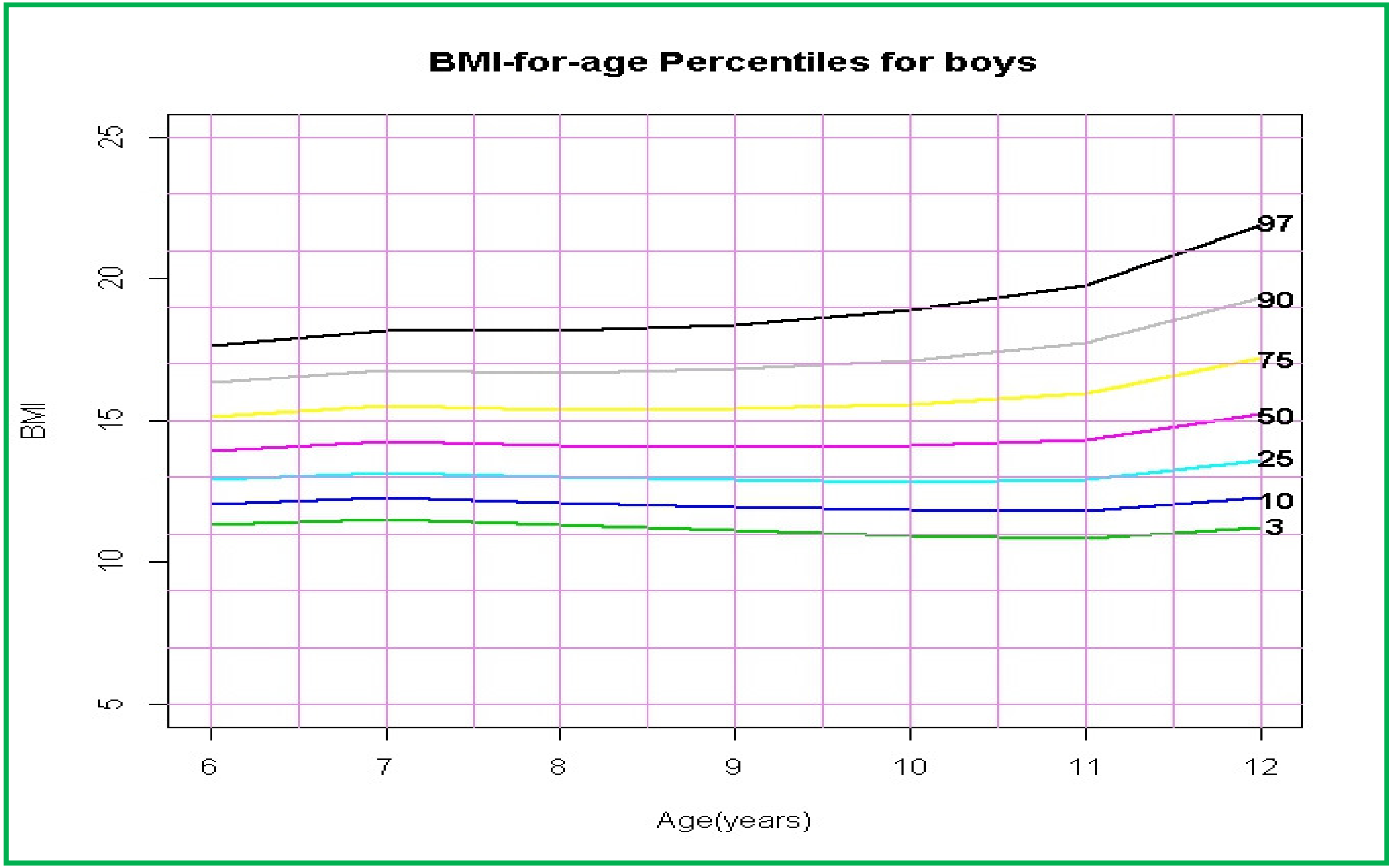


Figure62A: Body Mass Index percentiles curves for boys from 6 to 12 years. Centiles are: 3rd, 10th, 25th, 50th, 75th, 90th and 97th

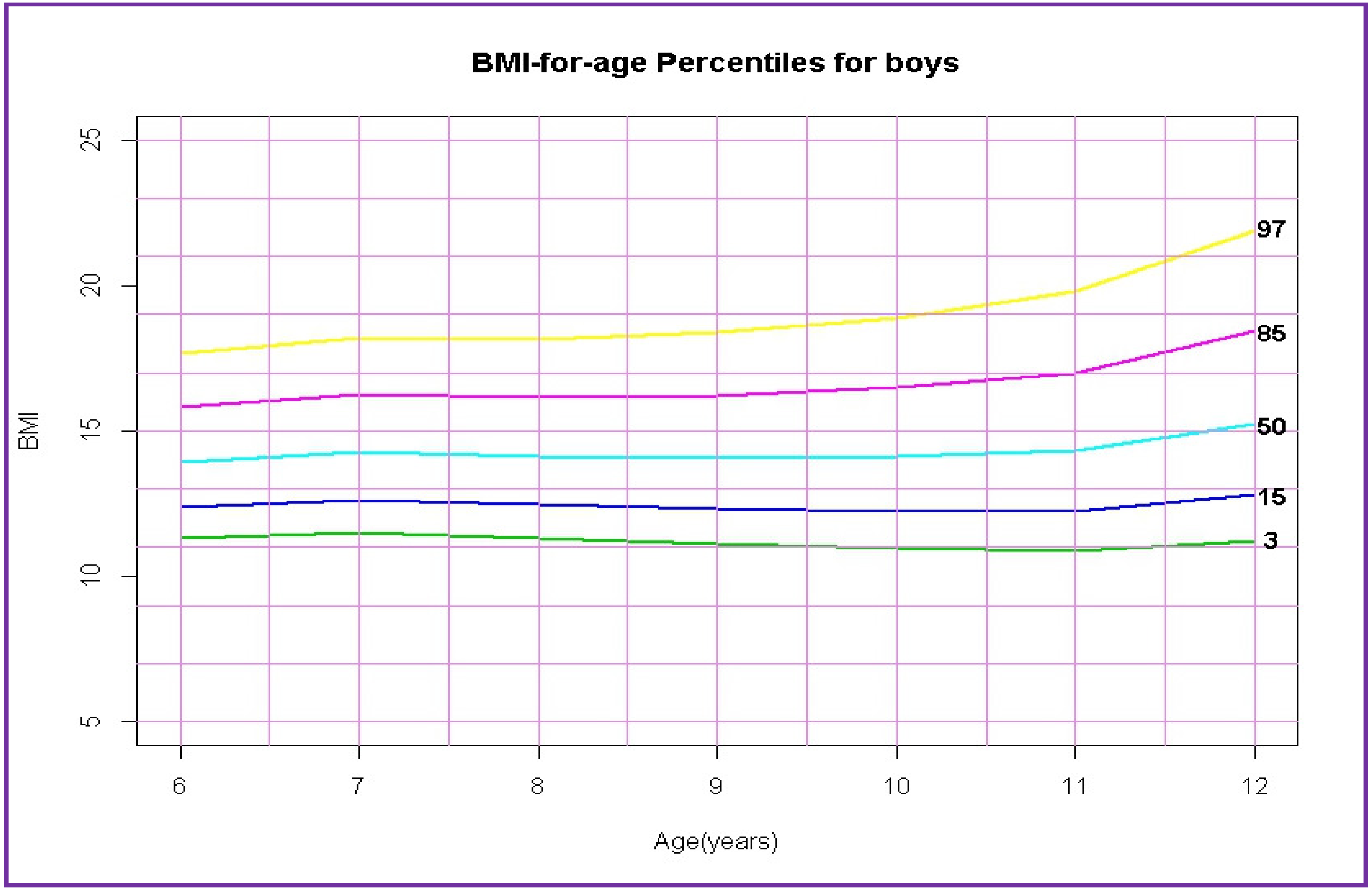


Figure62B: WHO standard Body Mass Index percentiles curve for boys from 6 to 12 years. Centiles are: 3rd, 15th, 50th, , 85th and 97th

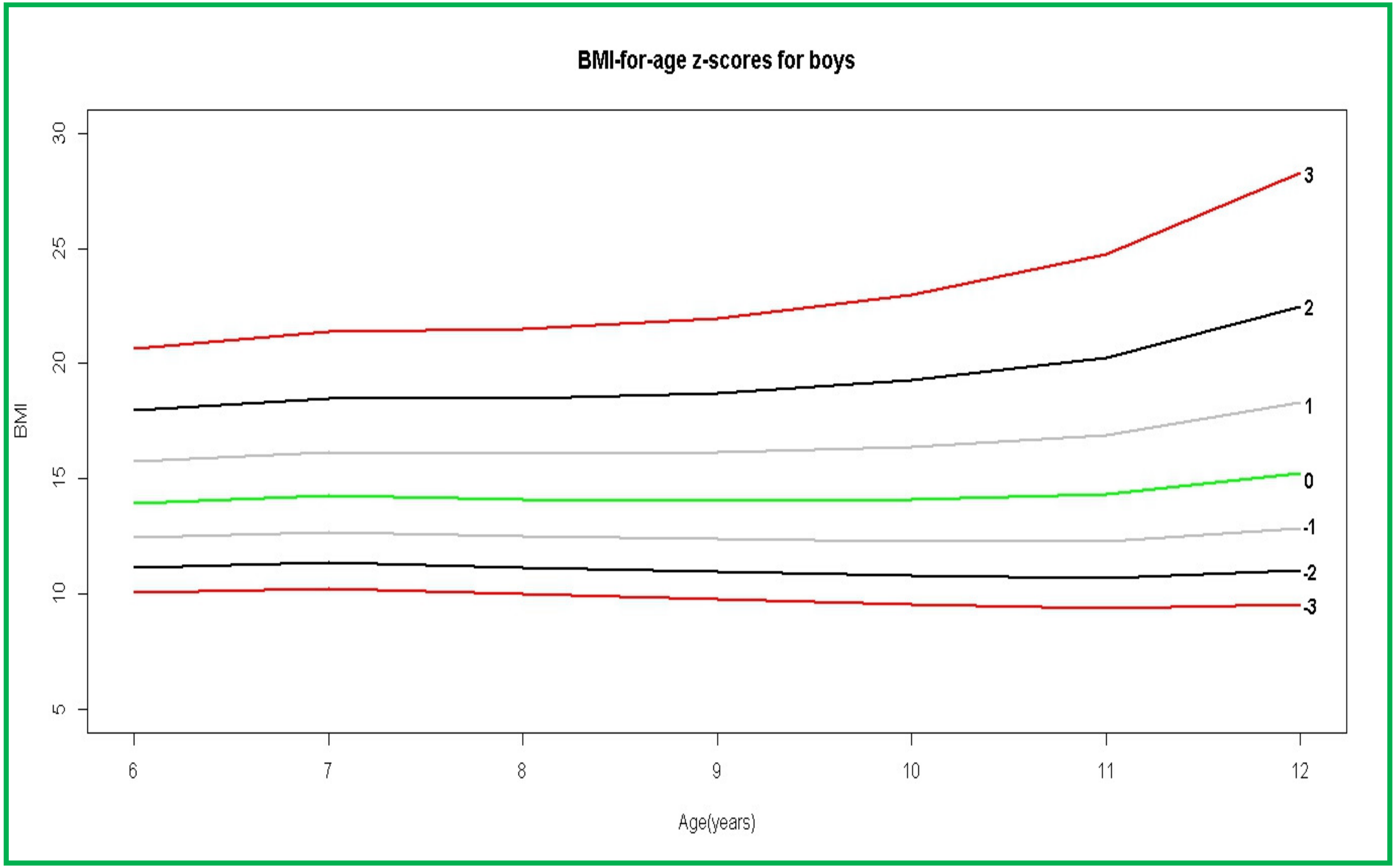


Figure63: BMI-for-age Z scores for boys from 6 to 12 years

4.8 Construction of Body Mass Index reference chart for girls

4.8.1 Sample size and mean body mass index(BMI)

There were 2520 weight observations for girls. Cross-sectional sample size, mean weight and standard deviation for each age group are shown in Tables 62.

Table 62 Cross-sectional sample sizes and BMI-for-age for girls

Age (years)	No. of girls	BMI	
		Mean	SD
6 years	360	13.52	1.46
7 years	360	14.10	1.97
8 years	360	13.78	1.82
9 years	360	14.02	1.82
10 years	360	14.52	2.12
11 years	360	15.15	2.47
12 years	360	16.34	2.41

Each age group wise 360 girls were taken for the study. Mean height and weight of girls shows there is a gradual increase for each age.

4.8.2 Normality Checking

Normality of body mass index data distribution was checked by graphical and mathematical methods. Graphically it was tested using Histogram & normal Q-Q plot and mathematically it was tested using Kolmogorov-Smirnov normality test (z=3.36 p=0.001), skewness(0.85) & kurtosis(1.46).(Figure 64-67) Table 63 shows each agewise mathematical values of skewness and kurtosis for 6-12 years girls.

Calculated Kolmogorov-Smirnov normality test value is Z=3.51 and it is statistically significant, it indicates that the 6-12 years boys BMI is not distributed normally.

Calculated skewness value is 0.85, so it shows presence of positive skewness among 6-12 years girls BMI. Calculated kurtosis value is 1.46, it is having lower BMI value than normal , so it shows presence of platykurtic among 6-12 years girls BMI. Skewness (0.85) and kurtosis (1.46) values indicates, the BMI distribution is skewed to right with a less peak than normal distribution.

Table 63: BMI Mean, SD and percentiles for girls

Age	Mean	Median	SD	skewness	Kurtosis
6 years	14.06	13.76	1.74	0.57	0.11
7 years	14.57	14.58	1.76	0.46	0.52
8 years	14.20	14.10	1.89	0.81	1.46
9 years	14.23	14.09	1.77	0.68	1.14
10 years	14.52	14.04	2.35	1.15	1.89
11 years	14.27	14.13	2.19	0.56	0.79
12 years	15.82	15.65	2.86	0.50	0.30

Table 63 shows the mathematical values of each age wise skewness and kurtosis for 6-12 years boys BMI. Each age group of girls shows, body mass index values are above “0”, so girls BMI values are positively skewed. Similarly each age wise kurtosis values are below “3”, so BMI values are platykurtic. 6-12 years girls BMI data shows presence of skewness as well as kurtosis.

Normality of girls BMI is assessed using graphical method of histogram with normal curve. Figure 64 and figure 65 of histogram with normal curve shows, 6-12 years girls BMI is not normally distributed and it is skewed to right side.

Normal Q-Q plot and Detrended Q-Q plot graphically helps to find the normality of the data. If the observations follow approximately a normal distribution, the resulting plot should be roughly a straight line with a positive slope. Figure 66 and figure 67 Q-Q plots shows there is a deviation from the diagonal line with positively skewed distribution.

4.8.3 Model selection and results

The model BCPE($x=age^{\lambda}$, df(μ)=3, df(σ)=4, ν=1, τ=2) served as a starting point to construct the body mass index reference curves. Improvement of the model's fit was investigated by studying changes in global deviance at varying levels of the age-transformation power λ. Table 64 shows the global deviance for a grid of λ values. The smallest global deviance corresponds to age-transformation power λ=0.90. This smallest deviance value of λ value was taken for model fitting.

Table 64: Global deviance (GD) for models within the class BCPE(x=age$^{\lambda}$, df(μ)=3, df(σ)=4,ν=1, τ=2) for BMI-for-age for girls

Power(λ)	Global Deviance(GD)
0.10	12796.57
0.20	12814.55
0.30	12822.63
0.40	12786.44
0.50	12806.33
0.60	12789.45
0.70	12792.40
0.80	12796.51
0.90	**12786.78**
1.00	12789.59

After choosing the age-transformation power λ=0.90, the search for the best df(μ) and df(σ) followed, with the parameters ν and τ had the fixed values 1 and 2, respectively. Best combination Akaike Information Criteria(AIC) and Generalized Akaike Criteria(GAIC) with penalty equal to 3 was used to find the suitable degrees of freedom, which correspond to df(μ)=4 df(σ)=4 . So the final selected model is BCPE(x=age $^{0.9}$, df(μ)=4, df(σ)=4, ν=1, τ=2).

4.8.4 Goodness-of-fit assessment fitted model for 6-12 years girls

Goodness-of –fit for the selected model BEPE(x=age $^{0.90}$, df(μ)=4 df(σ)=4, ν=1, τ=2) was checked graphically as well as mathematically. Graphically it was tested using worm plots (graph) and mathematically it was tested using Q-test.

The worm plot for fitted model shown in figure68 (overall) and in figure69 (age wise) do not indicate any upward or downward shifts except 11th and 12th year. This may be due to some extreme values in that age groups.There is no evidence of worms shows midfit and all the worms are within 95% confidence interval.

Table 65: Q-test for z-scores form the model BCPE(0.90, 4,4,1,2) for body mass index for girls

Age	Z1	Z2	Z3	Z4
6 years	-0.488	-1.146	0.763	-1.941
7 years	2.019	-1.980	1.991	-0.486
8 years	-0.643	-0.692	1.985	0.405
9 years	0.263	-1.776	-1.514	-0.721
10 years	0.277	-0.639	1.668	0.877
11 years	-1.112	1.892	**2.992**	0.707
12 years	1.469	0.559	-1.467	**2.521**
TOTAL Q stats	6.021	8.311	10.301	9.316
Degrees of freedom for Q stats	2.0	5.0	6.0	6.0
P-value for Q stats	0.06	0.15	0.14	0.16

Note: Absolute values of z1,z2,z3 or z4 larger than 2 indicate misfit of , respectively, mean, variance skewness and kurtosis

In table 65 the Q-test was performed to assess the overall significance of the deviations of z1, z2, z3, and z4. Absolute deviations greater than 2 noted in the 11th year

Z3=-2.992 and 12th year z3=-2.521, however overall p-value for the Q –test is not significant (0.06, 0.15, 0.14, 0.16). There is no evidence to show that worm plots are misfit and all the worm plots are within 95% confidence interval.

Table 66: Final model Skewness and kurtosis for 6-12 years girls

****

Summary of the Quantile Residuals	
Mean	= 0.0002851734
Variance	= 1.002184
Coefficient of skewness	= 0.02909913
Coefficient of kurtosis	= 3.192959
Filliben correlation coefficient	= 0.9983532

****

Table 66 shows, after power transformation, fitted model quantile residual analysis shows normality of the data set with mean =0 (against 0), variance =1 (against 1), skewness =-0.03 (against 0), kurtosis=3.19 (against 3). It was shown in figure 70.

4.8.5 LMS values and percentiles for 6-12 years girls

Table 67 shows the 3rd, 10th, 25th, 50th, 75th, 90th and 97th predicted percentile values of BMI–for-age for 6-12 years boys with their respective lamda,-mu- sigma values. The percentiles which fall below the 3rd percentile indicate underweight, the 15th to less than the 85th percentiles indicate normal, while 85th to 97th percentile indicates overweight. The percentile equal to or greater than the 97th percentile indicates obesity.

Figure 71A shows the age related smoothened percentile reference chart for standard values and Figure 71B shows the WHO standard percentile curve.

Table67: LMS values and percentiles for 6-12 years girls

Age	L	M	S	SD	Percentiles(BMI)						
					3rd	10th	25th	50th	75th	90th	97th
6 years	1	13.4	0.0084	1.5	10.9	11.7	12.5	13.5	14.5	15.6	16.8
7 years	1	13.7	0.0088	2.0	11.0	11.9	12.7	13.8	14.9	16.1	17.5
8 years	1	13.7	0.0093	1.8	10.8	11.7	12.6	14.0	14.9	16.1	17.7
9 years	1	13.8	0.0097	1.8	10.8	11.7	12.7	14.3	15.1	16.5	18.1
10 years	1	14.3	0.0101	2.1	11.0	12.0	13.1	14.8	15.7	17.2	19.1
11 years	1	15.0	0.0101	2.5	11.4	12.5	13.7	15.4	16.6	18.3	20.4
12 years	1	16.1	0.0097	2.4	12.1	13.3	14.6	16.9	17.8	19.7	22.1

4.8.6 LMS values and Z-score for 6-12 years girls

Table 57 shows the -3, -2, -1, 0, 1, 2, 3 standard deviations predicted z-score values of BMI for 6-12 years girls with their respective lamda,-mu- sigma values. Figure 72 shows the age related z score reference chart.

Table 61 shows 6-12 year old boys' predicted z scores of -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD body mass index values and their respective lamda-mu-sigma values. . It is the only indicator that includes all the three measurements of weight, height and age. Body Mass Index is the most widely used diagnostic tool for screening and identifying underweight, overweight and obesity in population for both adults and children. WHO suggest a set of thresholds based on single standard deviation spacing. Underweight: <-2SD, Overweight: between +1SD and <+2SD, Obese: >+2SD.Figure 63 shows the age related z-score reference chart.

Table68: LMS values and Z score for 6-12 years girls

Age	L	M	S	SD	Z score(BMI)						
					-3	-2	-1	0	1	2	3
6 years	1	13.4	0.0084	1.5	9.6	10.8	12.1	13.4	15	17.1	19.8
7 years	1	13.7	0.0088	2.0	9.6	10.9	12.3	13.7	15.5	17.8	20.9
8 years	1	13.7	0.0093	1.8	9.3	10.7	12.1	13.7	15.5	18	21.3
9 years	1	13.8	0.0097	1.8	9.3	10.6	12.2	13.8	15.8	18.5	22.2
10 years	1	14.3	0.0101	2.1	9.3	10.8	12.5	14.3	16.5	19.5	23.7
11 years	1	15	0.0101	2.5	9.6	11.2	13	15	17.5	20.9	25.8
12 years	1	16.1	0.0097	2.4	10.1	11.9	13.9	16.1	18.8	22.6	28.1

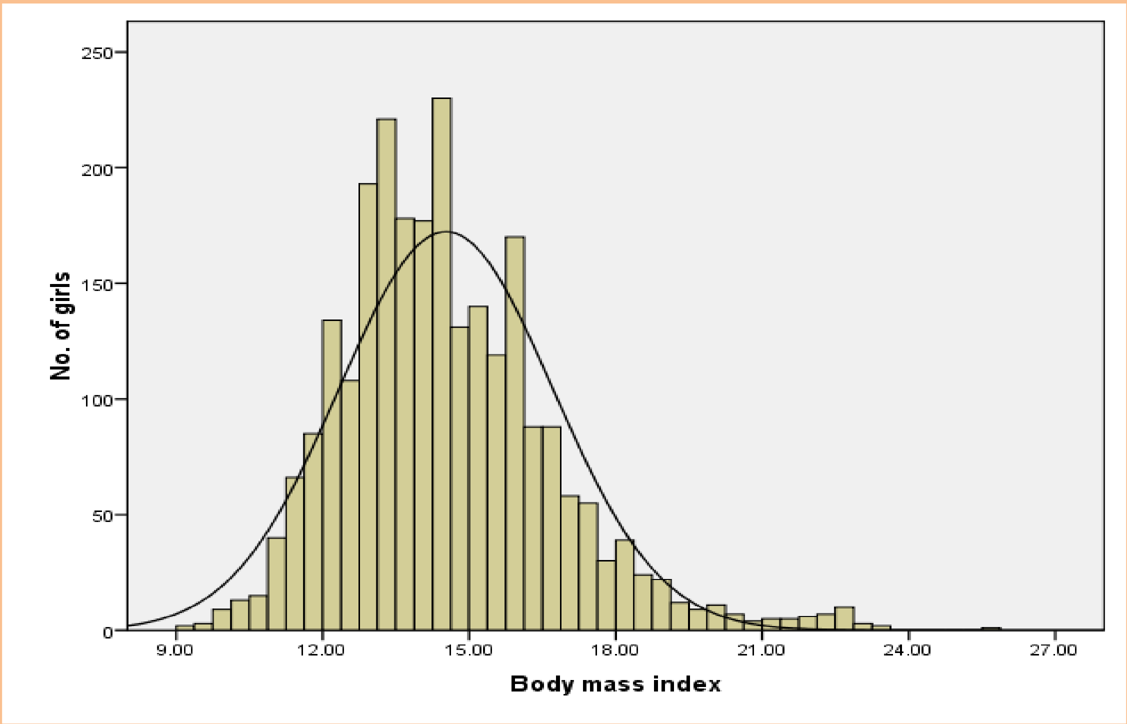


Figure64 : Histogram with normal curve shows the BMI-for-age of 6-12 years children are distributed positively skewed (Mean =14.5 median= 14.2 skewness=0.85 kurtosis=1.46)

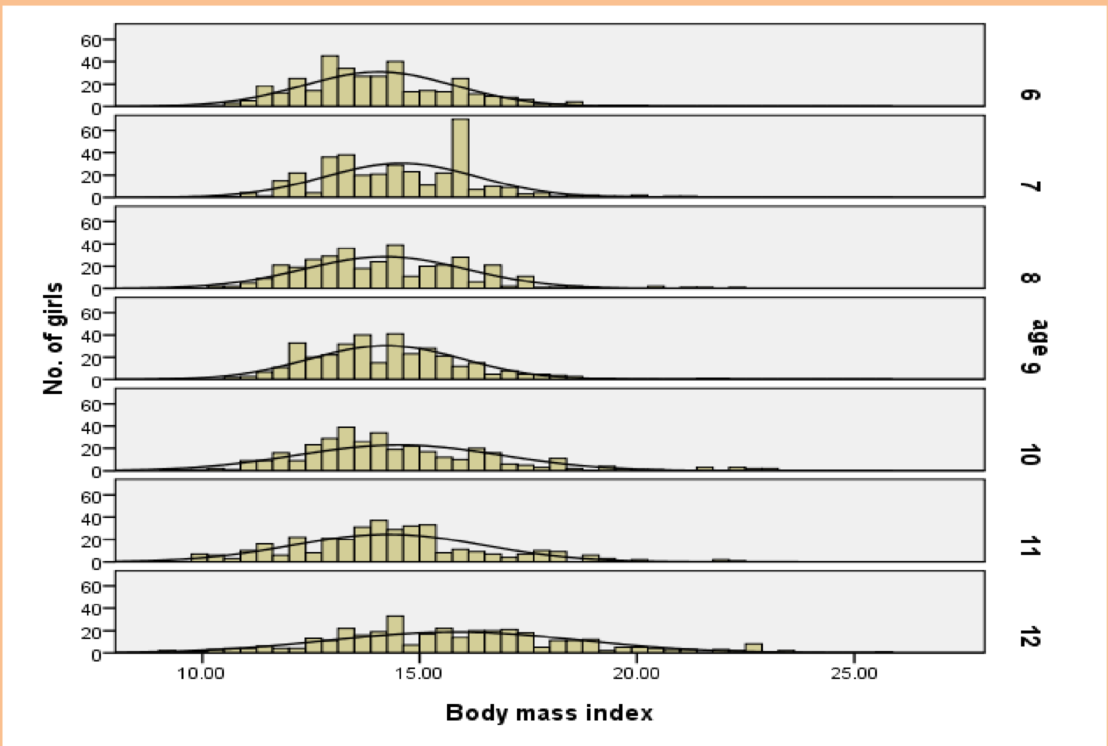
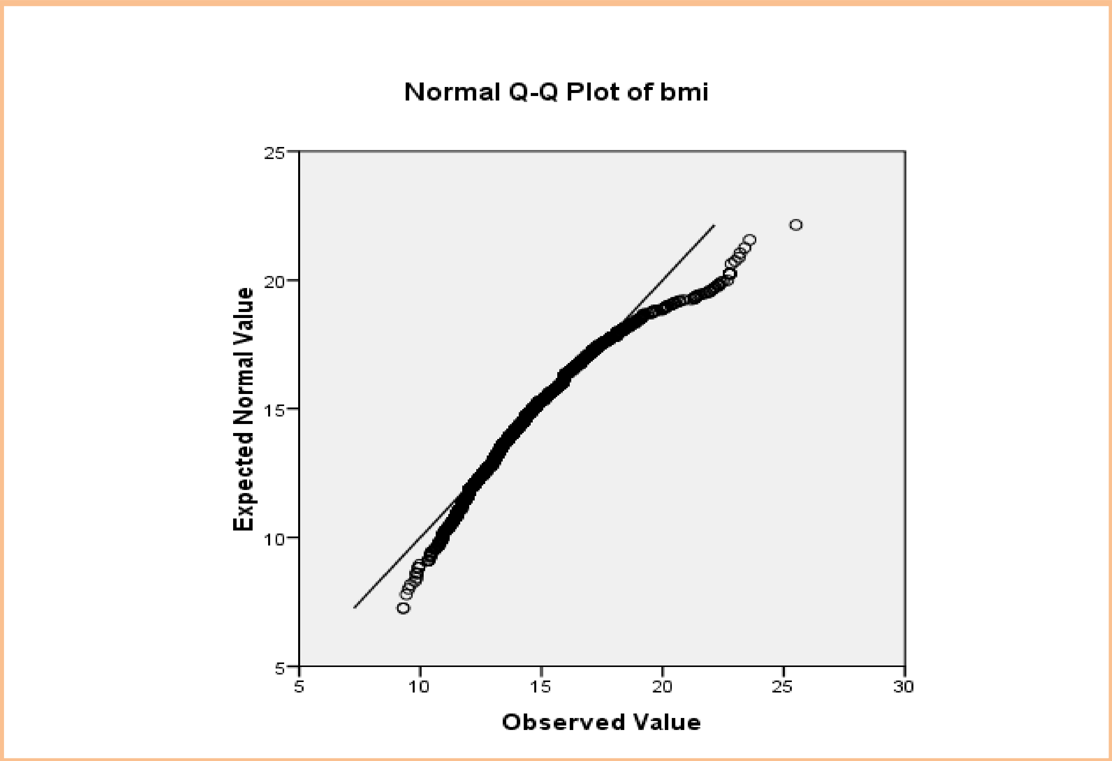


Figure 65: Histogram with normal curve assess the normality of BMI-for-age for 6-12 years girls



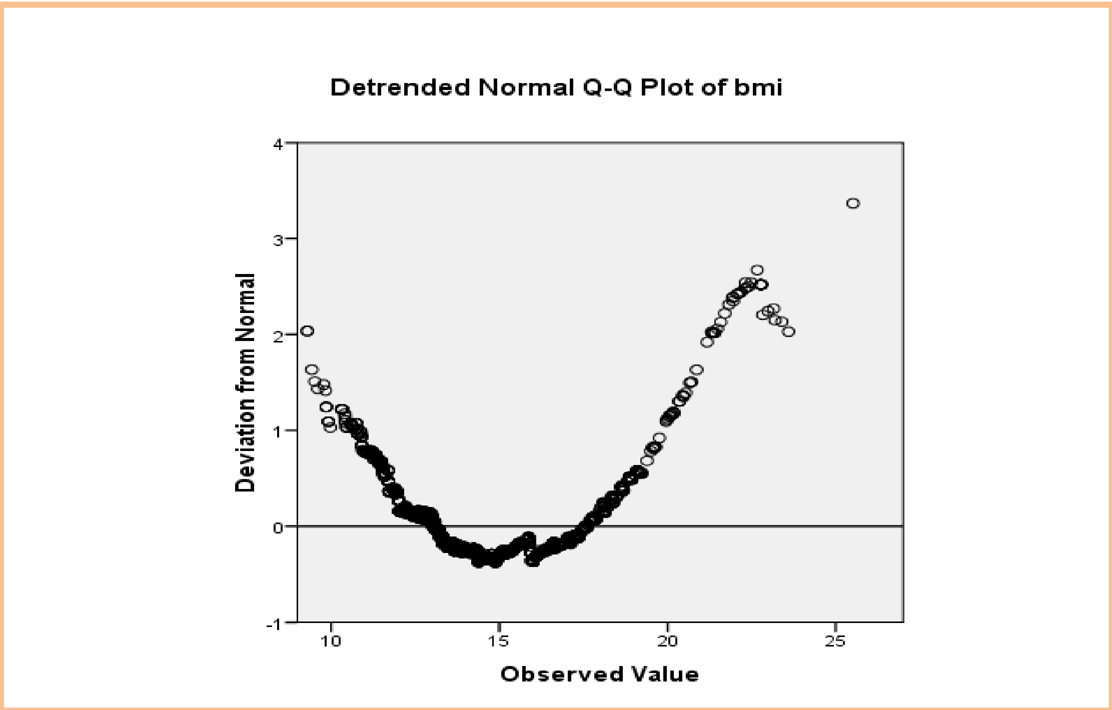


Figure66: Normal Q-Q plot and detrended normal Q-Q plot assess the normality of BMI among 6-12 years girls

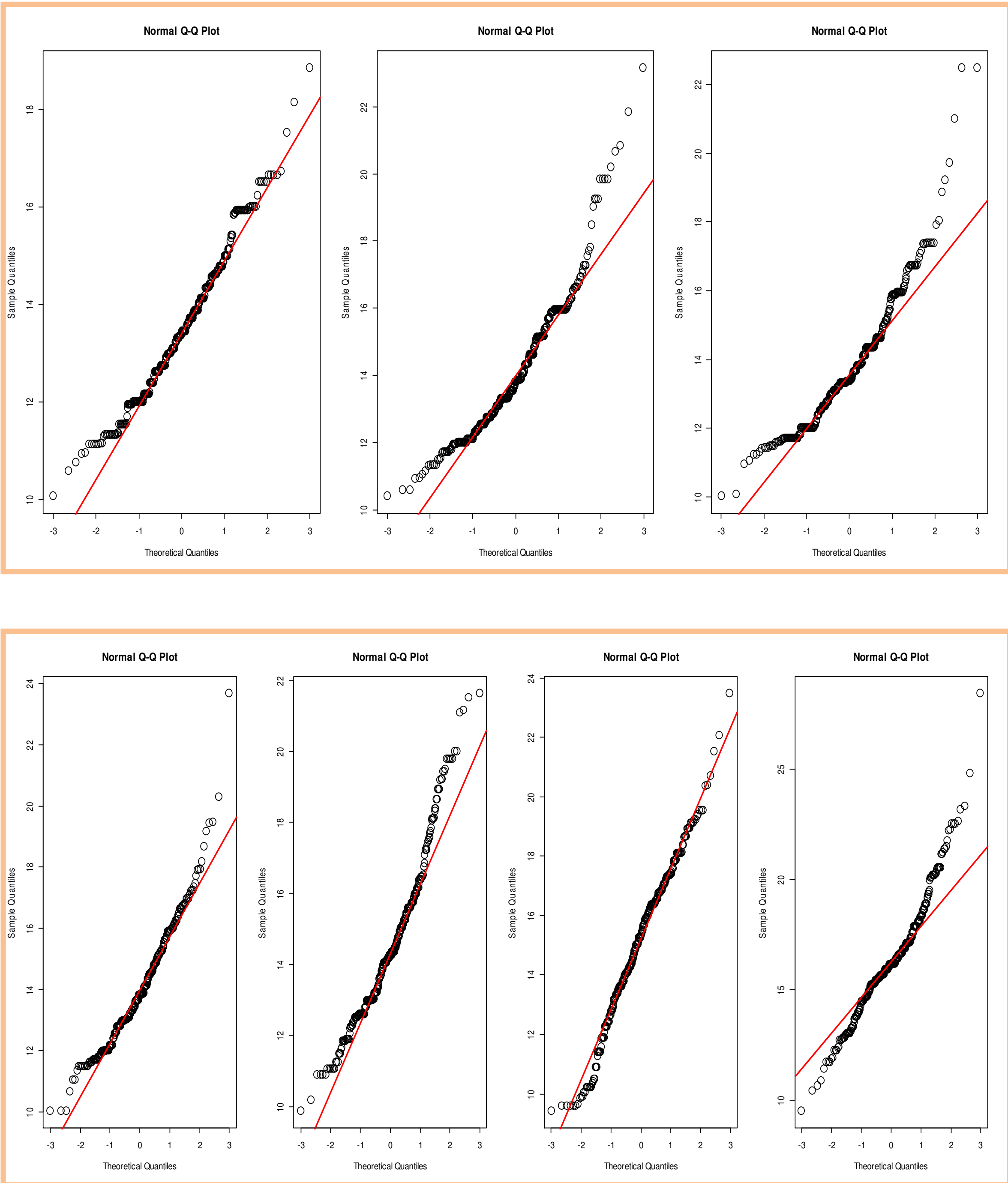


Figure67: Normal Q-Q plot assess the each agewise normality of BMI-for-age among 6-12 years girls

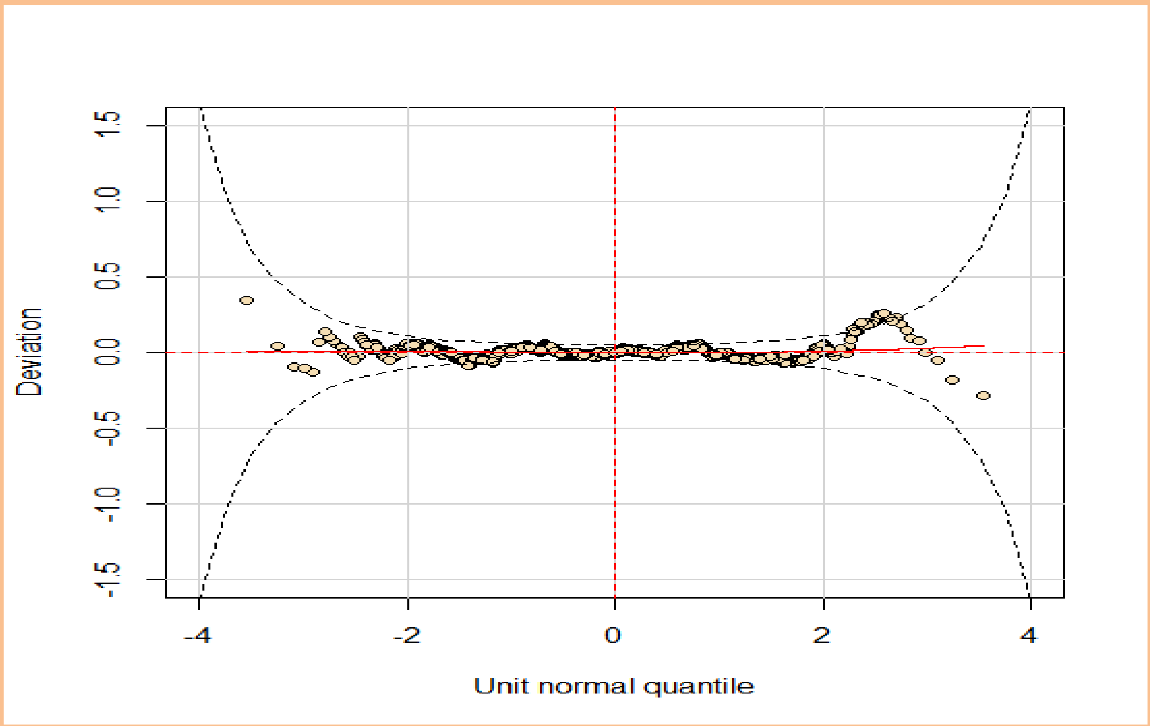


Figure68: Worm plot assess the normality of fitted body mass index data for 6-12 years girls

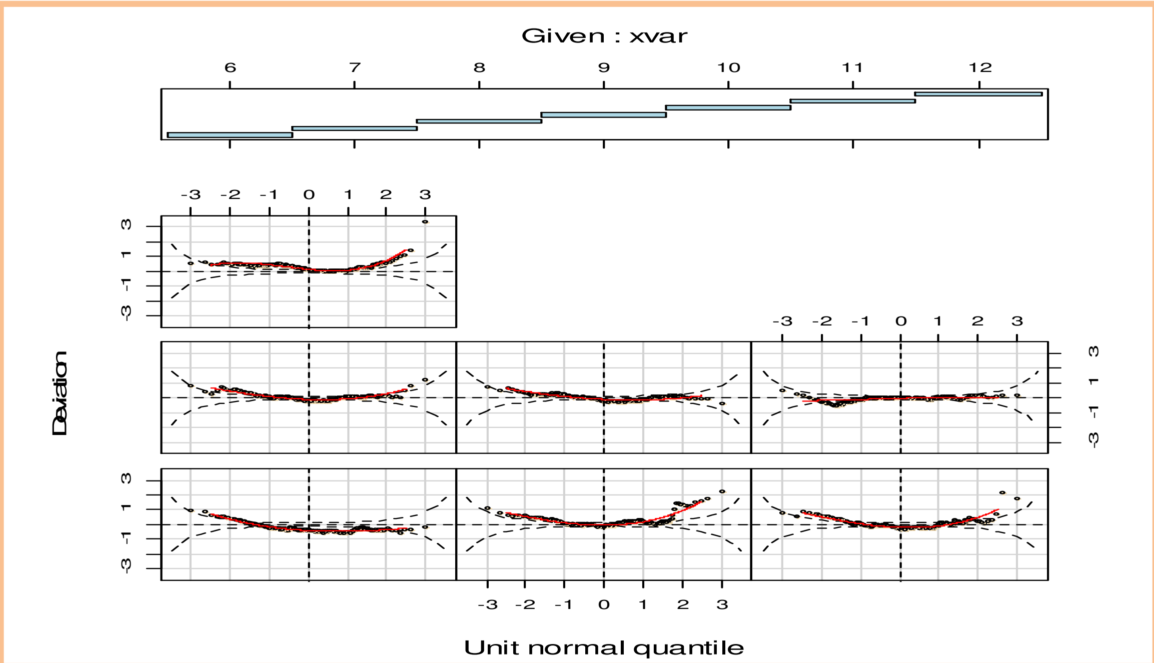


Figure 69: Worm plots of Z scores model of df(μ)=4 df(σ)=4, ν=1, τ=2 with age transformation $x=age^{0.90}$ for 6-12 years body mass index of girls

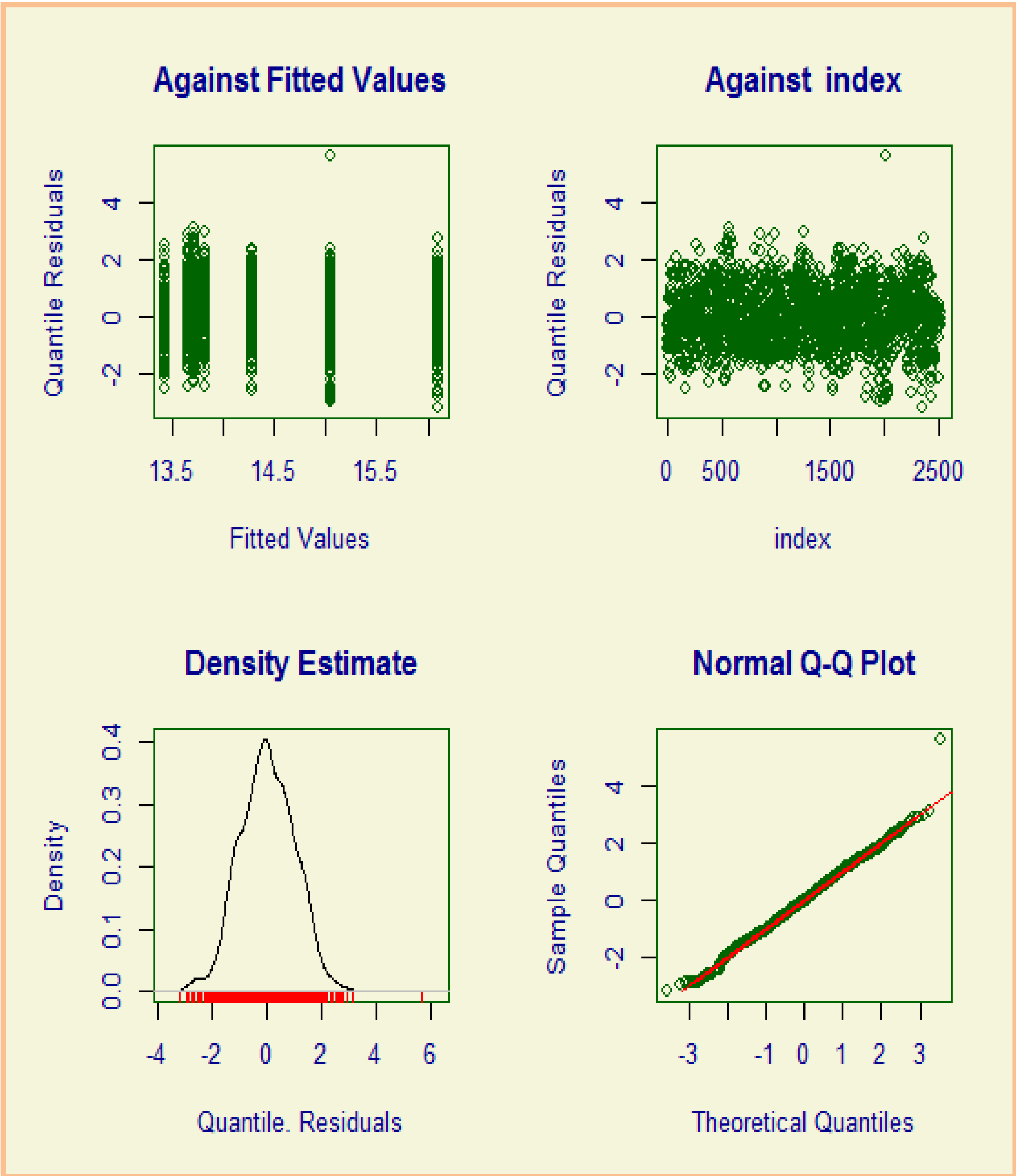


Figure 70 :Normalized residue charts of fitted model BCPE(x=age $^{0.90}$ df(μ)=4 df(σ)=4, ν=1, τ=2) for 6-12 years Body Mass Index of girls

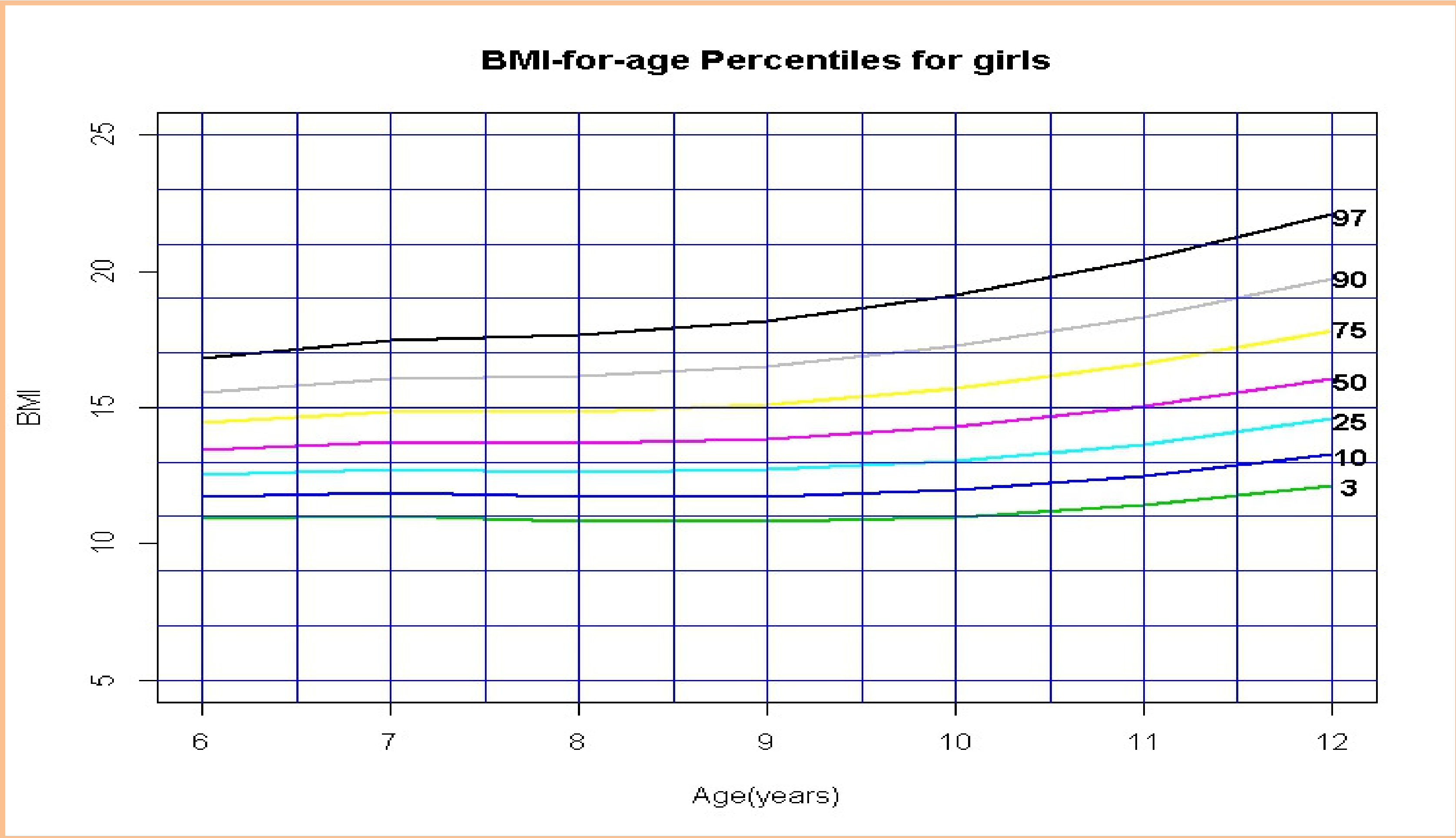


Figure71A: Body Mass Index percentiles curves for girls from 6 to 12 years. Centiles are: 3rd, 10th, 25th, 50th, 75th, 90th and 97th

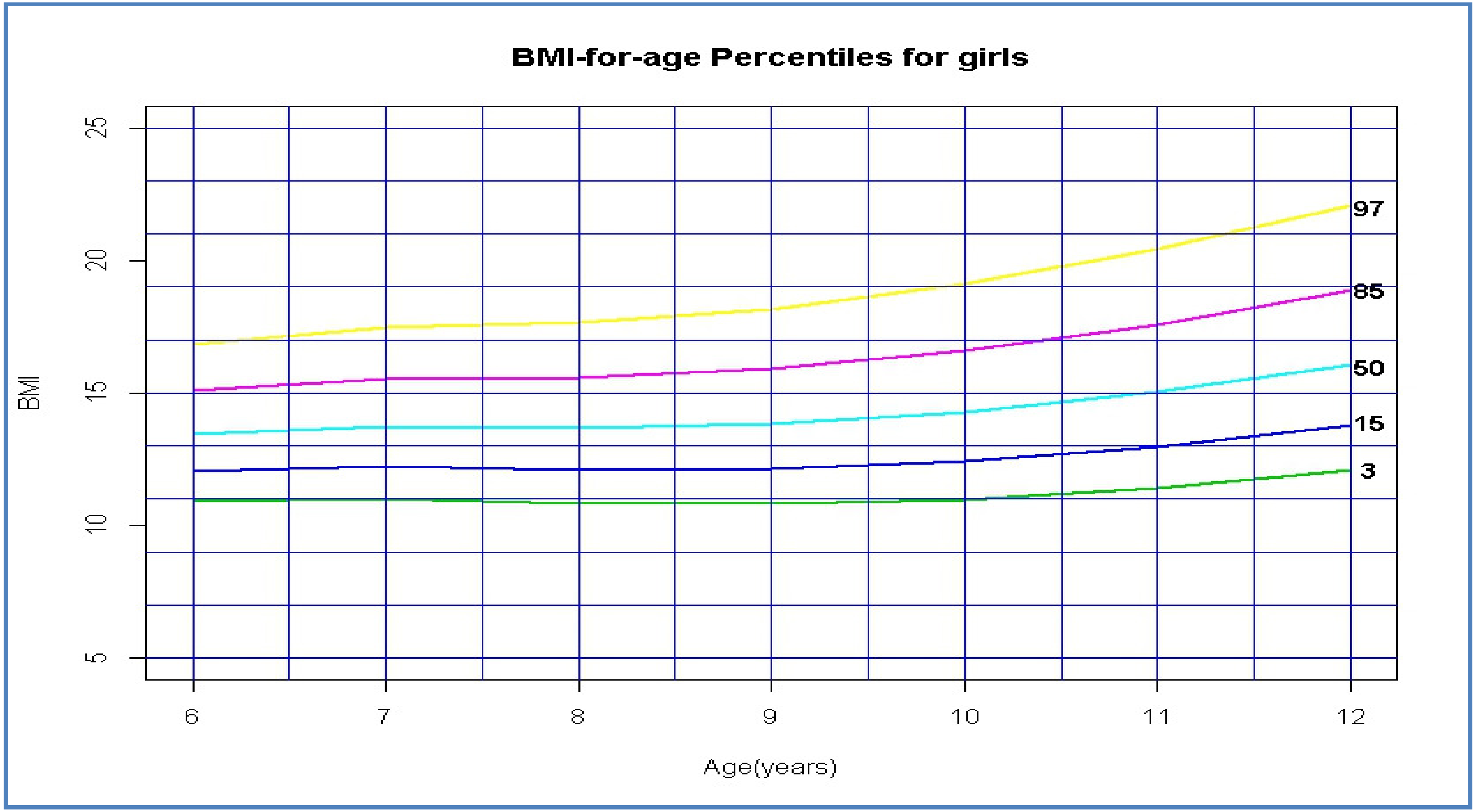


Figure71B: WHO standard Body Mass Index percentiles curve for girls from 6 to 12 years. Centiles are: 3rd, 10th, 25th, 50th, 75th, 90th and 97th

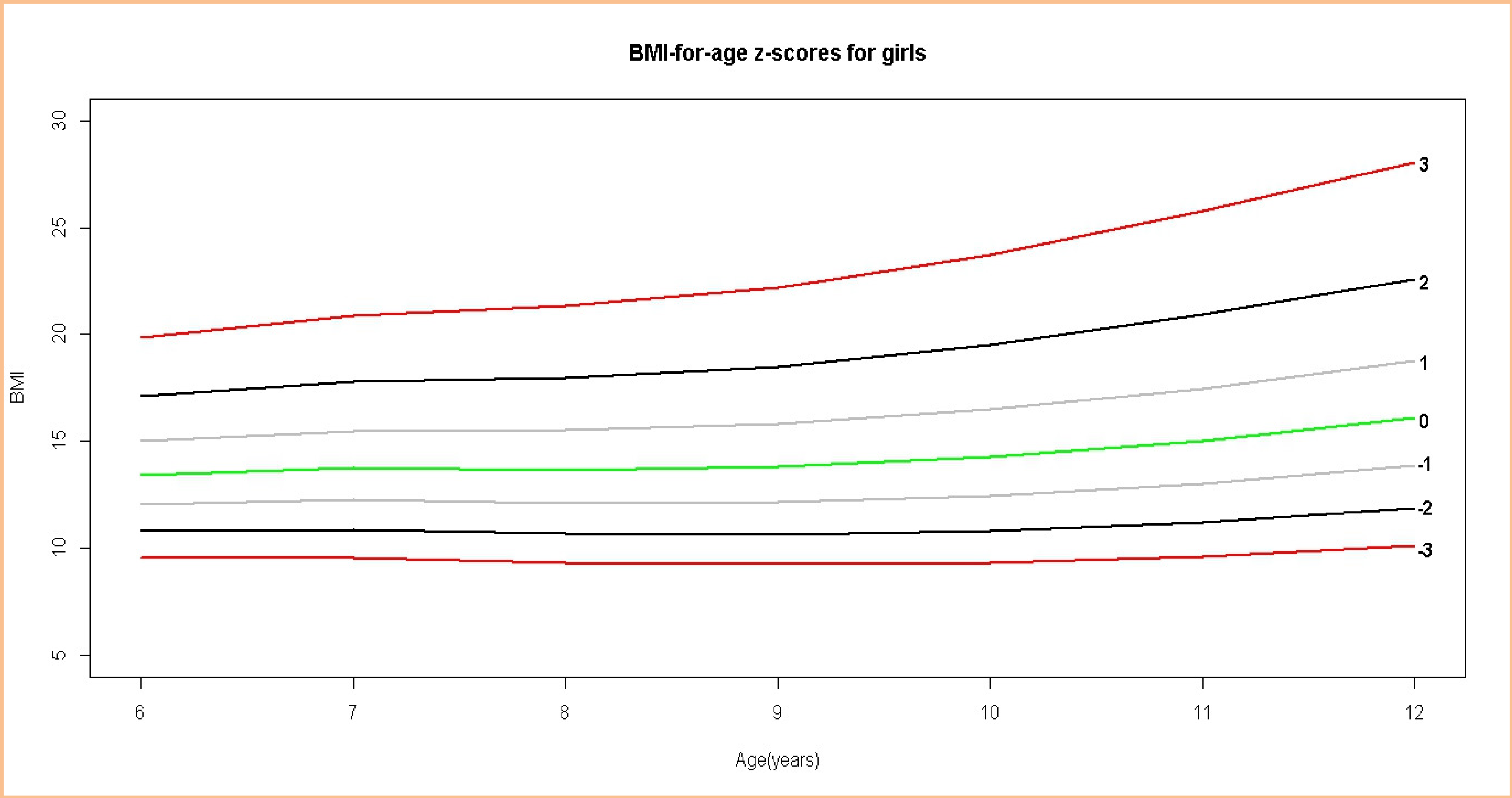


Figure72: BMI-for-age Z scores for girls from 6 to 12 years

4.9 Comparison of NCHS/WHO/CDC charts with present study .

4.9.1 Comparison of Median weight-for-age with NCHS/WHO2007/CDC2000 values

Table 69: Comparison of Median weight-for-age among boys and girls

		6 years	7 years	8 years	9 years	10 years	11 years	12 years
Boys	WHO	20.5	22.5	25.4	28.1	31.2		
	CDC	20.7	23.1	25.6	28.5	31.9	35.9	40.4
	Agarwal et al	19.0	21.0	22.6	24.4	27.0	30.6	34.8
	Present study	17.1	18.8	20.2	21.9	24.2	27.5	30.9
Girls	WHO	20.2	22.4	25.0	28.2	31.9		
	CDC	20.2	22.8	25.6	29.0	32.9	37.2	38.6
	Agarwal et al	17.5	19.0	20.8	23.5	26.9	30.9	35.0
	Present study	16.1	18	19.3	21.4	24.6	28.3	32.5

Table69 compares the median weight for age percentile with WHO, CDC and Indian study with present study for boys and girls. Weight for age percentile values of present study children are lower than those of the WHO/CDC 50th percentile values at all ages. Comparing with agarwal study our observations are almost similar to that of him for both boys and girls.

4.9.2 Comparison of Median height-for-age with NCHS/WHO2007/CDC2000 values

Table 70: Comparison of Median height-for-age among boys and girls

		6 years	7 years	8 years	9 years	10 years	11 years	12 years
Boys	WHO	116.0	121.7	127.3	132.6	137.8	143.1	149.1
	CDC	115.4	121.8	127.8	133.5	138.6	143.5	149.0
	Agarwal et al	114.2	119.7	123.6	128.2	133.6	139.6	145.8
	Present study	111.3	116.7	120.4	125.2	130.8	135.7	140.9
Girls	WHO	115.1	120.8	126.6	132.5	138.6	145.0	151.2
	CDC	114.7	121.5	127.6	132.9	138.0	143.9	151.2
	Agarwal et al	112.5	117.4	123.2	129.2	135.2	140.9	146.0
	Present study	110	114	119.5	124.6	131	137.1	142.9

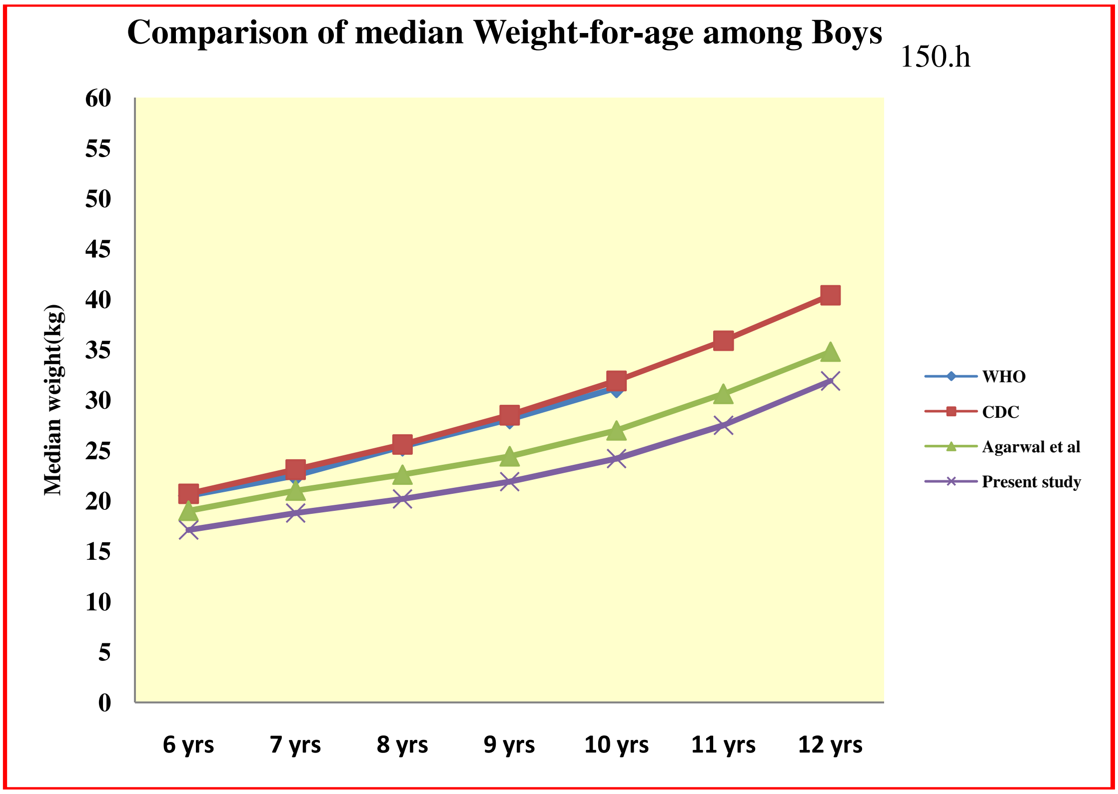
Table70 compares the median height for age percentiles with WHO, CDC, Indian study with present study for boys and girls. Height for age percentile values of present study children are lower than those of the WHO/CDC 50th percentile values at all ages. Comparing with agarwal study it is near for both boys and girls children.

4.9.3 Comparison of Median BMI-for-age with NCHS/WHO2007/CDC2000 values

Table71: Comparison of Median BMI-for-age among boys and girls

		6 years	**7 years**	**8 years**	**9 years**	**10 years**	**11 years**	**12 years**
Boys	WHO	15.3	15.5	15.7	16	16.4	16.9	17.5
	CDC	15.4	15.5	15.8	16.1	16.6	17.2	17.7
	Agarwal et al	14.7	14.8	14.8	15.1	15.4	15.8	16.4
	Present study	13.9	14.1	14.3	14.5	14.7	14.9	15.4
Girls	WHO	15.3	15.4	15.7	16.1	16.6	17.2	18.0
	CDC	15.2	15.4	15.8	16.3	16.8	17.4	18.1
	Agarwal et al	14.3	14.6	14.9	15.1	16.1	16.9	17.8
	Present study	13.5	13.8	14.0	14.3	14.8	15.4	16.9

Table 71 compares the median Body Mass Index percentile with WHO, Indian study with present study for boys and girls. Body Mass Index percentile values of present study children are lower than those of the WHO/CDC growth charts at all ages. Comparing with agarwal study it is near for both boys and girls.



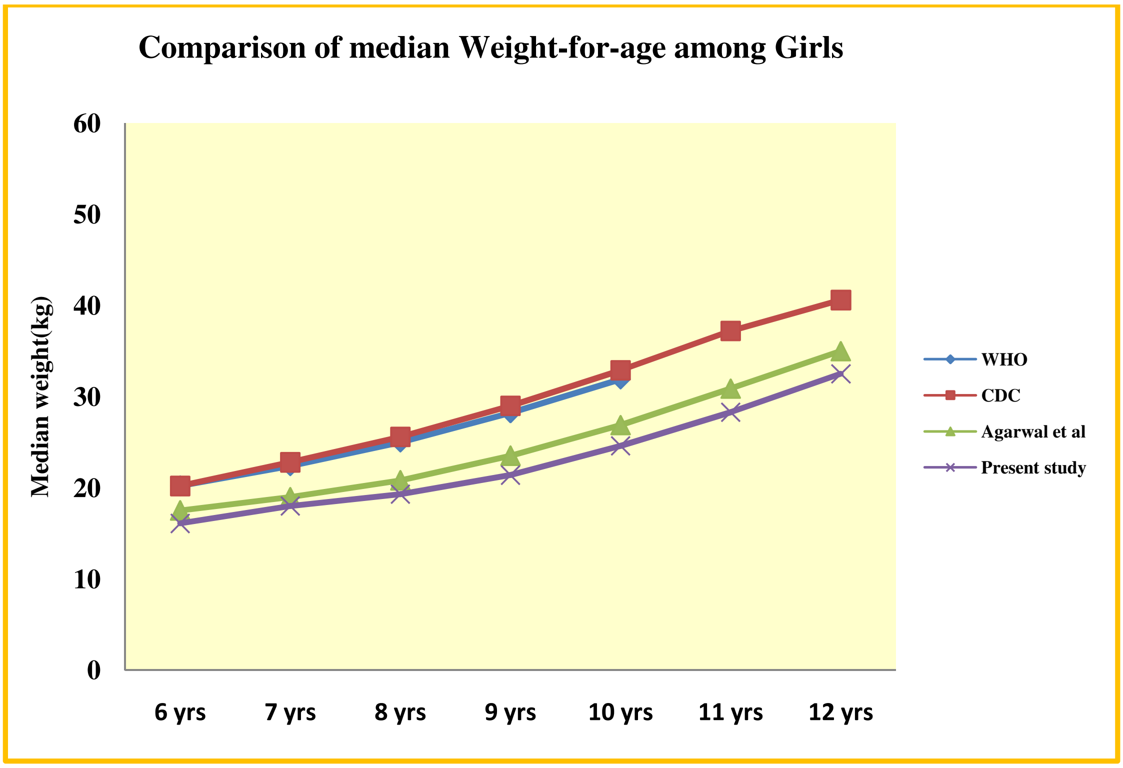
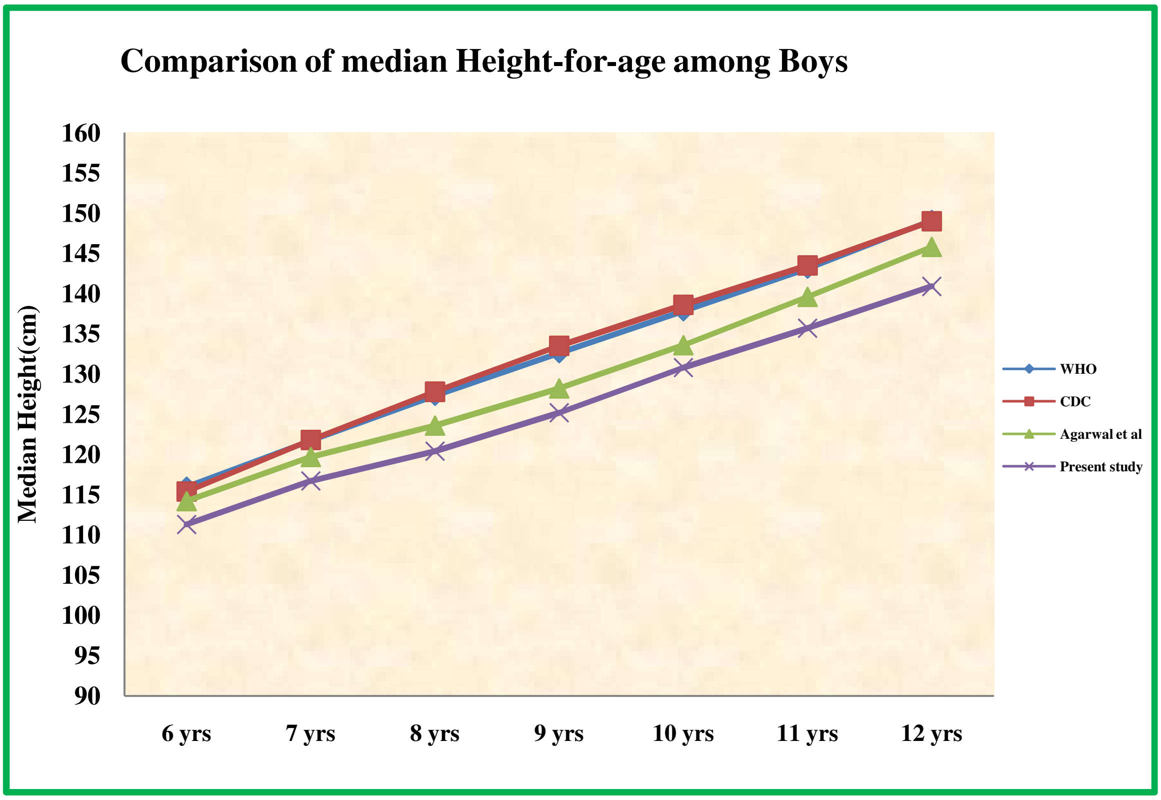


Figure 73: Comparison of median weight for age percentile values with WHO, CDC, Indian study with present study



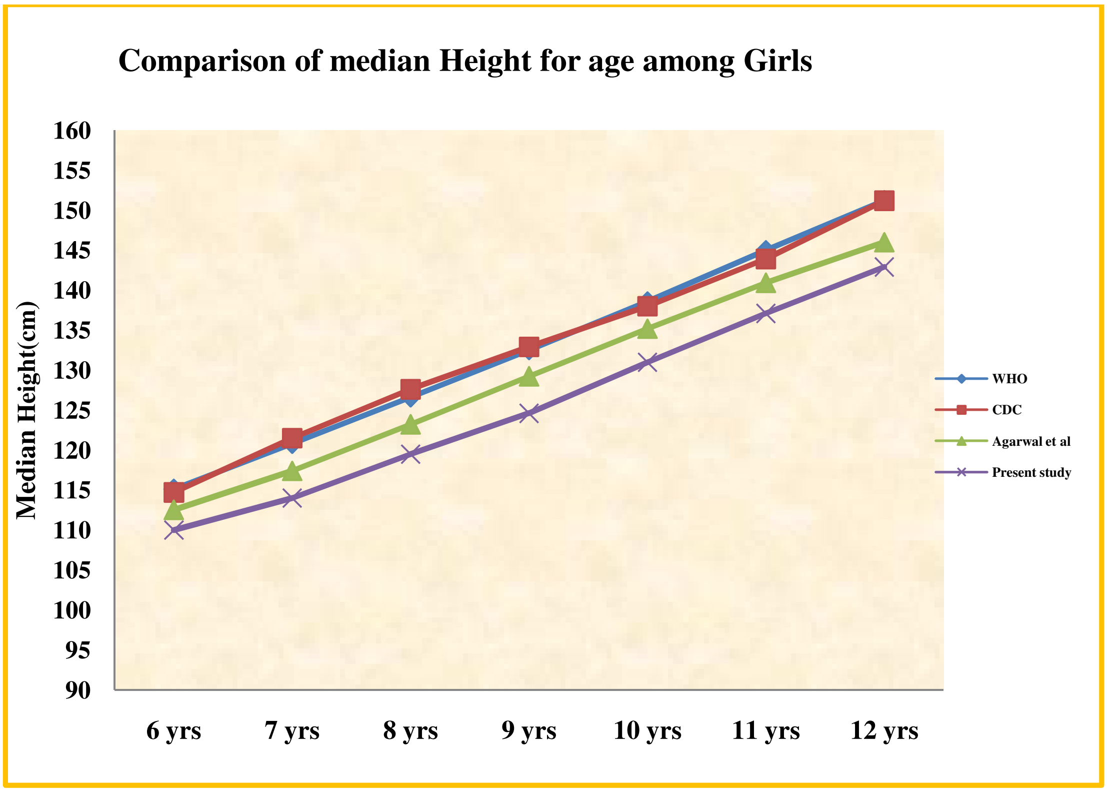
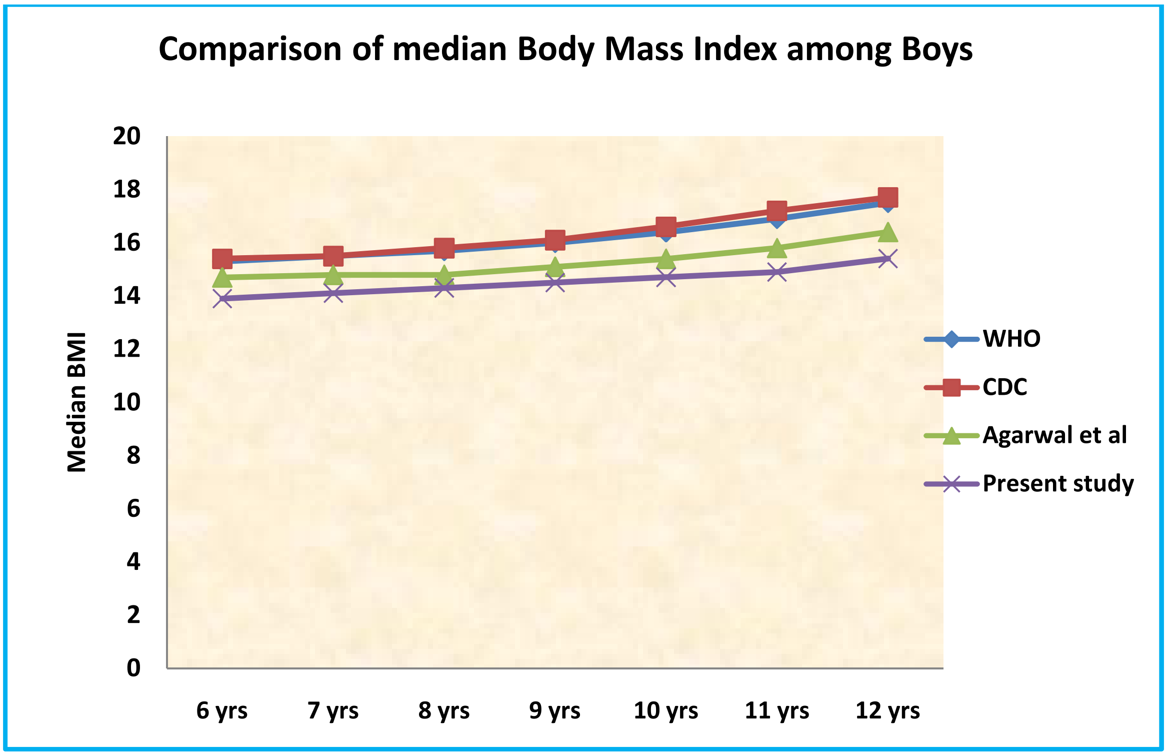


Figure 74: Comparison of median height for age percentile with WHO, CDC, Indian study with present study



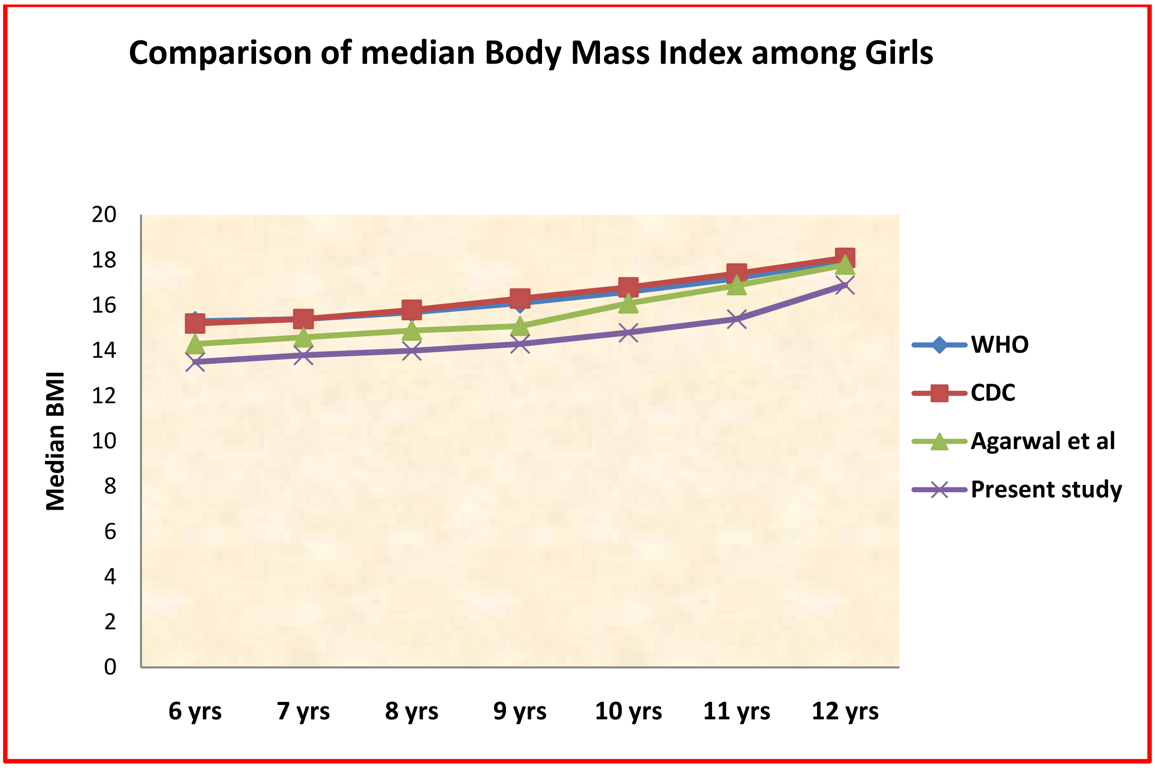


Figure 75: Comparison of median Body Mass Index percentiles with WHO, CDC, Indian study with present study

4.10 Prevalence of underweight, overweight, obesity

4.10.1 Prevalence of underweight (weight-for-age)

Table 72: Prevalence of underweight (weight-for-age :WAZ score)

	Total undernutrition (%, 95% CI)	**Moderate undernutrition (%, 95% CI)**	**Severe undernutrition (%, 95% CI)**
	(<-2 z-score)	**(<-2 z-score &> =-3 z-score)**	**(<-3 z-score)**
boys(2520)	(856) 34.0% (32.1-35.8 .)	(816) 32.4% (30.6-34.2)	(40)1.6% (1.1- 2.1)
Girls(2520)	(743) 29.5% (27.7-31.3)	(728) 28.9% (27.1-30.7)	(15) 0.6% (0.3- 0.9)
Overall(5040)	(1599) 31.7% (30.4-33.0.)	(1544) 30.6% (29.4-31.9)	(55) 1.1% (0.8- 1.4)

The prevalence of underweight of the studied children is presented in Table 72. Overall prevalence of underweight is 31.7%, it is 34% among boys and it is 29.5% among girls based on NCHS reference distributions of *Z*-scores for weight-for-age. Overall prevalence of moderate underweight is 30.6%, it is 32.4% among boys and it is 28.5% among girls. Similarly overall prevalence of severe underweight is 1.1%, it is 0.6% among boys and it is 1.6% among girls .The boys had a risk of 1.23 (95%CI: 1.09-1.39) times greater to be underweight than the girls. Percentage of overall underweight (boys *vs.* girls: 34.0% *vs.* 29.5%) were higher in boys. Overall mean ± SD of WAZ score is -1.45±0.90. The distributions of *Z*-scores for weight-for-age were shown in figure 76.

4.10.2 Prevalence of stunting (height-for-age)

Table 73: Prevalence of stunting (height-for-age: HAZ score)

	Total undernutrition (%, 95% CI)	**Moderate undernutrition (%, 95% CI)**	**Severe undernutrition (%, 95% CI)**
	(<-2 z-score)	**(<-2 z-score and >=-3 z-score)**	**(<-3 z-score)**
Boys(2520)	(506) 20.1% (18.5-21.6)	(373) 14.8% (13.4-16.2)	(133)5.3% (4.4- 6.2)
Girls(2520)	(486) 19.3% (17.7-20.8)	(373) 16.9% (15.4-18.4)	(60) 2.4% (1.8- 4.0)
Overall(5040)	(992) 19.7% (18.6-20.8.)	(799) 15.9% (14.8-16.9)	(193) 3.8% (3.3- 4.4)

The prevalence of underweight of the studied children is presented in Table 70. Overall prevalence of stunting is 19.7%, it is 20.1% among boys and it is 19.3% among girls based on NCHS reference distributions of *Z*-scores for height-for-age. Overall prevalence of moderate stunting is 15.9%, it is 14.8% among boys and it is 16.9% among girls. Similarly overall prevalence of severe stunting is 3.8%, it is 5.3% among boys and it is 2.4% among girls. The boys had a risk of 1.05 (95%CI: 0.92- 1.20) times greater to be stunting than the girls. Percentage of overall stunting (boys *vs.* girls: 20.1% *vs.* 19.3%) were higher in boys. Overall mean ± SD of WAZ score is -1.19±1.01. The distributions of *Z*-scores for weight-for-age were shown in figure 74.

4.10.3 Comparison of wasting (weight-for-height)

Table 74: Prevalence of wasting (weight-for-height: WHZ score)

	Total undernutrition (%, 95% CI)	**Moderate undernutrition (%, 95% CI)**	**Severe undernutrition (%, 95% CI)**
	(<-2 z-score)	**(<-2 z-score and >=-3 z-score)**	**(<-3 z-score)**
Boys(1800)	(436) 24.2% (22.3-26.3)	(320) 17.8% (16.1-19.6)	(116)6.5% (5.4- 7.7)
Girls(1800)	(423) 23.7% (21.8-25.7)	(371) 20.8% (19.0-22.7)	(52) 2.9% (2.2- 3.8)
Overall(3600)	(859) 24.0% (22.6-25.4)	(691) 19.3% (18.0-20.6)	(168) 4.7% (4.0- 5.4)

The prevalence of wasting of the studied children is presented in Table 71. Overall prevalence of wasting is 24.0%, it is 24.2% among boys and it is 23.7% among girls based on NCHS reference distributions of *Z*-scores for wasting. Overall prevalence of moderate wasting is 19.3%, it is 17.8% among boys and it is 20.8% among girls. Similarly overall prevalence of severe wasting is 4.7%, it is 6.5% among boys and it is 2.9% among girls .The boys had a risk of 1.03 (95%CI: 0.88- 1.20) times greater to be wasting than the girls. Percentage of overall wasting (girls *vs.* girls: 24.2% *vs.* 23.7%) were higher in boys. Overall mean ± SD of WAZ score is -1.06±1.26. The distributions of *Z*-scores for weight-for-height were shown in figure 75.

4.10.4 Prevalence of overweight and obesity

Table 75: Prevalence of Overweight/obesity (Body Mass Index: BMI score)

	Boys(2520)	**Girls(2520)**	**Overall(5040)**
Under weight (n, %, 95% CI)	(570) **22.6%** (21.0-24.3)	(460) **18.3%** (16.8-19.8)	(1030) **20.4%** (19.3- 21.7)
Normal (n, %, 95% CI)	(1577) **62.6%** (60.6-64.4)	(1746) **69.3%** (67.4-71.1)	(3323) **65.9%** (64.6- 67.2)
Over weight (n, %, 95% CI)	(282) **11.2%**(10.0-12.5)	(254) **10.0%** (8.9-11.3)	(536) **10.6%** (9.8- 11.5)
Obese (n, %, 95% CI)	(91) **3.6%**(2.9-4.4)	(60) **2.4%**(1.8-3.1)	(151) **3.0%** (2.6- 3.5)

The prevalence of overweight, obesity of the studied children is presented in Table 75. Overall prevalence of overweight is 10.6%, and obese is 3%. Boys are having more overweight and obese than girls based on CDC2000 reference distributions of *Z*-scores for BMI. The boys had a risk of 1.22 (95%CI: 1.04- 1.43) times greater to be overweight/obesity than the girls. Percentage of overall overweight/obese (boys *vs.* girls: 14.8% *vs.* 12.4%) were higher in boys. The distributions of *Z*-scores for BMI were shown in figure 79.

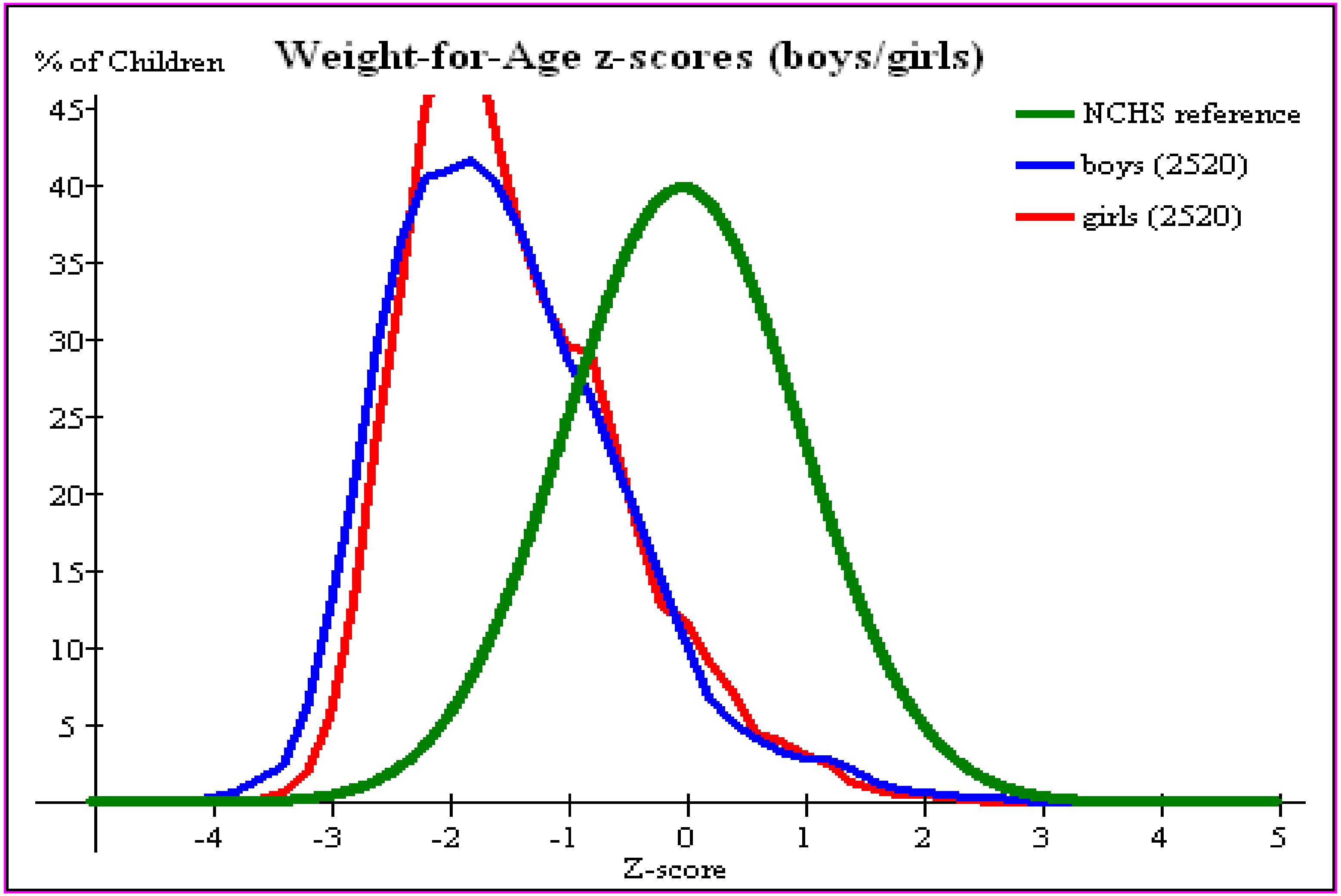


Figure 76: Distribution of weight-for-age *Z*-score for 6-12 years children

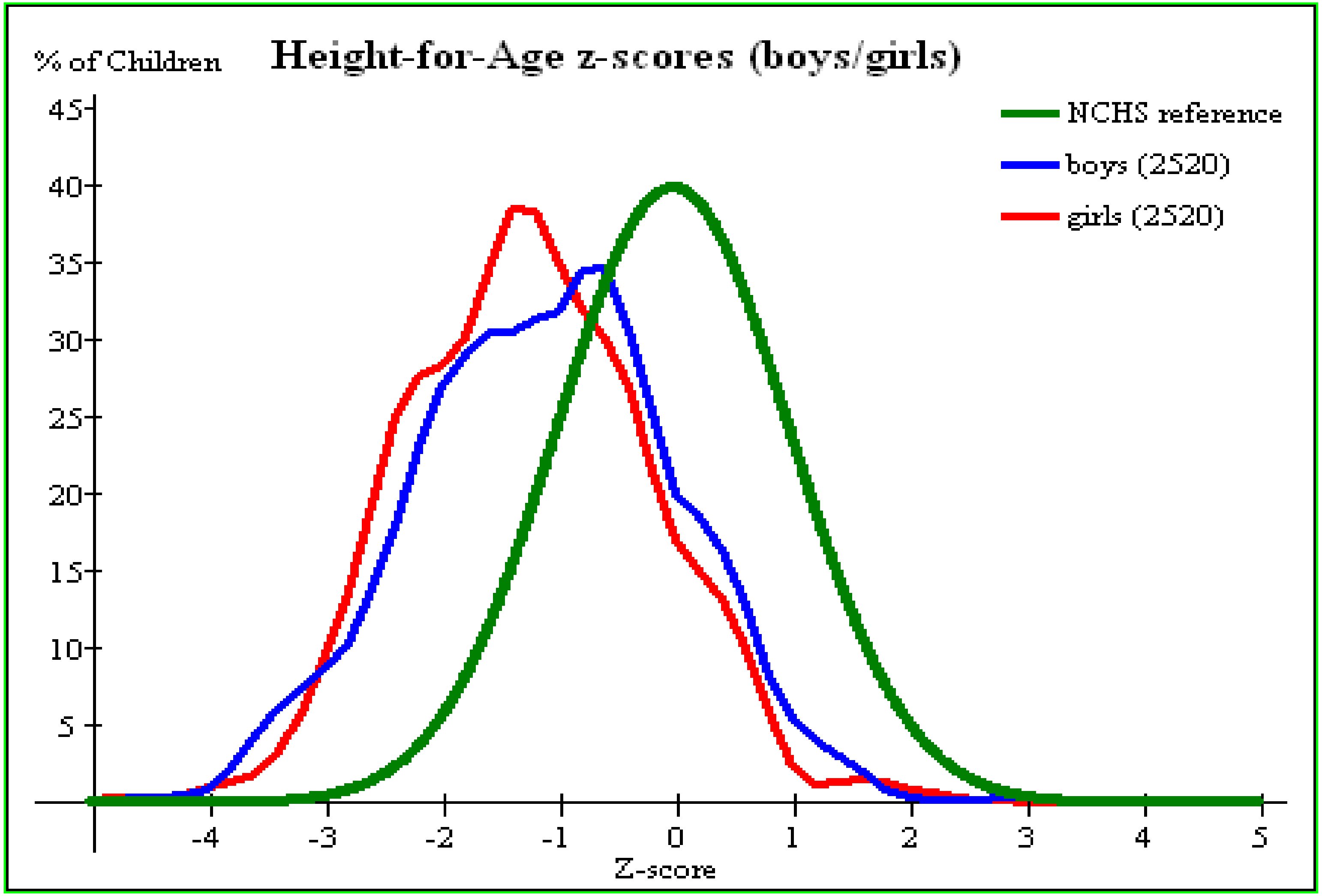


Figure 77: Distribution of height-for-age *Z*-score for 6-12 years children

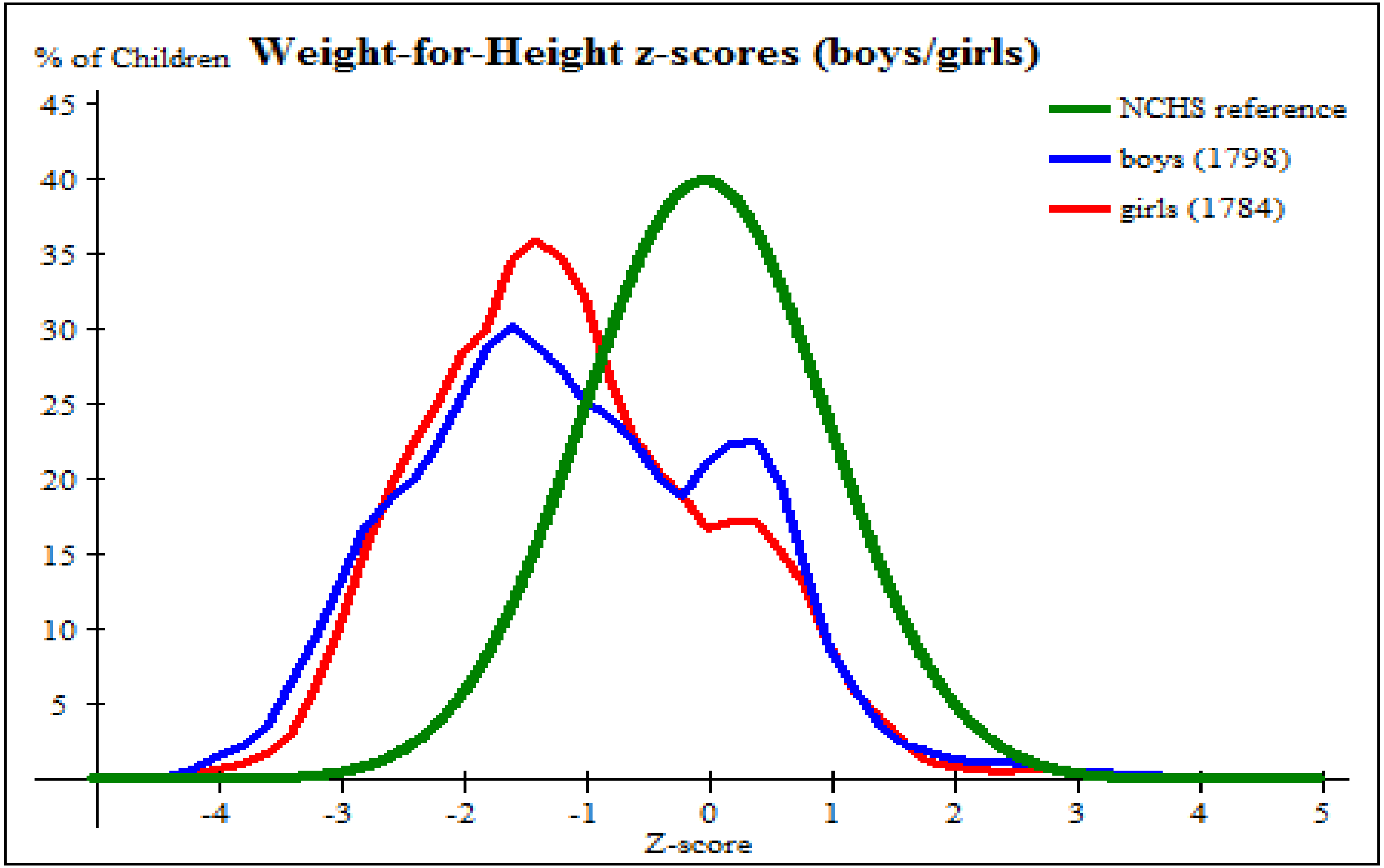


Figure 78: Distribution of weight-for-height *Z*-score for 6-10 years children

CHAPTER V

DISCUSSION

"Fitting smooth centile curves has always been something of a subjective exercise, or even a black art" [63]. For developing percentile charts, the population based cross-sectional multi-site (various schools) study design was used in this study, it is the strongest study design to select representative sample of the population. In addition, the protocol of collection of data from urban-rural and public-private school helped to cover the socio economic status of the population. Also age wise and gender wise equal sample size representation adopted in this method helps to get good representative sample for construction of reference centile charts.

Growth charts based on cross-sectional data have several advantages: 1) they provide information on the secular trends; 2) data collection can be carried out in a relatively short period; 3) the sample can be relatively large and representative for demographic variables; 4) less cost, time and man power needed; 5) there is no dropout rates and 6) age-related phenomenon in different decades can be studied.

A total of 24 schools, comprising of 12 Government, 12 private schools in three districts from Tamil Nadu state were selected through cluster sampling method for the collection of data. From these schools, a total of 5040 children (in the age group of 6-12 years) which included 2520 children from private schools, 2520 children from Government schools were screened for normal, overweight, obesity and underweight by measuring their height and weight and calculating the Body Mass Index. All precautions were taken to ensure accuracy of data collection in all steps of the study from its planning, piloting, execution, analysis and presentation stages. World Health Organization standards were followed to collect and check the quality of obtained data[4].

The main purpose of this study was to develop reference percentile charts for weight-for-age, height-for-age, weight-for-height and Body Mass Index of children between 6-12 years using Lamda-mu-sigma(LMS) method. To achieve the purpose, Generalized LMS method called lamda-mu-sigma-additional parameter (LMSP) method was adopted for making reference centile charts in this study. Smoothened centiles were obtained based on a 4-parameter probability model, the Box Cox Power Exponential or BCPE distribution, whose parameters can be used to calculate centiles or z-scores for any age.

Before the BCPE model applied, The x-axis needs a power transform to spread out the time axis and better capture periods of rapid growth. The optimal power λ is determined by minimization of global deviance.

At each point on the time axis, a probability distribution is identified, characterized by the 4 BCPE parameters, namely μ (median), σ (coefficient of variation), υ (a measure of skew), and τ (a measure of kurtosis).

Then, the optimal smoothing model as specified as degrees of freedom (df) for each model parameter. For each anthropometric measure, smoothing degrees of freedom were identified through sequential minimization of the Generalized Akaike Information Criterion (GAIC), with an adjustable penalty term to balance accurate representation of sample centiles and overall smoothness. A penalty =2 reduces to the familiar Akaike

Information Criterion (AIC) and favours local fit, while a penalty=3 favours smother curves.

All fitted models were subsequently confirmed through appropriate diagnostic procedure- including worm plots, Q-statistics and residual plots. Worm plot is used for preliminary model building and the Q-test is used determine the final model.

The fitted models of data are listed below:

Weight-for-Age

BCPE [$x=age^{0.80}$, df (μ)=4, df (σ)=3, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.30}$, df (μ)=4, df (σ)=3, df(υ)=1, df(τ)=2]; for girls

Height-for-Age

BCPE [$x=age^{0.10}$, df (μ)=3, df (σ)=3, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.70}$, df (μ)=3, df (σ)=3, df(υ)=1, df(τ)=2]; for girls

Weight-for-Height

BCPE [$x=age^{0.80}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.70}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for girls

Body Mass Index

BCPE [$x=age^{0.90}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.90}$, df (μ)=4, df (σ)=4, df(υ)=1, df(τ)=2]; for girls

Where λ is the power of the transformation applied to age before fitting the model; df(μ) is the degrees of freedom for the cubic splines fitting the median (μ); df(σ) the degrees of freedom for the cubic splines fitting coefficient of variation (σ); df(ν) the degrees of freedom for the cubic splines fitting the Box-Cox transformation power (ν) (fixed $\nu = 1$); and τ is the parameter related to the kurtosis (fixed $\tau = 2$).

The Box–Cox normal distribution is a particular case of the BCPE distribution for the case the fourth parameter τ is equal to 2 (i.e. mesokurtic case). They called this generalization of the LMS method is the LMSP method.

Box-Cox Power Exponential distribution takes the idea of having a range of power transformations (rather than the classic square root, log, and inverse) available to improve the efficacy of normalizing and variance equalizing for both positively- and negatively-skewed, and for both leptokurtic-platykurtic variables. Construction of local curves helps to measure growth pattern of school going children and to determine the population at risk of malnutrition may be much more helpful than using international norms or charts obtained from other populations. Comparing our charts with those of NCHS/WHO2007/CDC2000 showed significant differences between growth patterns of our children and other populations. Estimated median 50th percentile shows Tamil Nadu children anthropometric measurements are lower than NCHS/WHO2007/CDC2000 standard children. Similar differences have been highlighted in other studies of various countries.

Similar methodology was adopted in the construction of WHO/CDC reference charts for 1-5 years children[135], modified 2007 WHO reference charts of 5-19 years children[50], Iranian study on body mass index for 25 to 60 months children[75], and Cospian study on reference chart for 15-19 years children[80]studies are adopted BCPE distribution method.

Smoothened height, weight and BMI percentile curves were obtained and comparison was made with the World Health Organization 2007 (WHO) and United

States' Centers for Disease Control and Prevention 2000 (USCDC) references. The study revealed that total prevalence of overweight was 10.6% (9.8%- 11.5%) and obesity was 3.0% (2.6%- 3.5%), which was similar to other studies conducted in India where the prevalence of overweight ranged from 8% - 18% and obesity ranged from 2%- 8% .Midha T *et al.,* meta-analysis based on 9 studies (92862 children) shows prevalence of overweight is 12.64% and obese is 3.39 in India [(101)]. Panjikkaran ST *et al.,* study conducted at Kerala shows among 7-12 years school going children (3000 children) revealed that 6.2% were overweight and 3.6% were obese [(136)]. Chhatwal *et al.,* punjab study shows 14.2% were overweight and 11.1% were obese for 9-15 years children [(103)]. Kalpana *et al.,* coimbatore study shows, among 11470 school going 7-12 years children 7.6% were overweight and 5.6% were obese [(104)]. Kaur *et al.,* study shows, among 16595(2-18 years) children 8.7% were overweight and 2.8% were obese [(105)]. Sood *et al.,* study shows among 9-18 years children 13.1% were overweight and 4.3% were obese [(106)]. Khadilkar *et al.,* study shows overall overweight and obese is 18.2% based on 20243 children study [(93)]. Mahajan *et al.,* from pandicherry study shows prevalence of overweight and obesity was 4.98% and 2.24% respectively among 6-12 years children [(107)]. Jahnavi V *et al.,* study from Hydrabad shows prevalence of overweight and obesity was 6.6% and 2.8% among 11-16 years children [(108)]. Uma iyer *et al., study shows form Baroda* shows prevalence of overweight and obesity was 11.7% and 9.9% among 6-12 years children [(137)]. Anju *et al., study shows form karnataka* shows prevalence of overweight and obesity was 13.1% and 5.0% among 5-16 years children [(138)]. Muhammad Ramzan *et al.,* study from Pakistan shows prevalence of overweight was 8.83 and obesity was 5.61 among 6-11 years children [(139)].

Children's anthropometric data were compared with those in new standard of WHO for school-aged children. Underweight, stunting and wasting were defined as weight-for-age, height-for-age and weight-for-height with age and sex specific Z-score below -2SD. Malnutrition was defined Z-score less than -2 SD for three anthropometric indices. Present study shows prevalence of underweight is 31.7% (30.4% - 33.0%) , stunting is 19.7% (18.6% - 20.8%) and wasting is 24% (22.6% - 25.4%) among 6-12 years children. Some of the Indian and abroad studies are having similar results to the present study. Bose *et al.,* study shows 16.9% are underweight, 17.2% are stunting and 23.1% are wasting [(140)].Sutanu Dutta et al., West bengal study *shows* 33.7% are underweight, 17.9% are stunting and 29.4% are wasting [(141)]. Patil SN et al., Maharastra study *shows* 19.0% are underweight, 30.3% are stunting and 16.8% are wasting [(142)]. Umesh kapil et al., Delhi study *shows among 6-9 year children* 52.5% are underweight, 45.1% are stunting and 11.1% are wasting [(143)]**.** Khor Geok Lin *et al.,* Malaysia study *shows under 18 years children* 27.7% are underweight, 29.1% are stunting and 8.9% are wasting [(144)]. Zalilah Mohd Shariff *et al.,* Kuala Lumpur study *shows among 6-12 years children* 14.5% are underweight, 16.7% are stunting and 9.2% are wasting [(145)]**.** Anwar *et al.,* Pakistan study *shows among 6-12 years children* 45.3% are underweight, 36.1% are stunting and 25.2% are wasting[(146)]**.** Delvarianzadeh et al Iran study shows among 6-18 years children underweight, stunting and wasting was 14.7%, 15.3% and 11.6% [(147)]**.**

In this present study, the height and weight for males and females at the start of school-going ages were almost similar. However, the differences between them became considerably bigger as they grew older. Generally males tend to be taller and heavier than females except 11-12 years. The mean height and weight of girls are lower than girls until 10 years of age, but then become similar or higher than those of girls. This increase in height and weight may be considered as an early sign of the onset of puberty in girls.

The comparison between the reference charts from this study and the NCHS/WHO2007/CDC 2000 reference charts indicated that the growth patterns of Tamilnadu school children have improved, although their heights and weights, on average, were still lower than those of school children from the United States.

6-12 years children had relatively low mean z-scores for weight and height at each age as compared with the WHO2007/CDC2000 standard while pace of growth in height is almost same as WHO2007/CDC2000 standard at each age. Therefore children were considerably more likely to be classified as underweight/stunted/wasted by WHO2007/CDC2000 standard

With regards to a future growth monitoring study in the same region, the data obtained in this study may serve as a starting point for observations/comments. Among the various methods introduced in previous decades, the LMS method is raised as the most frequently accepted and utilized refined curve-fitting method to obtain growth references representing parallel curves for any anthropometric parameter in children and adolescents. The comparison of our data showed that there were relatively considerable differences in height and weight WHO references. Additional well-designed and longitudinal studies like the present study must be conducted in all regions of Tamil Nadu. Since there is a secular trend in upward increase both in height and weight, a comparison of growth curves requires both methodological and secular similarity to determine similarity or difference. Local references would then provide a useful tool for health planning and screening inter-population differences.

The limitations of this study is, the data used in this study are cross-sectional and obviously of less validity compared to longitudinal data. Reference values for the body composition of children are best obtained from longitudinal studies, which can evaluate natural changes in the distinct growth and development stages. Another limitation is, only 6-12 years age children alone taken for study. Smoothed reference data from growth charts are often presented as either percentiles or *z* scores (standard deviation scores). For height and weight, percentiles increase monotonically with age; this property needs to be preserved in the smoothing. To achieve this more age interval is needed like 5-19 years children. Despite all these obstacles, the charts prepared by using well-known methods and based on a data set of a representative sample of Tamil Nadu children maybe preferred over those prepared by using data of other populations. Therefore, we can use our local charts instead of international ones until our longitudinal data has been prepared.

CHAPTER-VI

SUMMARY AND CONCLUSION

This chapter deals with the summary of the study and conclusions drawn. It clarifies the limitation of the study in the construction of pediatric reference percentile charts and specifies the recommendation for the future study in this area.

Population based cross-sectional multi-site study design was used to collect the Demographic information and anthropometric measurements of school children (equal boys and girls) in the age group of 6–12 years, studying in government and private schools located in 3 districts of Tamil Nadu were studied between July 2010 to December 2012. A representative sample of 5040 school children were enrolled to achieve the

The Primary outcome

1. Construction of percentile charts using LMS method
2. Calculation of Z score using LMS method

Secondary outcome

1. Making Weight-for- age centile chart for boys and girls separately
2. Making Height-for-age centile chart for boys and girls separately
3. Making weight-for-height centile chart for boys and girls separately
4. Making Body Mass Index centile chart for boys and girls separately
5. Calculation of WAZ, WHZ and HAZ Z score for boys and girls separately
6. Comparison of American National Center for Health Statistics /Center for

Disease Control/World Health organization (NCHS/CDC2000/WHO2007) reference population with locally weighted

7. Estimation of prevalence of malnutrition , overweight and obesity among Tamil Nadu children

The construction of the Paediatric percentile curves followed a careful, methodical process. This involved a) detailed examination of existing methods, including types of distributions and smoothing techniques, in order to identify the best possible approach; b) selection of a software package flexible enough to allow comparative testing of alternative methods and the actual generation of the curves; and c) systematic application of the selected approach to the data to generate the models that best fit the data.

Anthropometric measurements of Height, Weight and Body Mass Index were represented as the mean/median and standard deviations (SD) for each age and sex separately and socio demographic variables are expressed as frequencies with their percentages. Age wise Coefficient of Variation was calculated using Mean and SD for anthropometric measurement data.

Normality of weight and height distribution was examined graphically by using Histogram, Quantile-Quantile plot, Detrended Q-Q plot and kolmogrove-smirnov normality test, skewness and kurtosis methods were used to assess the normality mathematically.

Differences in height, weight and BMI between sexes were tested by using independent t-test. For comparison of present chart median percentiles with NCHS, CDC2000 and WHO2007, Z-score indexes of Weight-for-age (WAZ), Height-for-age (HAZ), Weight-for-age (WHZ) and BMI-for-age were calculated.

Choice of distribution:

To construct smoothened percentile reference charts the LMSP method was adopted. GAMLSS parameters and Box-Cox Power Exponential (BCPE) distribution were used for model fitting to data. The Box-Cox power exponential (BCPE) with four parameters μ (for the median), σ (coefficient of variation), ν (Box-Cox transformation power) and τ (parameter related to kurtosis) was selected as the most appropriate distribution for constructing the curves. The BCPE is a flexible distribution that simplifies to the normal distribution when ν=1and τ=2. Also, when $\nu \neq$1and τ=2, the distribution is the same as the Box-Cox normal (LMS method distribution). The BCPE is defined by a power transformation (or Box-Cox transformation) having a shifted and scaled (truncated) power exponential (or Box-Tiao) distribution with parameter τ .Apart from other theoretical advantages, the BCPE presents as good as or better goodness of fit than the modulus exponential-normal distributions.

Choice of smoothing technique:

Using GAMLSS, comparisons were carried out for height-for-age, weight-for-age and weight-for height. The cubic spline smoothing technique offered more flexibility than other methods like fractional polynomials in all cases. For the length-for-age and weight-for-age standards, a power transformation applied to age prior to fitting was necessary to enhance the goodness of fit by the cubic splines technique.

Choice of smoothing technique for construction of reference curves.

In summary, the BCPE method, with curve smoothing by cubic splines, was selected as the approach for constructing the reference curves. This method is included in a broader methodology, the GAMLSS, which offers a general framework that includes a wide range of known methods for constructing growth curves. The GAMLSS allows for modelling the mean (or location) of the growth variable under consideration as well as other parameters of its distribution that determine scale and shape. Various kinds of distributions can be assumed for each growth variable of interest, from normal to highly skewed and/or kurtotic distributions. Several smoothing terms can be used in generating the curves, including cubic splines, lowess (locally weighted least squares regression), polynomials, power polynomials and fractional.

Selection of best model using GAIC value.

The process for selecting the best model to construct the curves for each growth variable involved selecting first the best model within a class of models and, second, the best model across different classes of models. The Akaike Information Criteria and the generalized version of it were used to select the best model within a considered class of models. In addition, worm plots and Q-tests were used to determine the adequate numbers of degrees of freedom for the cubic splines fitted to the parameter curves. To determine the best model maximum penalized likelihood, Akaike Information Criteria(AIC) and Generalized Akaike Criteria with penalty equal to 3 [GAIC(3)] were used. To assess the goodness of fit Worm plot and Q-test were used.

Types of curves generated:

Percentile and z-score curves were generated ranging from the 99th to the 1st percentile and from + 3 to - 3 standard deviations, respectively. Due to space constraints, only the z-score curves for the following lines: -3SD, -2SD, -1SD, Median, +1SD, +2SD, +3SD and percentile lines: 3rd, 10th , 25th ,50th ,75th , 90th and 97th were presented.

Z-scores were used to compare data against known reference values to facilitate interpretability by showing how distant from a reference point is a measured parameter. Using the Z-scores derived from the NCHS, CDC and WHO2007 standards, the nutritional status of the subjects (in terms of shortness, underweight and overweight) were determined and the prevalence of each form of malnutrition were compared.

The following statistical software's are used for the construction of percentile curves and computation of Z-scores.

1. Statistical Package for the Social Sciences (SPSS), version 16.0,
2. lmsChartMaker light program (version5.4, Medical Research Council, UK).
3. Generalized Additive Model for Location, Scale and Shape (*GAMLSS*) package in R software version 2.15.1,
4. WHO Anthro plus Version 1.0.4,
5. EPI INFO version 3.5.1 were used.

To achieve the primary outcome, centile charts are constructed by LMSP model using BCPE distribution. Based on this LMS method, weight-for-age, height-for-age, weight-for height and BMI-for-age charts are obtained for both boys and girls separately.

It can generate any required centiles, not just the conventional set of 7 (fifth, 10th, 25th, median, 75th, 90th, and 95th); and individual measurements of height and weight can be accurately and directly converted to *z* scores or centiles.

Estimated median 50th percentile values are compared with National Center for Health Statistics (NCHS), World Health Organization 2007 (WHO) and United States' Centers for Disease Control and Prevention 2000 (USCDC).

Prevalence of underweight, wasting, stunting, normal weight, overweight, obesity was obtained using z scores.

The present study shows that height and body weight increases along with the advancing of age in both boys and girls. Overall socioeconomic development in the last few decades and improvements in nutrition are likely among the factors that explain the increase in both height and body weight observed in the present research. The age groups wise comparison also shows that girls are slightly taller and heavier than boys in the age group 11–12 years, whereas boys are taller and heavier than girls in the age group 6–10 years. The probable reasons for this include the early occurrence of adolescent growth spurt among girls.

Also study results highlights the double burdens of underweight and overweight, though underweight is a more urgent problem than overweight among boys and girls.

Therefore, to reduce both forms of malnutrition, with special attention to underweight, it is essential to educate and create awareness programs at the community levels. Government and nongovernmental organizations should be involved in creating and protecting an environment that supports the healthy growth and development of children. Health education programs and effective policies are urgently required to promote healthy eating and physical activity and to ensure adequate access to health services. Further studies need to be conducted in order to understand clearly whether the coexistence of underweight and overweight among children is related to the influence of socioeconomic conditions, nutritional status, due to cultural and lifestyles, or any other yet unanticipated reasons. Health care professionals should develop and implement preventive and management programs to curb the potential economic drain that could result from obesity or underweight.

Limitations

1. This study was conducted based on cross sectional study design method

Centile charts are a useful way of allowing comparison of an individual measurement for a child against the population pattern. Centile charts allow the use of probability in assessing the likelihood of an individual child having a growth disorder. A number of types of growth charts exist, these include: cross-sectional; longitudinal and longitudinal tempo-conditional.

Cross-sectional charts involve the measurement of large numbers of children once. These charts enable global comparisons between and within countries by placing a child's measurements in relation to the normal population. After the age of 9 years they are heavily influenced by the wide variation in the timing of puberty. These charts are not efficient for tracking the growth of an individual child over time.

2. This study was limited to children of 6-12 years children alone.

Growth monitoring and promotion of optimal growth are essential components of primary health care for infants and children. Serial measurements of weight, height/length for all children, and head circumference for infants and toddlers, compared with the growth of a large sample population of children depicted on a selected growth chart help to confirm a child's healthy growth and development. It is necessary to develop reference chart from birth to 19 years children for both gender. It will cover both preschool children as well as school going children.

3. Study limited to only three districts in Tamil Nadu

It is more advantageous to collect the sample information from each districts by agewise, sexwise, urban-rural areawise, socio economic statuswise, religionwise representative data will reflect the true representation of population data.

Recommendation for health policy and education

1. **Weight-for-age** is the earliest, simplest and most important anthropometric measurement to be adopted as an indicator for nutritional status in routine clinical examination of the children. A classification of varying degrees of malnutrition is based on this indicator. This classification is also linked to ultimate health outcome mortality. Weight-for-age is important clinically and is used to assess the recent malnutrition in communities. Underweight in children reflects the level of socioeconomic development as well as that of education and health delivery system. It exposes those sections of society where under nutrition is prevalent and needs to be rectified. It requires educating the concerned society about nutrition, sanitation, environmental conditions and child care.

2. **BMI-for-age** is an effective screening tool for identifying children who have an unhealthy amount of body fat; however, it is not a diagnostic tool. It should be used as guidance for further assessment, referral, or intervention, rather than as diagnostic criterion for classifying children. BMI-for-age charts are less affected by differences in the timing of puberty than simple height and weight charts, but care must be taken not to confuse heavy musculature with obesity in a minority of children. A decision about whether a child with a given BMI is truly over-'fat' or simply over 'weight' requires additional information such as their state of pubertal maturation, co-morbidities, family history and ethnic background, level of physical activity and frame size, and use of good clinical judgment. As with other anthropometric measures, serial measurements of BMI are more revealing and the pattern of BMI-for-age on the growth chart is more informative than the actual BMI number.

3. **Weight-for-Height** can be used as an indicator of current nutritional status, and can be useful for screening children at risk and for measuring short-term changes in nutritional status. Wasting, or low weight for height, is a strong predictor of mortality among children under five. It is usually the result of acute significant food shortage and/or disease. Wasting in children reflects the level of socioeconomic development as well as that of education and health delivery system. It exposes those sections of society where wasting is prevalent and needs to be rectified. It requires educating the concerned society about nutrition, sanitation, environmental conditions and child care.

4. **Height-for-age** reflects cumulative linear growth. It deficits indicate past or chronic inadequacies nutrition and/or chronic or frequent illness, but not measure short-term changes in malnutrition. Stunting, or low height for age, is caused by long-term insufficient nutrient intake and frequent infections. Stunting generally occurs before age two, and effects are largely irreversible. Stunting is an indicator of past growth failure. Information on stunting for individual children is useful clinically as an aid to diagnosis. Health providers should educate the concerned society about nutrition, sanitation, environmental conditions and child care.

5. **Growth monitoring** should be a routine part of health care for all school going children. Growth monitoring and promotion of optimal growth are useful to provide a tool for nutrition and health evaluation of individual children, initiate effective action in response to abnormal patterns of growth, teach parents how nutrition, physical activity, genetics and illness can affect growth and, in doing so, motivate and facilitate individual initiative and improved child-care practices, provide regular contact with primary health care services and facilitate their utilization.

   To achieve this, health sector should be adequately trained to monitor growth and promotion at the individual level as:

   a. accurately measuring weight, length or height, and head circumference

   b. precisely plotting measurements on the appropriate, validated growth chart

   c. correctly interpreting the child's pattern of growth

d. Discussing child's growth with the parent(s)/caregiver and agreeing on subsequent action when required

e. on-going monitoring and follow-up, when required, to evaluate the response to the recommended action to improve the child's growth.

6. **Importance of Accurate Measurements** and Plotting should emphasise to health care providers. Accurate, reliable measurements are fundamental to growth monitoring and to making sound clinical judgments on the appropriateness of the child's pattern of growth.

Accurate measurements have three components:

1. A standardized measurement technique
2. Quality equipment which is regularly calibrated and accurate and
3. Trained measurers who are reliable and precise in their technique.

Reliable growth data does not require expensive equipment, just careful technique and accurate charting. Childs measurement should be consistently and accurately recorded in an age and gender-appropriate growth record, carefully plotted and then analyzed to identify any disturbances in the pattern of growth. Failure to plot measurements and/or document growth abnormalities also contribute to missed opportunities to identify and address nutrition or illness-related growth problems.

7. Considerations in Interpreting Growth Charts.

Measurements taken one time only describe a child's size serial measurements are need to provide information on a child's growth. Plotting repeated measurements on the same growth chart is the most useful approach to assessment.

If a child is growing normally, the lines connecting the plotted values will usually be parallel to one of the centile lines on the chart and lie within one of the inter-centile spaces , it means, area between two adjacent centile lines.

If a child's growth values start to 'track' up or down significantly (i.e., there is a consistent change in centile position by two or more inter-centile spaces for weight or by one or more inter-centile spaces for height), further investigation is necessary to identify the cause.

Assessing growth involves looking at the overall curve of weight-for-age, height-for-age, and weight-for-height or BMI-for-age to determine whether a child is tracking along the growth curves or is crossing centiles downwards or upwards.

The direction of serial measurements on the curve is more important than the actual percentile.

When a child's growth deviates from a given centile curve, an abnormality in growth may be suspected; however, some shifts in growth are normal. In most children, height and weight measurements follow consistently along a 'chennals' (i.e. on or between the same centile(s)). Normal children oftenshift one to two major centiles (i.e. 3^{rd}, 10^{th} , 25^{th} ,50^{th} ,75^{th} , 90^{th} and $97^{th,}$) for both height and weight, with the majority settling into a channel towards the 50th centile.(i.e. regression toward the mean) rather than away.

Health professionals can allot the time to teach children and their parents/caregivers how to interpret their individual pattern of growth on the growth chart and to involve them in decision making about any potential actions they can take to correct abnormalities in the rate of weight gain and/or linear growth.

8. Reduction of malnutrition in rural and urban areas requires a holistic approach, especially when targeting populations of school-age children. For effective implementation of this approach in rural and urban areas following interventions are recommended.

a). Skills-based nutrition education for the family

Nutrition education should address family as a whole and not just the women. Nutrition education should focus on communication for behavioral change. The nutrition-related activities need to be based on qualitative research that has identified cultural and institutional constraints to good nutrition, detrimental attitudes and practices toward food and eating behavior. With creative thinking, nutrition and health-related activities can be incorporated into group activities, but needs to be perceived to be relevant to their lifestyles rather than imposed.

b). Fortification of food items

Any food commodity, be it sugar, milk, pulses, rice or condiments can be fortified with micronutrients.

c). Effective infection control

In slum environments, children are especially susceptible to a host of diseases and infections that compromise their health and immunity and, in turn, their nutritional status. Malnutrition and childhood diseases are interconnected and mutually reinforce one another. It is therefore extremely important that childhood diseases are identified, and appropriately treated, to contain the effect of the disease on child health.

d). Training public healthcare workers

Service providers should be equipped with knowledge and skills to implement a nutrition program efficiently. Appropriate training methodologies and tools need to be developed to train the service providers. Trained community link workers do not only enhance access to healthcare for the entire community but also deliver healthcare services and education to mothers and children where the public healthcare system is absent.

e). Deliver integrated programs

Intersectoral collaboration is recognized as one of the strategies to address problems of malnutrition. Nutrition education can have a significant effect in promoting healthy eating habits, and schools can contribute to reduce nutrition-related problems by integrating nutrition interventions into a comprehensive school health program.

f). Female literacy programs

Efforts directed towards improvement of female literacy, women empowerment and restricting family size will have a positive impact on the nutritional status of school children.

Recommendations for further studies:

1. The same type of study may be conducted at various primary, secondary, higher secondary schools with large samples, to generalize the outcome.
2. Study can be conducted based on longitudinal study design.

3. This study can be extended to cover 5-19 years of children.
4. Month wise anthropometric information can be collected.
5. Head circumference-for-age, Chest circumference-for-age, Arm circumference – for-age and Skinfold thickness-for-age can be constructed using LMS method
6. Study can be conducted at larger scale to give the representation of all districts in Tamil Nadu.

CONCLUSIONS

The following conclusions were drawn from the study.

1. Boys are taller than girls in all age groups, and the differences are significant in all ages. Increment of growth is more in boys from 6-10 and it is more in girls in 11-12 years.

2. Boys are heavier than girls from 6 -10 years and girls are heavier from 11-12 years and the differences are not significant at in all ages except 6^{th} year and 8^{th} year.

3. Boys are having more BMI than girls except 11-12 years and the differences are significant at in all ages except 9^{th} & 10^{th} years.

4. There is more variation in weight and body mass index of coefficient of variations than height coefficient of variation.

5. In this present study, the height and weight for males and females at the start of school-going ages were almost similar. However, the differences between them became considerably bigger as they grew older. Generally males tend to be taller and heavier than females except 11-12 years. The mean height and weight of girls are

lower than boys until 10 years of age, but then become similar or higher than those of boys. This increase in height and weight may be considered as an early sign of the onset of puberty in girls.

6. The study revealed that total prevalence of overweight and obesity was similar to other states of India when considering Body Mass Index of children between 6-12 years. Boys are having more overweight and obese than girls based on CDC2000 reference distributions of *Z*-scores for BMI.

7. Present study shows prevalence of underweight, stunting and wasting is more in boys than girls among 6-12 years children.

8. Prevalence of weight and height wise normal children was lower than international levels, suggesting the nutrition status of our state children are lower than that of children in developed countries, and has not reached the international level.

9. For weight-for-age ,the specifications of the BCPE models that provided the best fit to generate the 6-12 years boys and girls reference curves were:

   Weight-for-Age

   BCPE [$x=age^{0.80}$, df (μ)=4, df (σ)=3, df(υ)=1, df(τ)=2]; for boys

   BCPE [$x=age^{0.30}$, df (μ)=4, df (σ)=3, df(υ)=1, df(τ)=2]; for girls

10. For height-for-age, the specifications of the BCPE models that provided the best fit to generate the 6-12 years boys and girls reference curves were:

Height-for-Age

BCPE [$x=age^{0.10}$, df (μ)=3, df (σ)=3, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.70}$, df (μ)=3, df (σ)=3, df(υ)=1, df(τ)=2]; for girls

11. For weight-for-height, the specifications of the BCPE models that provided the best fit to generate the 6-12 years boys and girls reference curves were:

Weight-for-Height

BCPE [$x=age^{0.80}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.70}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for girls

12. For BMI-for-age, the specifications of the BCPE models that provided the best fit to generate the 6-12 years boys and girls reference curves were:

BMI-for-Age

BCPE [$x=age^{0.90}$, df (μ)=3, df (σ)=4, df(υ)=1, df(τ)=2]; for boys

BCPE [$x=age^{0.90}$, df (μ)=4, df (σ)=4, df(υ)=1, df(τ)=2]; for girls

13. Comparing present study charts with those of NCHS/WHO2007/CDC2000 chart showed significant differences between growth patterns of our children and other populations. Estimated median 50th percentile shows Tamil Nadu children anthropometric measurements are lower than NCHS/WHO2007/CDC2000 standard children.

Form the above analysis, we can conclude among the various methods introduced in previous decades, LMSP method based on BCPE distribution is more flexible as it takes into account the presence of skewness as well as kurtosis in the distribution when constructing age related smooth percentiles. It can be utilized as refined curve-fitting method to obtain growth references representing parallel curves for any anthropometric parameter in children and adolescents.

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APPENDIX – A

- **IRB Approval**
- **Permission from Director of Elementary Education**

Institute of Child Health and Hospital for Children

MADRAS MEDICAL COLLEGE

HALLS ROAD, EGMORE, CHENNAI - 600 008.

Ph : 28191135 / Direct : 28194181 / Fax : 044 - 28194181.

Date......................

Ref.No.Dir/EC/ICH/07

Institute of Child Health and Govt.
Hospital for Children, Chennai 8.
Dated: 19.9.08

The Institutional Review Board (Ethical Committee) of Institute of Child Health and Hospital for Children, Chennai was held on 5.9.2008 at 2.00 PM at the Deputy Superintendent's chamber.

MEMBERS PRESENT: Dr.R.Kulanthai Kasthuri, Chairperson

Members:

1. Dr.K.Gita
2. Dr.V.Vijayakumar
3. Prof.Girija Shyam Sundar
4. Dr.Rema Chandramohan
5. Mrs.Muthulakshmi, Advocate

Title: "A study on Development of Pediatric Reference Chart" – Thiru.A.Venkatesan.

The Institutional Review Board satisfied with the proposal submitted by you. Hence the Board is pleased to approve the study.

Director and Superintendent i/c.

To

Thiru.A.Venkatesan,
Lecturer in Statistics,
ICH & HC
Chennai 600008.

Proceedings of the Director of Elementary Education, Chennai-6
Rc.No.10220/J3/2010, dated- 30.03.2010.

Sub: Ph.D.research scholar –The TamilNadu Dr.M.G.R.Medical University, Chennai-32— request-permission - 1-8th std students anthropometric measurements –Regarding.

Ref: Letter dated-23.3.2010 of the Thiru. A.Vengatesan, Lecturer in Statistics, Institute of Child Health & Hospital for Children, Egmore, Chennai-8.

With reference to your letter dated 23.3.2010 Permission is granted to collect anthropometric information of School Children in the age group of 6-12 years in the following taluks of Tamilnadu.

1.	Tiruvallore (Tiruvallore and palliput taluk)
2.	Trichirapalli (Srirangam and Musri taluk)
3.	Madurai (Thirumangalam and Usilam patti taluk)

In this Connection kindly ensure that students' studies are not affected while collecting anthropometric information in the above mentioned taluks.

Director of Elementary Education. 1/6

29.3.10

To
Thiru.A.Venkatesan,
Lecturer in Statistics,
Institute of Child Health & Hospital for Children,
Egmore, Chennai-600 008.
Copy to- District Elementary Educational Office,
Tiruvallore, Trichy, Maduri for information and to render Assistance to Thiru.A.Venkatesan to collect School Children information.

M.K.29.3.2010.

APPENDIX – B

List of experts for content validity of the tool used in the study.

APPENDIX-B

List of experts for content validity of the tool used in the study.

- Dr. L. Jeyaseelan, M.Sc., Ph.D., FRSS., FSMS., Professor, Department of Biostatistics, Christian Medical College , Vellore.

- Dr. K. Nedunchelian, M.D., DCH., Assistant Professor of Paediatrics, Institute of Child Health and Hospital for Children, Madras Medical College, Chennai – 600003.

- Dr. John Solomon M.D. D.C.H., FRCPCH (London), M.Med.Sc Hematology (U.K), Head of the Department of Hematology & Oncology, Government Stanley Medical College and Hospital, Chennai-600003.

- Mrs. Visalakshi M.Sc., M.P.H., Lecturer in Biostatistics, Department of Biostatistics, Christian Medical College, Vellore.

- Mrs. Grace Rabekah M.Sc., Lecturer in Biostatistics, Department of Biostatistics, Christian Medical College, Vellore.

CERTIFICATE OF CONTENT VALIDITY

This is to certify that the Socio-demographic and Anthropometric measurements tool developed by Mr.A.Vengatesan, Ph.D. Research Scholar in The Tamil Nadu Dr. M.G.R. Medical University for his topic **"A study on development of Pediatric reference charts"** is validated by me and he can proceed with this tool to conduct main study.

Signature :

Name :

Seal :

Date :

CERTIFICATE OF CONTENT VALIDITY

This is to certify that the Socio-demographic and Anthropometric measurements tool developed by Mr.A.Vengatesan, Ph.D. Research Scholar in The Tamil Nadu Dr. M.G.R. Medical University for his topic **"A study on development of Pediatric reference charts"** is validated by me and he can proceed with this tool to conduct main study.

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CERTIFICATE OF CONTENT VALIDITY

This is to certify that the Socio-demographic and Anthropometric measurements tool developed by Mr.A.Vengatesan, Ph.D. Research Scholar in The Tamil Nadu Dr. M.G.R. Medical University for his topic **"A study on development of Pediatric reference charts"** is validated by me and he can proceed with this tool to conduct main study.

.

Signature :

Name :

Seal :

Date :

CERTIFICATE OF CONTENT VALIDITY

This is to certify that the Socio-demographic and Anthropometric measurements tool developed by Mr.A.Vengatesan, Ph.D. Research Scholar in The Tamil Nadu Dr. M.G.R. Medical University for his topic **"A STUDY ON DEVELOPMENT OF PEDIATRIC REFERENCE CHARTS"** is validated by me and he can proceed with this tool to conduct main study.

Signature :

Name :

Seal :

Date :

APPENDIX – C

Questionnaire to assess Socio-demographic variables and Anthropometric measurements – in English

APPENDIX-C

INTERVIEW SCHEDULE

SECTION A

SOCIO-DEMOGRAPHIC DATA

Serial Number :

School Name : **District :**

Name of child : **Address :**

1. Age of Child (in years):

2. Gender:
   a) Male
   b) Female

3. Education:
   a) Primary school
   b) Middle school

4. Mother age :
   a) 21 - 30 years
   b) 31 - 40 years
   c) 41 - 50 years
   d) > 50 years

5. Mother Education:
   a) Illiterate
   b) Primary school
   c) Middle school
   d) High school
   e) Higher secondary school
   f) College

6) Mother Occupation:

a) House wife
b) Agriculture
c) Daily wage
d) Govt. Employee
e) Private Employee
f) Student

7) Marital status

a) Married
b) Widow
c) Divorced
d) Separated

8) Father Age:

a) 21 - 30 years
b) 31 - 40 years
c) 41 - 50 years
d) > 50 years

9) Father Education:

a) Illiterate
b) Primary school
c) Middle school
d) High school
e) Higher secondary school
f) College

10. Father Occupation:

a) Business
b) Agriculture
c) Daily wage
c) Unemployed
d) Govt. Employee
e) Private Employee
f) Student

11. Family Income (in rupees):

   a) <= Rs. 1000
   b) Rs. 1001 – 3000
   c) Rs. 3001 – 5000
   d) Rs. 5001 -10000
   e) > Rs. 10000

SECTION B

Anthropometric measurement form

1) Weight (in kg) :

2) Height (in cm) :

3) Body Mass Index :

APPENDIX – D

Questionnaire to assess Socio-demographic variables and Anthropometric measurements – in Tamil

APPENDIX-D

<u>தகவல் குறிப்பேடு</u>

<u>பிரிவு – அ</u>

வரிசை எண் : மாவட்டம் :

பள்ளியின் பெயர் : முகவரி :

குழந்தையின் பெயர் :

1. குழந்தையின் வயது (வருடங்களில்) :

2. பாலினம் : அ) ஆண் ஆ) பெண்

3. கல்வி : அ) தொடக்கநிலை பள்ளி
   ஆ) இடைநிலை பள்ளி

4. தாயின் வயது : அ) 21-30 வருடங்கள்
   ஆ) 31-40 வருடங்கள்
   இ) 41-50 வருடங்கள்
   ஈ) >50 வருடங்கள்

5. தாயின் கல்வியறிவு : அ) படிக்காதவர்கள்
   ஆ) தொடக்கநிலைப் பள்ளி
   இ) இடைநிலைப் பள்ளி
   ஈ)உயர்நிலைக் பள்ளி
   உ) மேல்நிலைப் பள்ளி
   ஊ) பட்டதாரி

6. தாயின் தொழில் : அ) இல்லத்தரசி
   ஆ) விவசாயம்
   இ) கூலி
   ஈ) அரசு பணியாளர்
   உ) தனியார் கம்பெனி
   ஊ) மாணவர்

7. திருமணம் : அ) திருமணமானவர்
   ஆ) கைம்பெண்
   இ) விவாகரத்து ஆனவர்
   ஈ) பிரிந்து வாழ்பவர்

8. தந்தையின் வயது :

அ) 21-30 வருடங்கள்
ஆ) 31-40 வருடங்கள்
இ) 41-50 வருடங்கள்
ஈ) >50 வருடங்கள்

9. தந்தையின் கல்வியறிவு :

அ) படிக்காதவர்கள்
ஆ) தொடக்கநிலைப் பள்ளி
இ) இடைநிலைப் பள்ளி
ஈ) உயர் நிலைப் பள்ளி
உ) மேல்நிலைப் பள்ளி
ஊ) பட்டதாரி

10. தந்தையின் தொழில் :

அ)வணிகம்
ஆ) விவசாயம்
இ) கூலி
ஈ) அரசு பணியாளர்
உ) வேலையில்லாதவர்
ஊ) தனியார் கம்பெனி
எ) மாணவர்

11. மாத வருமானம் (ரூபாய்) :

அ) < ரூ.1000
ஆ) ரூ.1001-3000
இ) ரூ.3001-5000
ஈ) ரூ.5001-10000
உ) >ரூ.10000

பிரிவு - ஆ

1. எடை (கிலோகிராமில்) :

2. உயரம் (சென்டிமீட்டரில்) :

3. உடல் பருமன் :

APPENDIX – E, F, G, H

Information Form & Consent Form

in English & Tamil

APPENDIX-E

Institute of Child Health & Hospital for Children
Egmore, Chennai-600008. India.

A study on development of pediatric reference charts

Investigators:

Dr. L.Jeyaseelan	Guide	0416-2262703
Dr. K. Nedunchelian	Co-Guide	044-28191135
Mr. A. Vengatesan	Research scholar	044-28191135

INFORMATION FORM

Pediatric Growth monitoring chart is an excellent tool for assessing the growth and development of a child and for detecting the earliest changes in growth to enable one to take appropriate action at the earliest. Normal growth is an indicator of the overall well-being of a child.

Aim of the study:

To develop a reference standard for the growth parameters of Weight, Height, and Body Mass Index for the children of both sex in the age group of 6- 12 years.

To compare the present reference standard with WHO & CDC charts.

To estimate the prevalence of malnutrition including obesity among Tamil Nadu children

This study tells about the health and nutrition status of children in our community. It combines an interview with a anthropometric measurements of your children. It includes your family members, age, income and occupation status. This interview and measurement will take about 15 minutes.

Data collected in this survey will be used to discuss many health issue of children. The information will be used only for research and statistical reports purpose. All data collected will be kept strictly private confidentiality will be maintained.

You may take part in the survey interview or not. That is your choice. No penalties or loss of benefits will come from refusing. If you choose to take part, you may choose not to answer any question.

If you have any doubts regarding the study you can meet the investigators or can contact by telephone and collect the required information.

Risks and benefits:

No risk involved in this procedure.

The potential benefit is identification of prevalence of malnutrition and nutritional status of community.

APPENDIX-F

INFORMED CONSENT FORM

- I agree to participate in the study titled "A study on development of pediatric reference charts".
- I confirm that I have been told about this study in my mother tongue (tamil) and have had the opportunity to ask questions. I confirm that I have been told about the risk and potential benefits for my child's participation in this study.
- I understand that my child's participation is voluntary and I may refuse to participate at any time without giving any reason, without my child's benefits being affected.
- I agree not to restrict the use of any data or results that arise from this study.

Name of the child: ____________________________

Name of the Guardian/Care giver: ____________________________

Signature: ____________________________

Date: ____________________________

Thumb print of illiterate Parent/Guardian

Name of the Witness : ________________________________

Signature of the witness : ________________________________

Date : ________________________________

Name of Investigator : ________________________________

Signature of investigator : ________________________________

Date : ________________________________

APPENDIX-G

அரசு குழந்தைகள் நல மருத்துவமனை மற்றும் ஆராய்ச்சி நிலையம், சென்னை, இந்தியா

<u>குழந்தைகளின் வளர்ச்சியை கண்காணிக்க உதவும்</u>
<u>அடையாள விளக்கப்படம் பற்றிய ஆய்வு</u>

<u>ஆய்வாளர்கள்</u>

டாக்டர். ஜெயசீலன்	முதன்மை வழிகாட்டி	**0416-2262703**
டாக்டர்.கே.நெடுஞ்செழியன்	துணை வழிகாட்டி	044–28191135
திரு.அ.வெங்கடேசன்	ஆய்வாளர்	044–28191135

<u>பகுதி–1</u>

<u>தகவல் தாள்</u>

குழந்தை வளர்ச்சி கண்காணிப்பு விளக்கப்படமானது குழந்தையின் வளர்ச்சியையும், முன்னேற்றத்தையும் ஆரம்ப நிலையிலேயே கண்டறிந்து தக்க நடவடிக்கை எடுக்க உதவும் கருவியாகும். இயல்பான வளாச்சி என்பது குழந்தையின் ஆரோக்கியமான வளர்ச்சியின் குறியீடாகும்.

<u>ஆய்வின் நோக்கம் :</u>

ஆறு வயது முதல் 12 வயது வரையுள்ள குழந்தையின் வளாச்சியை அறிய உதவும் விளக்கப்படத்தை உருவாக்குவதும், அதனை CDC விளக்கப்படத்துடன் ஒப்பிடுவதும், தமிழகத்தில் சத்து குறைவுடைய பருமன் அதிகமுள்ள குழந்தைகளின் சதவிகிதத்தை அறிவதும் ஆய்வின் நோக்கமாகும்.

இந்த ஆய்வின் மூலம் குழந்தைகள் நலம் சத்து பற்றிய விவரங்களை தெரிந்து கொள்ளலாம். இந்த ஆய்வு நேர்முக வினாவுடன் உச்சி முதல் பாதம் வரை உள்ள வளர்ச்சி விவரங்களை கொண்டதாகும். மேலும் குடும்ப உறுப்பினர்கள் வயது, மாத வருமானம் மற்றும் தொழில் பற்றிய விவரங்களை உள்ளடக்கியது. நேர்முக ஆய்வையும், குழந்தைகளின் அளவுகளையும் எடுக்க 15 நிமிடங்கள் ஆகும்.

இந்த ஆய்வின் மூலம் திரட்டப்படும் விவரங்கள் குழந்தைகளின் நல சம்பந்தமான விவரங்களை பேச பயன்படுத்தப்படும் இந்த விவரங்கள் ஆய்வுக்காகவும், புள்ளி விவரங்களை தருவதற்காக மட்டும் பயன்படுத்தப்படும். இந்த ஆய்வில் உங்கள் குழந்தை பங்கேற்கும் விவரங்களின் இரகசிய தன்மை முற்றிலும் பாதுகாக்கப்படும்.

இந்த ஆய்வில் பங்கேற்பது தன்னிச்சையானது. நீங்கள் பங்கேற்க மறுப்பதால் தண்டனையோ அல்லது உங்களுக்கு கிடைக்க வேண்டிய நன்மையோ கிடைக்காமல் போகாது. நீங்கள் பங்கேற்கும் பட்சத்தில் உங்கள் விருப்பத்திற்கேற்ப வினாக்களுக்கு விடையளிக்கலாம்.

இந்த ஆய்வில் உங்கள் குழந்தையை பங்கேற்க செய்வது பற்றி வேறு ஏதேனும் விவரங்கள் தெரிந்து கொள்ள நினைத்தால் மேலே குறிப்பிட்டுள்ள ஆய்வாளர்களை நேரிலோ அல்லது தொலைபேசியின் மூலமாகவோ தொடர்பு கொண்டு அவற்றை பெற்றுக் கொள்ளலாம்.

<u>அபாயங்கள் மற்றும் நன்மைகள் :</u>

இந்த முறையில் விவரங்கள் திரட்டப்படுவதில் எந்த அபாயமும் இல்லை. ஆய்வில் திரட்டப்படும் விவரங்கள் மூலம் சத்து குறைபாடுள்ள குழந்தைகள் பற்றிய விவரங்களை அறியலாம்.

APPENDIX-H

பகுதி - II

தகவலளிக்கப்பட்ட ஒப்புதல் படிவம்

- குழந்தைகள் அடையாள விளக்கப்பட ஆய்வில் கலந்துக் கொள்ள சம்மதிக்கிறேன். ☐
- இந்த ஆய்வு பற்றி எனக்கு விளக்கமாக எனது தாய் மொழியில் (தமிழ்) சொல்லப்பட்டது. இந்த ஆய்வில் பங்கெடுத்துக் கொள்வதால் எனது குழந்தைக்கு ஏற்படக் கூடிய அபாயங்கள் மற்றும் நன்மைகள் பற்றி எனக்கு விளக்கப்பட்டது. இந்த ஆய்வில் எனது குழந்தையை பங்கெடுத்து கொள்ள முழுமனதுடன் சம்மதிக்கிறேன். கேள்விகள் கேட்பதற்கு எனக்கு வாய்ப்பு அளிக்கப்பட்டது. ☐
- இந்த ஆய்வில் பங்கேற்பது தன்னிச்சையானது. எந்த நேரத்திலும் என் குழந்தை பங்கேற்பதை எந்த விளக்கமும் தராமல் நிறுத்தி கொள்ளலாம். மற்றும் இதனால் என் குழந்தைக்கு கிடைக்க வேண்டிய பயன்களுக்கு எந்த இடையூறும் ஏற்படாது என எனக்கு தெரிவிக்கப்பட்டது. ☐
- இந்த ஆய்விலிருந்து கிடைக்கும் முடிவுகளை பயன்படுத்துவதை கட்டுப்படுத்தாமலிருக்க நான் சம்மதிக்கிறேன். ☐

குழந்தையின் பெயர் : ------------------------------

குழந்தையின் பெற்றோர் / கண்காணிப்பாளர் பெயர் : ------------------------------

குழந்தையின் பெற்றோர் /கண்காணிப்பாளர் கையெழுத்து : ------------------------

(தேதி ------ / ----- / --------)

எழுதப்படிக்கத் தெரியாத பெற்றோர் / கண்காணிப்பாளர் கை கட்டை விரல் ரேகை

☐

சாட்சியின் பெயர் : ------------------------------

சாட்சியின் கையெழுத்து : ------------------------------

(தேதி -------- / ------ -------)

ஆய்வாளர் / ஆய்வு மருத்துவர் பெயர் : ------------------------------

ஆய்வாளர் / ஆய்வு மருத்துவர் கையெழுத்து : ------------------------------

(தேதி -------- / ------ -------)

APPENDIX – I

Photo documentation of the research study


அனைவருக்கும் கல்வி இயக்கம் (SSA)
ஊராட்சி ஒன்றிய நடுநிலைப்பள்ளி

APPENDIX – J

Certificates from

Research Methodology - Workshop

Software Training - Workshop

Data Management and Data Presentation – Workshop

IOG

Certificate

The Journal of

OBSTETRICS AND GYNAECOLOGY

Certify that

Dr. VENGATESAN.

Attended

The Research Methodology Workshop

Organized By

PICSEP PROJECT and

Institute of Obstetrics & Gynaecology

Madras Medical College, Chennai

Under the Auspecies of

The Tamil Nadu Dr. M.G.R. Medical University

On 9 – 11 October 2009.

Dr. C.N. Purandare
President, FOGSI

Dr. Mahendra Parikh
PICSEP - Incharge

Dr. Adi Dastur
Editor, JOGI

Dr. Revathy Janakiram
Director & Superintendent, IOG

Biostatistics Resource and Training Centre

Christian Medical College,

Vellore, India.

Certificate of Participation

This certificate is awarded in recognition of the participation of

Mr. A. Vengatesan

in Short Course on Statistical Computing using R (Software Training)

held during August 29 – 31, 2012

Principal

L. Jeyaseelan

Course Co-ordinator

unicef

Institute of Child Health & Hospital for Children

ICH & HC Chennai

MADRAS MEDICAL COLLEGE
Egmore, Chennai - 600 008.

CERTIFICATE

This certificate is awarded in recognition of the Participation of

A. VENGATESAN

in the workshop on "Data Management and Data Presentation" held from 4th to 7th May 2010 at Chennai, conducted by the Institute of Child Health, Government of Tamil Nadu in collaboration with UNICEF Chennai.

Saradha Suresh

Dr. Saradha Suresh
Director & Superintendent
Institute of Child Health & Hospital for Children,
Egmore, Chennai - 600 008.

Satish Kumar

Dr. Satish Kumar
Chief of Field Office
UNICEF office
for Tamil Nadu & Kerala