UNIT 2 GROWTH STANDARDS AND REFERENCES

Contents
2.1 Introduction
2.2 How Can We Assess Human Growth?
2.3 Growth Charts
2.4 Process of Assessing Human Growth
2.5 Growth References: A Brief Concept
   2.5.1 Historical Background of Growth References
   2.5.2 Other Growth References in Use
2.6 Summary
2.7 References

Suggested Reading
Sample Questions

Learning Objectives

The main objective of this unit, is that you will:

- be aware of the different standards that are in use to assess human growth;
- know about the differences between growth references and growth standards;
- learn about the plotting of growth charts and how the curves are drawn;
- be aware of how the data obtained is compared with the references; and
- learn the different references that are in use today with emphasis on the National Centre for Health Statistics (NCHS) references, Centres for Diseases Control (CDC) charts and the WHO Multi-Centre Growth References (MGRS).

2.1 INTRODUCTION

The state of health of an individual is affected by the intake of food and its utilization. Nutrition is a physiological fact which helps organisms to assimilate the nutrients of the food for proper maintenance and growth and development of the body. It is a combination of processes by which all parts of the body receive and utilize the materials necessary for their growth and renewal of all the components. When a person receives and utilizes essential nutrients in proper proportions according to the requirements of body it is called optimum nutrition. It is the state of a well-balanced diet in which all the essential nutrients is supplied to meet the body’s requirements. On the other hand a poor nutritional status refers to the state of inadequate as well as excessive intake or improper utilization of the nutrients to meet the body’s requirements.

Growth is an anabolic process. Growth may be defined as an increase in size or mass, primarily resulting at the cellular level from hypertrophy and hyperplasia, and from interstitial accretion (Thompson, 1971). Based on the above definition, body cells, tissues, organelles, organs, organ systems and organisms all participate in growth process. Human growth, however, is linear till its cessation and turns transverse thereupon in adulthood. It represents most dramatic increase in size.
When a researcher measures human growth at regular intervals, the resultant curve assumes a relatively smooth shape and growth is then viewed as a continuous process. The curve of human growth can be divided into five distinct phases. These phases are:

i) rapid infant growth
ii) steady childhood growth
iii) very rapid adolescent growth
iv) mid-growth spurt and
v) slow growth as the individual approaches adulthood.

The majority of growth occurs during infancy and childhood, while the most important physical changes occur during adolescence. The important growth curves are the velocity curve, acceleration curve and distance curve. The methods of human growth studies are basically cross-sectional, longitudinal and mixed longitudinal in nature. Accurate and reliable measurements of the physical body size are necessary to assess the growth status of an individual. Positive increases in successive anthropometric variables such as weight and height generally is indicative of the fact that an individual is growing. Standardized techniques are the main criteria for the comparison of the data obtained with that of the references.

Measurement techniques for growth assessment can be easily assessed in the existing literature. The ‘Anthropometric Standardization Reference Manual’ (1998) is one of the best manuals that are used presently to record anthropometric data. The basic modality is the relation between growth and size is that the growth is a kind of velocity and measures the rate of change of size over a certain period of time. The measurements are taken at regular intervals over a specified period of time.

Did you know that the

• The oldest growth record is that compiled by De Montbeillard who had been measuring the height of his son about every 6 months from his birth in 1759 until the latter was 18 years of age in 1777.

• It was Scammon who translated the measurements recorded by De Montbeillard into centimetres. Scammon published his results in the form of a chart in the year 1921 in the premier journal “American Journal of Physical Anthropology” and his paper was entitled “The First Seriatim Study of Human Growth”.

By joining together the data points at each age, Scammon produced a curve that described the height achieved at any age, which became known as a height distance or height-for-age curve.

2.2 HOW CAN WE ASSESS HUMAN GROWTH?

Growth assessment is basically a kind of comparison. The comparison is with a reference normally called a ‘growth reference’. Without such a reference, growth assessment becomes arbitrary. Now the question arises: what is the difference between Growth Reference and Growth Standard? The difference between a growth reference and a growth standard is very pertinent and relevant to the development and application of growth charts.

Growth reference: A growth reference is a tool for providing a common basis for purposes of comparison (WHO Working Group on Infant Growth, 1995). Cameron (2002) defines a growth reference is essentially a database defining the statistical distribution of one or more measures of size or growth, indexed by sex, age and/or other factors.
**Assessment of Growth**

**Growth standard:** A growth standard is a concept of a norm or target, that is, a value judgment (WHO Working Group on Infant Growth, 1995). In simple terms, a reference describes “what is,” whereas a standard prescribes “what should be.”

In practice, however, reference values are often used as standards (de Onis and Habicht, 1996). The growth references have to take into account the effects of all the confounding factors. Growth references are sometimes called “Growth charts”.

The process of developing growth references is composed of the following successive stages:

i) choice of the reference population
ii) drawing of the sample
iii) data collection and data analysis
iv) production of the final growth chart

The function of the growth reference is to provide a way of displaying the expected growth as a function of the other factors affecting growth in a compact, accessible, and visually appealing form.

**Use of growth references**

The construction and release of growth charts has implications for health-care workers, child caregivers, agency officials, researcher, and others who use growth information.

### 2.3 GROWTH CHARTS

The data with regards to growth references can be either presented in a tabular form or as a chart plotted against age. The presentation in the form of charts has developed over the last hundred years (Tanner, 1981). The most significant underlying principle behind the preparation of the growth charts is that the curves should appear smooth.

The frequency distribution of each measurement is subsequently presented in several ways. At its simplest form, the mean and standard deviation (SD) of the measurement in question are tabulated by age and sex. Then, assuming a normal or Gaussian distribution, the mean and SD define the entire distribution and its centiles.

Now what is a centile? A centile is a point on the distribution that splits the population into two specified fractions. The median point is the 50th centile and is the midpoint of the distribution. It has 50% of the distribution to the left of it and 50% to the right. The third centile has 3% of the distribution to the left and 97% to the right.

Curves are drawn on the chart to represent the distribution at each age. Usually seven curves are drawn on the chart. The curves correspond to the mean, one SD above and below the mean, two SDs above and below the mean and three SDs above and below the mean. As a result, each curve is placed one SD apart on the chart. The seven curve pattern has been used for the World Health Organization (WHO)/U.S. Centers for Disease Control (CDC)/National Center for Health Statistics (NCHS) international growth references.

A set of several centiles can also be utilized in the growth chart to represent the range of the distribution. The usual set is the seven centiles 3rd, 10th, 25th, 50th, 75th, 90th, and 97th, approximately two thirds of an SD apart for a normal distribution.

The centiles are joined to form a centile curve. A centile curve, thus, is a curve joining the values of a specified centile at different ages. The percentage chance of an individual’s value lying below a given centile curve is shown by the value of the centile.
2.4 PROCESS OF ASSESSING HUMAN GROWTH

The curves on the chart represent either centiles or fractions of an SD above or below the mean. The subject's measurement is plotted on the chart and the corresponding centile or SD relative to the mean is to be noted. By convention, an individual's position on the growth chart is known as the SD score (SDS) or z-score.

Comparison between the Centile and the SD score scales

<table>
<thead>
<tr>
<th>Centile</th>
<th>SD score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centiles are on a scale from 1 to 99 and centered on 50.</td>
<td>The SD score scale is centered on 0</td>
</tr>
<tr>
<td>A centile refers to the percentage chance of a reference child having a</td>
<td>The SD score scale has an SD of 1, and is normally distributed.</td>
</tr>
<tr>
<td>smaller value than the subject under observation.</td>
<td></td>
</tr>
<tr>
<td>Centiles are easier for subjects and their parents to comprehend.</td>
<td>SD scores are preferred by researchers, as they give better statistical results.</td>
</tr>
</tbody>
</table>

There are two important points to remember; Firstly, the international growth reference uses SDs rather than centiles to quantify the size of malnourished individuals who lie well below the third centile and secondly, there is yet another method of using the percent of the median. Here the recorded anthropometric measurement is expressed as a percentage of the median value for the individual's age and sex.

Percent of the median: This method is used mainly in the developing countries and is a simpler version of the SD score. The main difference between the two is that the former does not take into account the variability of the measurement, while the SD score does.

So we know that an individual's position on the growth chart can be expressed as:
- a centile
- a SD score
- a percentage of the median

2.5 GROWTH REFERENCES: A BRIEF CONCEPT

The main basis for the construction of a growth reference is the reference population from which the data needs to be obtained. The reference population chosen should portray the expected growth, based on the purposes for which the reference will be used. The most important decision the researcher has to take at the onset is the choice of reference population. This refers to how a reference shall behave, how the reference is to be used, used by whom, and on whom. The first basic question that arises is the reference to be used as a clinical or public health tool. And the second basic question would be is it intended to reflect "optimal" or "typical" growth?

Clinical tool: When the care of the individual patients is concerned, the growth chart becomes an integral part of the clinical set up. Since the measurement of an individual's measurement and interpretation is a direct measure of his/her health, the medical assessment involves interpreting the centiles/SD/percentage of the median. The reference population needs to be clearly defined in terms of geographical, cultural or social features.
Can you give an example of a growth reference that is used for clinical purposes? The British reference which is representative of ethnic White children living in England, Scotland, and Wales and developed countries in 1990 (Freeman et al., 1990) is an ideal example.

**Public health tool:** For public health purposes the applicability of the chart to the individual is not the primary concern. In this case, the underlying principle is to document the growth status of a group of individuals. Subsequently the growth of the group is compared with that of other groups. Here the position of the individual in the growth chart does not bear prime importance. Furthermore, the growth chart need not be based on any particular group of individuals.

Can you give an example of a growth reference that is used for public health purposes? The WHO/CDC/NCHS growth charts are examples of such charts.

The reference population consists of individuals who are identified on health grounds. Those with growth disorders, retarded growth and suffering from malnutrition need to be excluded. The most common form of growth study is the cross-sectional survey for growth references. Other forms include longitudinal and mixed longitudinal surveys, based on their growth standards are constructed.

The age range of the data is another important aspect that needs to be looked into. Regarding the sample size, ideally there should be 200–300 individuals per age group.

What measurements should be used in the references? This would depend on the nature of the study design. Ideal measurements would be height, weight, mid-upper arm circumference, waist circumference, head circumference and skinfold thicknesses.

### 2.5.1 Historical Background of Growth References

A variety of growth references were developed and used, especially in the United States since the early 1900s. Most of these earlier references have considerable limitations, including lack of coverage for infants and preschool children and limited representation of ethnic, genetic, socioeconomic, environmental and geographic features (www.academia.edu).

Until the late 1970s, a number of growth charts were utilized to assess child growth. Then in the year 1977, the National Center for Health Statistics (NCHS) published a new set of growth charts for children aged <18 years based on data from the Fels Longitudinal Growth Study and nationally representative surveys. The NCHS later became a part of the CDC in the year 1987.

The CDC began revising the curves after another round of data collection was completed in 1994 and the new charts were released in 2000. In 1997, the WHO launched the MGRS to collect data on the growth of children worldwide based on strict inclusion criteria. Data collection was completed in 2003, and the new growth charts were released in 2006.

Are you aware that the Stuart/Meredith Growth Charts were widely used in the United States during the mid-1970s? These charts were based on stature and weight measurements of White children living near Iowa City and in Boston from 1930 to 1945. However, the oldest well known growth reference is that developed by the National Centre for Health Statistics (NCHS).

**The National Centre for Health Statistics Reference**

In the year 1971, the American Academy of Pediatrics and the Maternal and Child Health Program of the Bureau of Community Health Services, U.S. Public Health
Service, recommended new growth charts based on data from the NCHS Health Examination Surveys. This led to the development of the NCHS Growth Charts. The NCHS Growth Charts were released in the year 1977 and were recommended for the clinical assessment of infants and children (Owen, 1973).

In 1978 the CDC came up with a normalized version of the NCHS curves (Dibley et al., 1987). The WHO subsequently recommended these normalized charts for international applications (World Health Organisation, 1978). This normalised version enabled the expression of body measurements in terms of standard deviations from the median or z-scores (Waterlow et al., 1977).

The 1977 NCHS Growth Charts consists of 14 sex-specific growth charts. These growth charts were developed for infants aged from birth to 36 months and for children aged from 2 years to 18 years (Hamill et al., 1977, 1979).

The charts included in the 1977 NCHS Growth Charts are:

- **Weight-for-age**
  - Birth to 36 months
  - 2 years to 18 years

- **Length-for-age**
  - Birth to 36 months

- **Weight-for-length**
  - Birth to 36 months
  - Boys (49 cm to 103 cm)
  - Girls (49 cm to 101 cm)

- **Head circumference-for-age**
  - Birth to 36 months

- **Stature-for-age**
  - 2 years to 18 years

- **Weight-for-stature**
  - Boys (90 cm to 145 cm)
  - Girls (90 cm to 137 cm)

A similar recommendation for new growth charts was made by the Food and Nutrition Board of the National Academy of Sciences in 1974. The recommendation emphasized the urgent need for new growth charts for infants and children. The charts were to be based on nationally representative survey data and supplemented with data collected from infants in the Fels Longitudinal Growth Study (Food and Nutrition Board et al., 1974). A subsequent recommendation for the same was advanced a year later by a study group sponsored by the National Institute of Child Health and Human Development, National Institutes of Health (Roche and McKigney, 1976).

**Sources of data used for the preparation of the NCHS growth charts**

A basic point here is, that it was only when nationally representative cross-sectional survey data became available for the United States for most of the age range among children that growth charts began to be developed by the NCHIS.

Since the U.S. National survey data were not available for the period from birth to 1 year, the NCHS used the national survey data available from the longitudinal growth study of the Fels Research Institute in Yellow Springs, Ohio. Data from NHES II (1963–1965) for ages 6 years–11 years, (NHES III (1966–1970) for ages...
Assessment of Growth

12 years–17 years, NHANES I (1971–74) for ages 1 year–17 years were used to develop the NCHS Growth Charts. The NCHS charts from birth to 3 years are solely based on the Fels data.

There are certain demerits of the Fels data:

- The Fels data came from a single longitudinal study of infants from 1929 to 1975.
- The data was recorded mainly from formula fed, White middle-class infants.
- The data was collected from infants residing in a small, limited geographic area of south-western Ohio. Hence it was not a nationally representative data.
- The data was collected at birth and 1 month, at 3-month intervals from 3 to 12 months, and at 6-month intervals from 12 to 36 months. These intervals are not adequate to identify growth patterns during periods of rapid change.
- The size and growth patterns of Fels infants may not adequately represent current growth patterns of combined breast-fed and formula-fed infants in the U.S. population.
- There is an absence of the weight-for-stature references for adolescents.
- The Fels infant study could not assess the growth of individuals aged 18 years and over.

In December 1992, the NCHS sponsored the 1st workshop to look into the concerns that were raised about the 1977 NCHS Growth Charts. Since then, a number of workshops were sponsored by the NCHS to obtain expert input for revising the 1977 NCHS Growth Charts. The WHO independently also began to extensively review the uses and interpretations of growth information. The aim of these workshops was to provide options and recommendations that would be considered in making final decisions on how best to assess human growth.

Why the revision of the NCHS growth charts was needed? More recent and comprehensive U.S. national data on anthropometric measurements among U.S. children were becoming available. New additional U.S. national survey information was available after the publication of the 1977 NCHS Growth Charts. These were the NHANES II (1976–80) data beginning at 6 months of age and the NHANES III (1988–94) data beginning at 2 months of age. It was during the planning of the NHANES III, that increasing awareness of the concerns surrounding the 1977 NCHS Growth Charts influenced the decision to over sample children aged 2 months to 6 years.

The objectives of the revision were:

- To use improved statistical smoothing procedures, in conjunction with more comprehensive U.S. national survey data.
- To provide a better instrument for health care providers who evaluate the growth status of children in the United States.

The Advance Data report summarizing the development of the revised growth charts was issued in 2000 (Kuczmarski et al., 2000).

Centers for Disease Control and Prevention (CDC) Growth Charts

The 1977 NCHS charts were subsequently revised as more recent and comprehensive national data on body measurements for U.S. children became available. The new charts are called the Centers for Disease Control and Prevention (CDC) Growth Charts. The CDC Growth Charts were released in the year 2000. From a practical standpoint, the NCHS data were not designed to provide separate reliable growth
estimates for each of the racial-ethnic groups in the U.S. However, the 2000 CDC growth charts were produced for all children in the U.S. population.

Basically, when interpreted in the overall manner, the 1977 NCHS and the 2000 CDC growth curves appear to be quite similar. The differences that exist are pronounced in the charts for infants where national survey data were previously lacking rather than in the charts for older children. For infants, the major differences were in the head circumference-for-age charts. In the other infant charts, differences were generally at the outer (lower and upper) percentiles. For older children, there were almost no differences in the stature-for-age charts and only minor differences in the weight-for-age charts.

The 2000 CDC Growth Charts differ from the 1977 NCHS Growth Charts with regard to data and methods used in their construction. In addition, there are a number of new features in the 2000 charts that were not previously available. The CDC charts are recommended for use in clinical practice and research to assess size and growth in U.S. infants, children and adolescents.

In the development of the 2000 CDC Growth Charts, the reference population was the civilian, non-institutionalized population of the United States. A very important point to note here is that the reference population excluded infants with very low birth weight.

Now what do the CDC Growth Charts consist of? The construction of these new 2000 CDC Growth Charts was largely based on a descriptive approach. The new references were seen to portray the growth that is expected of children in the population typically or on average based on sex and age.

The 2000 CDC Growth Charts consist of a set of charts for infants, birth to 36 months of age and a set of charts for children and adolescents from ages 2 years to 20 years. These charts also include weight-for-stature charts for statures ranging from 77 cm to 121 cm. These specific charts are primarily intended for use among children aged from 2 years to 5 years.

The charts for infants include sex-specific smoothed percentile curves for weight-for-age, recumbent length-for-age, head circumference-for-age, and weight-for-recumbent length. The charts for children and adolescents include weight-for-age, stature-for-age, and body mass index (BMI)-for-age curves. The BMI-for-age charts represent a new tool that can be used by health care providers for the early identification of children who are at risk for becoming overweight at older ages.

The 2000 CDC charts have no age or pubescence restrictions which was applicable to the earlier NCHS charts with regards to weight-for-age. Even though the revised charts were developed for children 2 years to 5 years of age, in practice they may accommodate some shorter children with chronologic ages 5.0 years and over.

The new features in the 2000 CDC Growth Charts considered National survey data, Body mass index-for-age charts, Extended age range, Additional percentiles and Corresponding percentiles and z-scores.

The World Health Organization Multicentre Growth References (WHO Growth Charts)

It was in the year 1993 that the WHO undertook a comprehensive review of the uses and interpretation of anthropometric references of human growth. It was subsequently recommended that the NCHS/WHO growth reference, which had been recommended for international use since the late 1970s, did not adequately represent early childhood growth and that new growth curves were necessary. The
World Health Assembly endorsed this recommendation in 1994 and entrusted the WHO to formulate new growth curves for children.

As a result, the WHO undertook the Multicentre Growth Reference Study (MGRS) to generate new curves for assessing the growth and development of children the world over. The study was done from 1997 to 2003 and the new international growth standards for children aged 0 months – 59 months was released in April 2006 (World Health Organisation, 2006). These new standards are called the WHO Growth Charts.

**The necessity of the new MGRS references**

- The world was beginning to be very conscious about the global increase in childhood obesity.
- The limitations of the NCHS/WHO reference that was being used till then.
- The statistical methods used during the development of the NCHS/WHO growth curves had limited features to correctly model the pattern and variability of growth.
- The MGRS is unique in that it was purposely designed to produce a standard rather than a reference.

**The uniqueness of the MGRS**

a) It was purposely designed to produce a standard by selecting healthy children living under conditions likely to favour the achievement of their full genetic growth potential.

b) The mothers of the children selected for the construction of the standards were breastfeeding their infants and not smoking.

c) By selecting privileged, healthy populations the study reduces the impact of environmental variation.

d) The study has included children from a number of diverse setting (Brazil, Ghana, India, Norway, Oman and the U.S.).

e) The study has explicitly identified breastfeeding as the biological norm and established the breastfed child as the normative model for growth and development.

f) The new MGRS standards also includes scales for 6 main motor developmental milestones that were absent in the earlier references.

**The data collection**

The MGRS combined a longitudinal follow-up of infants and children from birth to 24 months and a cross-sectional survey of children aged 18 months to 71 months. Primary growth data and related information were gathered from 8440 healthy breastfed infants and young children from widely diverse ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and USA) (www.who.int).

**The criteria for the selection of the reference population for the World Health Organization Multicentre Growth Reference Study**

- Socio-economic status that does not constrain growth
- Low altitude
- Low mobility of the target population
- Minimum of 20% of mothers willing and able to follow specified infant feeding recommendations
Existence of breast-feeding support system
Local presence of qualified collaborative institutions
Rate of hospital deliveries
Sufficient number of eligible births
Feasibility.

Differences between the 2000 CDC growth charts and the WHO growth charts

The basic differences lie in their overall conceptual approach in describing human growth. Moreover, the reference populations used to create the 2006 WHO and 2000 CDC growth curves vary with respect to inclusion and exclusion criteria, geographic location, number and frequency of measurements and sample size.

<table>
<thead>
<tr>
<th>2000 CDC Growth Charts</th>
<th>WHO Growth Charts</th>
</tr>
</thead>
<tbody>
<tr>
<td>The 2000 CDC growth charts are growth reference, not a standard, and describe how certain children grew in a particular place and time. The CDC charts describe the growth of children in the U.S during a time span of approximately 30 years (1963–1994).</td>
<td>The WHO charts are growth standards that describe how healthy children should grow under optimal environmental and health conditions. The curves were created based on data from selected communities worldwide, which were chosen according to specific inclusion and exclusion criteria.</td>
</tr>
</tbody>
</table>

The anthropometric parameters used to construct the MGRS are head circumference for age for both sexes, arm circumference for age for both sexes, triceps skinfold for age for both boys and girls and subscapular skinfold for age for both boys and girls. Careful procedures for training and measurement standardization were followed, and high-quality instruments were used for weight and length (or stature) measurements. In the WHO study, the researchers recorded two measurements independently and further repeated the measurements that exceeded preset maximum allowable differences.

Recommendations

- Use of the 2006 WHO international growth standard for the assessment of growth among all children aged <24 months, regardless of type of feeding, is recommended.
- When using the WHO growth charts, values of 2 standard deviations above and below the median, or the 2.3rd and 97.7th percentiles (labelled as the 2nd and 98th percentiles on the growth charts), are recommended for identification of children whose growth might be indicative of adverse health conditions.

2.5.2 Other Growth References in Use

Two of the other growth references in use include the reference for body mass index (BMI) of Cole et al. (2000) and the references provided by the The Euro-Growth Study of van't Hof et al. (2000).

2.6 SUMMARY

This Unit starts with a brief sum up about growth and its phases. The differences between growth and size have been considered. The focus then shifts to growth assessment. Though there are differences between growth references and standards, in practice, reference values are used as standards.
Growth references are developed based on the choice of the reference population, the sample itself, processes of data collection and data analysis and the production of the final growth chart. The data with regards to growth references can be either presented in a tabular form or as a chart plotted against age. The curves on the chart represent centiles or fractions of an SD above or below the mean. The subject's measurement is plotted on the chart and the corresponding centile or SD relative to the mean is noted. An individual's position on the growth chart is known as the SD score (SDS) or z-score. There are differences between a centile and a SD score.

The construction of a growth reference is based on the reference population from which the data needs to be obtained. The reference population chosen show the expected growth, based on the purposes for which the reference will be used. The reference population consists of individuals who are identified on health grounds. Those with growth disorders, retarded growth and suffering from malnutrition are excluded. The anthropometric measurements used for the growth references are height, weight, mid-upper arm circumference, waist circumference, head circumference and skinfold thicknesses. Since the early 1900s, a number of growth references were developed and used. However, it was only in the year 1977 that the NCHS published a new set of growth charts for children aged below 18 years. The CDC revised the curves after 1994 and the new charts were released in 2000. In 1997, the WHO launched the MGRS to collect data on the growth of children worldwide based on strict inclusion criteria. Data collection was completed in 2003, and the new growth charts were released in 2006.

2.7 REFERENCES


**Website**

[www.uct.academia.edu](http://www.uct.academia.edu) as on April 27, 2012

[www.who.int](http://www.who.int) as on April 15, 2012

**Suggested Reading**


**Sample Questions**

1) What do you understand by growth references and growth charts?

2) Give a brief description of the 2000 CDC Growth Charts.

3) What are the main important changes in the WHO Growth Charts?

4) Discuss in brief the different growth charts that have been used by researchers.