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ANTHROPOMETRY IN THE NUTRITIONAL ASSESSMENT OF PRESCHOOL CHILDREN

by

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INTRODUCTION

Nutrition has a double faceted challenge--that of preventing states of malnourishment and of reducing illnesses that are related to excessive nutritional intake (1). Normal healthy children have a genetically determined physical growth pattern that is affected by environmental factors, including nutrition (2,3). Progress along this pattern is one criterion used to assess the nutritional status of children (4,5) and is a reflection of the nutritional status of the population as a whole (6).

Relatively simple anthropometry has been used in surveys throughout the world to assess protein-energy malnutrition (PEM) in children (7-13). Recently attention has shifted from surveys to continuing surveillance of growth of children (14-16) because children have long been recognized as being "at risk" nutritionally (17). Interest in the use of anthropometric measurements to monitor growth of children is increasing because of the possibility of moderate malnutrition among marginated groups (16,18-22), the incidence of obesity among children (23), and the indication that many hospitalized patients need special nutritional support (24,25).

The purpose of this report was to review the literature regarding the use of anthropometric measurements to assess the nutritional status of preschool children.

NUTRITIONAL ASSESSMENT

Accurate assessment of nutritional status is crucial to the cycle of planning, implementing, and evaluating intervention programs. The issue of hunger looms over the world. In 1974 the United Nations reported that more than 460 million people were permanently hungry. In a step to end hunger, the United States has established a number of federal programs to assure an adequate diet to every citizen. Food aid programs may represent the unsung yet most effective antipoverty efforts of the last 15 years, but they still are far from adequate in their use as a tool of public policy (21). Malnutrition has become a subtle problem, characterized by a lack of various essential nutrients. Nutrition must be raised to a positive concept and the stigma of welfarism associated with nutrition programs must be removed (26). The Presidential Commission on World Hunger (20) recommended that resources of domestic hunger programs be increased and that the continuing nutritional status of Americans be assessed in a systemic way.

NUTRITIONAL RISK OF THE CHILD

National surveys (11,18,19) have identified preschool children and pregnant and lactating women as groups most at nutritional risk. This risk is compounded by marginal environments. A position paper by the American Dietetic Association on a National Nutrition Policy (14) stressed that surveillance on a continuing basis would involve reliable procedures to diagnose individuals who may be at nutritional risk.

The physical status of children of preschool age has been of considerable concern throughout the world. Mortality among 1-5 year old children in developing countries is highest among the 1-2 year old group (6).

If children survive the first 2 years, they often adapt to the health risks of their environment through stunted growth, and in this sense are less endangered by malnutrition than 1 and 2 year old children (12). The susceptibility of the child to nutritional deprivation will be greater during periods of more rapid growth (1).

The second year of life is fraught with risk. Jelliffe (27) suggested the word "secotrant" to signify the risk involved in the transition through the second year. The second year in particular is a period of rapid growth with high nutritional needs for swiftly increasing muscle mass (6). Increases in physical size are achieved by increase in both number and size of cells, and organs are vulnerable to compromised nutrition during stages of hyperplasia (3).

EVALUATION OF GROWTH OF CHILDREN

Tissues of the body grow at different rates. Increments in body weight represent the growth of many tissues (28). The interaction of genetic and environmental factors, including nutrition, effect differences among populations of children in body size, shape, and rate of growth. Larkin et al. (29) and Fitzhardinge and Steven (30) concluded that a multiplicity of factors existed as the cause of growth failure. Specifically, while birth weight seems strongly related to subsequent growth achievement, it cannot be used to explain all cases of inadequate growth in children.

Growth is marked by changes in body shape as well as increase in body size. Longitudinal studies reflect important information about changes in body composition. The ratio of subcutaneous fat and muscle changes early in life. After a rapid rise in fat from birth to 1 year of age, a gradual decline in fat follows to 6 or 7 years of age (31).

Superimposed on changes in fat content of the body are changes in muscle tissue. The muscle width grows at about twice the rate of bone width. The child is at nutritional risk in this critical age period if a deficit of amino acids leave the child incapable of following this growth progression (32).

Rate of growth is considered a sensitive indicator of nutritional status of the child. One time measurements or cross-sectional surveys with each child seen only once, show size achieved at a particular age. Serial observations or longitudinal studies over a defined period permit an extremely useful calculation of growth (1,6,33). Two measurements which permit calculation of growth of children provide a more fruitful interpretation than a single measurement of size. The larger the time span over which multiple observations are made, the surer will be the judgment whether the measurements of a given child are normal (5). Growth charts are constructed with the assumption that children maintain their relative sizes during growth and stay in the same percentiles (3,5).

NUTRITIONAL STATUS

Nutritional assessment measures the prevalence of disease by one or more indicators of nutritional status. The prevalence may be only an inexact approximation of the "true" prevalence of malnutrition (34). Nutritional monitoring and surveillance measure changes in the prevalence of "true" disease or in the risk of disease and require serial observations. Surveillance identifies potential problems. In nutritional screening a cut-off point is selected to identify an exact number of malnourished persons who can be treated. Criteria for screening depend not just on information but on the resources at hand. The cost of missing a case of malnutrition (false negative) and the cost of treating a well nourished child as malnourished (false positive) will limit numbers of persons to be treated where resources are scarce (34).

A source of confusion about indicators of nutritional status is the expectation placed on these indicators (13). It is unreasonable to expect the same indicator, such as arm circumference, to reflect equal usefulness in acute and chronic malnutrition (35), in vitamin deficiency and in protein-energy malnutrition (7), and as a predictor of morbidity. Anthropometry on presumably well children has an unmeasurable reassurance value (5).

Ideally nutritional assessment in the health program begins with an examination of the community to determine how the quality of life relates to the nutritional status of the community. After assessment of the community, four basic methods are employed. Dietary studies give presumptive evidence of nutrient intake which can help explain possible reasons for further findings. Laboratory investigations provide objective but limited biochemical measurements of nutrients within the body. Clinical studies evaluate physical signs of nutritional health or deficiency. Anthropometric methods employ standardized equipment and procedures to obtain physical measurements.

ANTHROPOMETRY OF PRESCHOOL CHILDREN

Among the basic methods of nutritional assessment, anthropometry has the distinction of having the highest accuracy and medium cost and requiring little skill and a minimum of time (15). A proliferation of nutritional status indices has occurred in the search for the most accurate, feasible, and economic anthropometric measurements (12). The relationship between various measurements and their relative advantages was described by the World Health Organization in a review of anthropometry in nutrition surveillance (17).

A comprehensive nutritional assessment procedure includes a profile of serial anthropometric measurements. Anthropometric measurements are frequently the first step in nutritional assessment. Because a child grows with time, no single set of measurements can characterize nutritional status. They have been used to measure growth, body mass, and body composition in the assessment of protein-energy malnutrition (PEM) in children. There is limited evidence that growth inhibition and body disproportion in human beings occurs, except in relation to protein and energy intake (17).

The Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council was established in 1951 (36). The committee acknowledged that no well defined methods and standards were in existence for the application of anthropometry to nutritional evaluation. The monograph on Assessment of Nutritional Status in the Community by Jelliffe (6) included standardized methods which continue to be used to identify and classify grades of PEM in children whose status may lie occult beneath the tip of the PEM iceberg (fig. 1) (37).

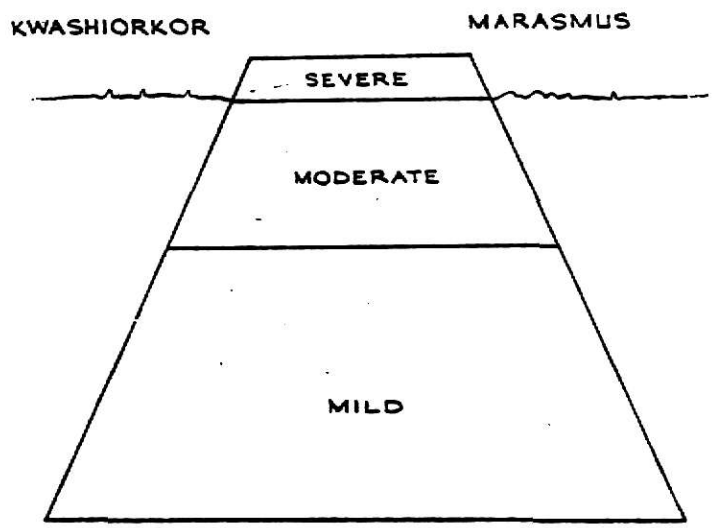


Fig. 1 The protein-energy malnutrition iceberg (37).

The difficulties of making anthropometric measurements on children begin with reliability of measurements and recordings and with decisions of which measurements to take, on which age group, and how to interpret data (17). Measurements should be made as much as possible the way the measurements were made for reference standards.

PROFILE OF MEASUREMENTS

Not all measurements are equally informative at all ages through maturity. The Committee on Nutritional Anthropometry (36) suggested measurements for the 1-6 year old group as follows:

- -minimum list for emergency conditions--length (crown-heel maximum), stem length (crown-rump maximum), standing length, weight
- -additional for surveys--chest circumference, arm and calf circumferences, and head circumference which could be eliminated at 3 years of age
- -desirable for surveys--bicristal and biacromial diameters and skin folds over triceps, below scapula and midaxillary
- -desirable for surveys, but impractical--postero-anterior X-ray film of hand and wrist

Jelliffe (6) recommended weight, length or height, arm circumference, and triceps skin fold where ages were known precisely and the following ratios if ages were not verifiable: weight-for-head circumference, weight-for-height, chest circumference-for-head circumference, and arm circumference-for-height. Despite this recommendation, recent textbooks of pediatrics (38-40) continued to omit discussions of arm circumference and skin folds.

Authors of current pediatric journal articles usually referred to weight, height, and head circumference (41-44) and less frequently to skin folds and arm circumference (45,46). Hospital nutrition support services are beginning to clarify their methods of assessment, but only a few authors (24,25) specified special parameters for assessment of children's needs for nutritional support. Growth curves of the National Center for Health Statistics (NCHS) (47) based on length or stature, weight, and head circumferences for children 0-36 months and for 2-18 years of age have been distributed to state and local health departments and have been adapted for use in hospitals, clinics, and physicians' offices (4,48).

Side of the body for measurements. By international convention some eighty years ago, the left side of the body was recommended for measurements (49). Generally the left side was chosen for measurements in surveys (12,13,49-51). Some authors (7,35,52) did not specify which arm was used and Burgert and Anderson (53) used both arms to compare triceps skin fold values between different calipers. Foster et al. (54) and Keet et al. (55) used the right arm for arm measurements. The Health Examination Survey (56) was based on skin folds on the right arm. Percentiles for triceps skin fold and arm muscle circumference in the

Ten-State Nutrition Survey of 1968-1970 (18) were based on right arm measurements. Blackburn et al. (57) described the protocol of nutritional assessment of hospitalized patients. During examination, arm measurements were to be taken on the non-dominant arm. The Handbook of Clinical Dietetics (58) recommended measurements on the dominant arm.

Age at which measurements are taken. Participants of a conference on "The Assessment and Recording of Measurements of Growth of Children" (5) recommended that weight, height or length, and head circumference should be taken at birth, at nursery discharge, and at 1, 2, 4, 6, 12, 18, 24, 30, and 36 months. Height and weight should continue to be taken at yearly intervals. Christakis (1) recommended that evaluation of growth data usually should be done at three month intervals in children under two years of age, but six month or yearly intervals were satisfactory for children over age two. During the course of therapy of malnourished hospitalized persons, body weight should be obtained daily and other anthropometric measurements every three weeks (57).

Some standards are based on age while others are age-independent. Measurements such as age-appropriate weight, length, and various circumferences are based on the principle that there are differences in rates of growth at various ages. Anthropometric techniques are based on measurement of one variable thought to be greatly affected by nutriture (numerator) compared with one less affected (denominator). The most obvious unaffected denominator is age. Since twenty deciduous teeth usually have erupted by 2 1/2 years of age, the dental second year may be used to establish approximate age (38).

If ages are not verifiable, ratios of a labile tissue to a stable tissue are recommended. Age-independent anthropometry is based on the ratio of a nutritionally unstable tissue such as subcutaneous fat or muscle mass compared with tissue upon which short-term malnutrition is likely to have less effect, such as height and head circumference (59-61). Since fat and muscle are most affected by acute malnutrition, weight and limb circumferences and mid arm muscle mass are likely to be reduced. The ratios of weight-for-height, arm circumference-for-height, and arm circumference-for-head circumference are comparisons of protein-energy stores with linear mass. The widely used denominator of height is relatively unaffected by acute nutriture, but is, of course, affected by chronic malnutrition (62).

Unlike age-independent anthropometry which is intended for a broad age range of early childhood, precise-age independence requires an approximate age category, especially of infants and secotrants (61). Measurements of this type may be of tissues which show a gradual change in the year considered; i.e., arm circumference shows a gradual change in the 2-4 year span (60) and triceps skin fold thickness changes gradually through the 1-5 year span (55).

SELECTION OF PARAMETERS OF MEASUREMENT

Traditionally the clinical assessment of growth is accompanied by basic measurements of height and weight, because rate of gain in both height and weight is accepted as a sensitive indicator of a child's state of health (29). Aside from height and weight, other indices may be of limited value in estimating nutritional status of U.S. children (1). If other indices prove meaningful for evaluating physical growth, the information should be applied. All measurements complement each other. Weight reflects body mass and height reflects linear growth. Arm circumference reflects muscle development or waste, whereas skin fold indicates calorie reserves.

Weight. Body weight alone is a limited measure of gross body size. The increment in weight gain during the second year is slightly less than the birth weight. A slow but constant yearly increment in weight averaging 2.0 kg during the third, fourth, and fifth years is apparent (38). Pomerance (63) collected data which reflected an average yearly increment of 2.3 kg from the second through the fifth year.

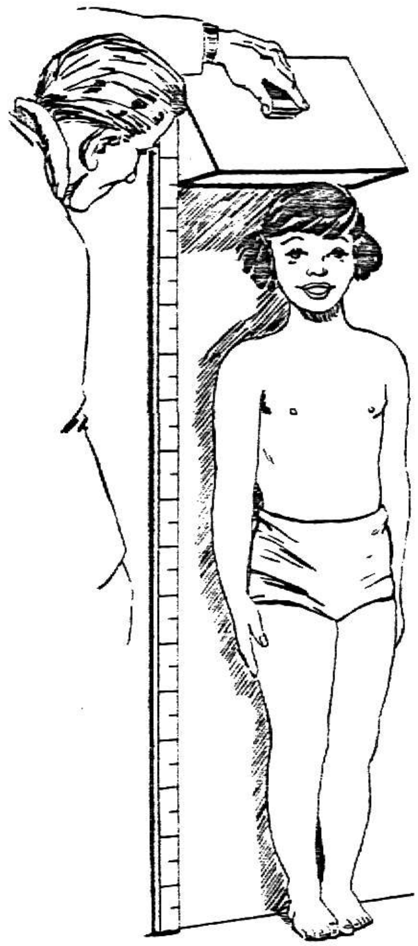
The National Center for Health Statistics (NCHS) reference data (47) for body weight from 2-18 years included standardized examination clothing weighing less than 0.1 kg between 2-5 years of age, and 0.1-0.3 kg from 6-18 years of age. Thus, shoes should not be worn during measurements. Weight was recorded to the nearest 0.1 kg (52,54) or to the nearest 0.25 kg (64). Beam, or lever, balance scales were preferred to spring-type scales because the latter become easily stretched from frequent use with expansion of the spring (6). Spring-type scales were used (12,13,65) and were standardized frequently with known weights.

Height or length. Measurements of height or length reflect total body length. Height increases at a slowly declining rate until the onset of puberty. Infants usually increase their length by 50% in their first year. Their length usually is doubled by 4 years of age and tripled by 13 years of age (3). The average child grows approximately 12.5 cm in the second year of life, 7.6-10 cm in the third year and approximately 5-7.5 cm per year thereafter until the growth spurt of puberty (2,63). Height velocities of less than 5 cm per year indicates need for further evaluation at a health center (66).

Standardized procedures for height or length are important. The NCHS reference data (47) for stature were obtained with children in stocking feet. Various reports (5,6,12,50) state that standing height is measured against a calibrated wall perpendicular with the floor, using a head board for horizontal fit at a right angle to the child's crown (fig. 2). The chin is parallel to the floor, bare heels are together, and heels, buttocks, and shoulders touch the vertical surface. Height usually is measured to the nearest 0.1 cm (54,64). Stadiometers have been used in some studies (33,47,66). Platform scales with moveable measurable rods were not recommended for measuring heights of children (5).

Supine body length (fig. 3) requires two examiners. One person holds the top of the infant's head in contact with a fixed headboard and the other holds the feet with toes pointed upward and brings a moveable foot board into contact against the heels (5). Hansman (67) and Pomerance (63) stretched out one leg leaving the other free so the infant would not feel restrained during their respective 40 year Denver study and 20 year New York study.

Length versus height. Some controversary exists about age to begin standing height instead of recumbent length. Vaughan et al. (38) suggested that recumbent length could be more accurate under 5 years of age at which time standing height becomes more convenient. According to Owen (5), recumbent length should be measured to the third year of life, although it may be impractical beyond 18 or 24 months. Hamill and coworkers (4) acknowledged that 2 year old children may be unwilling or unable to stand for satisfactory measurement of stature, so recumbent length may be used to 3 years. Hansman (67) measured children supine to 2 years and erect, subsequently. Length was used by Cheek et al. (52) and by Anderson (12) on children age 1-5 who were "too young to stand". Children between 3 and 6 years did not always comprehend the direction to stretch. Keys (36) stated that crown-heel length should be determined on patients who cannot readily stand.



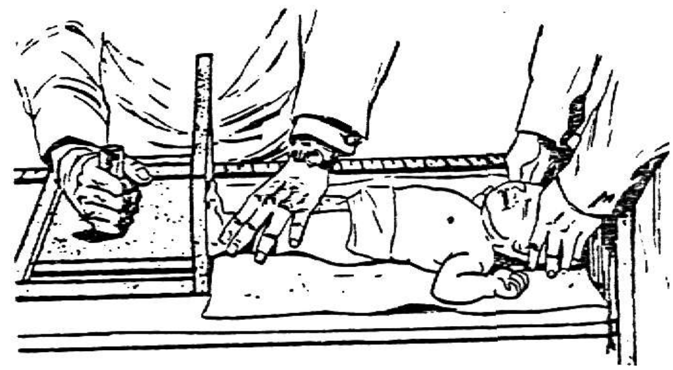
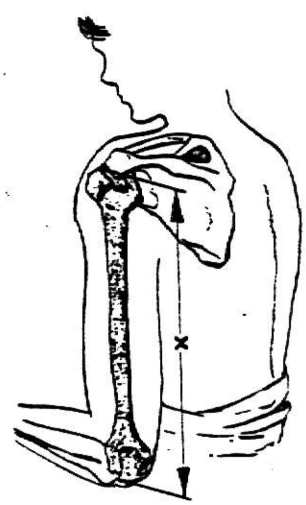


Fig. 3 Measurement of length of the infant (6).

Fig. 2 Measurement of height of the child (6).

Fig. 4 Measurement of head circumference (6).



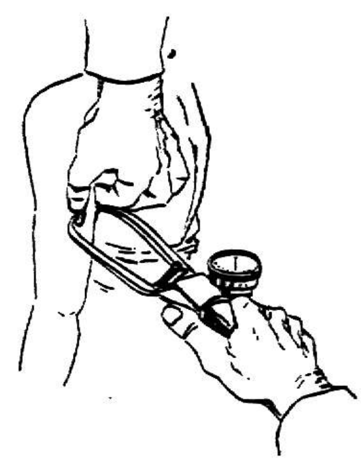


Fig. 5 Determination of midpoint of upper arm (37).

Fig. 6 Measurement of mid-upper arm circumference (37).

Fig. 7 Measurement of triceps skin fold with calipers (37).

The recumbent length may be as much as 2 cm greater than height (4,36); the difference may be closer to 1 cm after 4 or 5 years of age. If recumbent length is used beyond 5 years, the value obtained may be reduced by 1 cm to correspond to height (38). The difference would suggest growth deceleration. Percentile rankings would shift downward if length were plotted on the birth to 36 month chart of NCHS and stature were plotted at the next visit (4). The 2-18 year charts of NCHS specify height although some reference data taken between 2 and 3 years of age were, in fact, recumbent lengths.

Head circumference. The rapid increase in brain mass is accompanied by a rapid increase in the head circumference prenatally and during the first year. Head circumference achieves two-thirds of its potential growth by 24 months of age (68). Even though head circumference may not be useful for identifying malnourished children, it is an important screening measurement for micro- and macrocephaly due to nonnutritional medical abnormalities (4). A normal head size reflected the acute nature of a severe PEM of recently weaned Jamaican children (35). These children had a mean head growth of 1.9 cm after seven weeks of rehabilitation compared with an estimated gain of 0.75 cm.

The head circumference is taken to the nearest 0.1 cm with a non-stretchable tape which is applied firmly around the head just above the supra-orbital ridges or most prominent part of the frontal bulge, anteriorly, around the head at the same level on each side, and over that part of the occiput which gives maximum frontal-occipital circumference (fig. 4) (3,5,6,68). Head measurement may be discontinued at 3 years of age (36,38).

Chest circumference. The value of the chest circumference is in relation to the head circumference. After the first six months of life, the chest circumference should overtake that of the head, and the ratio of chest to head circumference should be greater than 1 (6). The chest of a child with PEM does not develop well; thus the chest circumference reflects nutriture. The chest circumference is taken mid-respiration at the level of the xiphoid cartilage to the nearest 0.1 cm (36,38). Coodin et al. (69) measured children at the level of nipples during quiet breathing but not necessarily at mid-respiration. The measurement is taken recumbent up to 5 years; the child stands thereafter (38).

Arm circumference. Various arm circumference indicators have been proposed (60). They have the advantage of being potentially easier, more rapid, and less expensive to obtain than weight and height. Arm circumference can be used to detect PEM in the vulnerable age group when mild forms of PEM may be missed by height and weight parameters (33). Arm circumference also can be used in relation to height or age. The mid-upper arm circumference allows a simple, but accurate, method of assessing the skeletal muscle compartment (70) which reflects the status of PEM. Growth retardation as shown by muscle depletion and by low weight-for-age are characteristic findings of PEM in children (6).

To measure arm circumference the midpoint of the upper arm must be determined (fig. 5). With the arm bent at the elbow at a 90^{o} angle and palm up, the midpoint is measured along the dorsal side of the upper arm between the acromial process of the scapula (bony protrusion on posterior of upper shoulder) and the olecranal process of the ulna (bony point of elbow). Measuring of mid-upper arm circumference follows location of midpoint with the arm hanging flaccid. A nonstretchable tape, 7-12 mm wide, is tightened snugly but not enough to cause skin contour indentation or pinching (fig. 6) (6). The measurement is taken to the 0.1 cm.

Skin fold thickness. Since subcutaneous adipose tissues constitute approximately 50% of adipose tissue stores, skin fold measurements can be used to judge total body fat (59). Skin folds can be measured accurately only at sites where a clean fold can be picked up from underlying tissues. The triceps and subscapular skin folds are considered to be the most satisfactory sites for measurement; they represent limb and trunk fat (56). The triceps skin fold thickness (TSF) was considered preferable by Jelliffe and Jelliffe (37) since standards are available.

Measurements of TSF are taken at a previously located midpoint on the upper arm on the posterior side directly in line with and mipoint to the acromion and olecranon of the child with the arm hanging free (fig. 7). (6). Foster et al. (54) placed partly closed right hand, palm up, into palm of left hand to measure skin fold for right arm. On crying babies, Keet et al. (55) had an assistant flex the elbow 45°.

The subscapular skin fold is measured 1" below the inferior angle of the scapula with the fold picked up at an angle of 45° to the spine (51,55,56). Biceps skin fold is measured over the midpoint of the muscle belly with the arm resting supinated on the subject's thigh (71). Frontal thigh skin fold is measured at the point of maximum circumference (72).

The examiner grasps a vertical pinch of skin and subcutaneous fat between thumb and forefinger 1 cm superior to site of measurement. The skin fold is gently pulled away from the underlying muscle tissue. This may be accomplished better by tightening the muscle, then relaxing it. While maintaining a grasp of skin fold, the jaws of the caliper are placed over the skinfold and allowed to close on its full pressure. Calipers should exert a constant pressure of 10 gm/mm^2 at all openings. Measurements generally were recorded to the nearest 1 mm or 0.5 mm.

STANDARDS OF REFERENCE

Identification of potential health and nutrition problems is based on "standards" which may have been derived from study samples. Appropriate standards must be selected based on the population being examined, availability of data on that segment of population presumed to have achieved optimal growth, and recommendations of agencies who have endeavored to standardize data from different parts of the world (1). Actual measurements can be compared to standards by:

$$\% \text{ standard} = \text{actual measurement} / \text{standard} \times 100$$

The Boston-Iowa standards, also called the Stuart-Meredith standards, were based on two sources of data. Standards of height and weight of children 1-4 years of age were based on measurements of children in Boston in the 1930's (73). Standards for children age 5-18 years of age were based on measurements of children and adolescents of Iowa City in the early 1940's (74). These norms have been used as reference standards in the United States and abroad. Although they are not based on the U.S. preschool population in the 1970's (10,29), the American Academy of Pediatrics recommended their use be continued for evaluation of height and weight until data collected in the Health Examination Survey (HES) can be used for new standards (5).

The head circumference standards developed by Nellhaus (68) also were recommended until data collected by the Fels Research Institute from 1929-1975 were grouped into percentiles by the National Center for Health Statistics (75). Tanner and Whitehouse (49) recently revised standards for triceps and subscapular skin folds on British children. Based on data derived from the United States Ten-State Nutrition Survey of 1968-1970 (18), Frisancho (9) reported percentiles for triceps skin fold, upper arm circumference, and muscle mass. Zeitlin (72) published percentile curves to serve as a reference standard for maximum thigh circumference. The current standards of reference are collated in appendix A-F.

Need for local standards. Jelliffe (6) stated that local standards in developing countries were based on measurements of children from low socioeconomic groups, who were, in fact, undernourished. Development of local standards were encouraged for different ethnic groups with potentially different patterns of growth (5,6,8).

The NCHS percentiles were recommended by the National Academy of Science Committee on Nutrition Advisory to the Center for Disease Control (76) and were recognized by participants in a workshop on "Physical Growth of Ethnic Groups Comprising the United States Populations" as the most appropriate available reference data (77). Data reported on preschool Indian children in Manitoba indicated that the NCHS growth standards for height, weight, and head circumference were valid and appeared to be applicable to children of most races (69). Habicht et al. (78) also considered that standards developed in western countries were relevant to children of most ethnic groups. They reported very small differences in growth among well-to-do ethnic groups--3% for height and 6% for weight. In contrast the growth differences in poor areas approached 12% for height and 30% for weight.

Gallo and Mestriner (79) reported on data collected on 2,115 children from birth to 18 years in Somalia. They found wide differences in the Somali means for height, weight, weight-for-height, and circumferences and the NCHS means. They proposed the construction of local growth charts. The Somali mean for height fell between the 10th and 25th percentiles of NCHS while the mean for weight fell between the 5th and 25th percentiles causing the Somali subjects to be analyzed below average for their age.