

to the value to be recorded. The tape is positioned so that large amounts of cranial hair (braids) are excluded. Anteriorly, the tape is placed just superior to the eyebrows and posteriorly it is placed so that the maximum circumference is measured. The tape need not be in the Frankfort Horizontal Plane, but the plane of the tape must be the same on both sides of the head. The tape is pulled tightly to compress hair and obtain a measure that "approximates" cranial circumference. The measurement is recorded to the nearest 0.1 cm.

### Purpose

Head circumference is a standard component of infant anthropometry because it is closely related to brain size (Cooke et al., 1977). After 36 months, growth in head circumference is slow although brain weight increases by about 30% after this age. Head circumference should be measured also in the parents of infants whose head circumferences are abnormal because head circumferences of parents and their offspring are closely associated and adjustment equations are available (Illingworth & Eid, 1971).

### Literature

There is widespread agreement regarding the technique to be used except that gentle pressure is used by some Dutch workers and in Swedish Infant Welfare Clinics. In addition, a wide tape (2 cm) is used in Swedish Infant Welfare Clinics. Measurements made with a tape 0.6 cm wide are about 0.5 cm smaller than those made with a tape 2 cm wide (Karlberg et al., 1976).

### Reliability

In the Fels Longitudinal Study the intermeasurer differences were small and independent of age, with technical errors of 0.09 mm and coefficients of variation of .02 (Roche et al., 1987). Wilmore and Behnke (1969) reported a test-retest correlation of .96 for measurements of young men 1 day apart.

### Sources of Reference Data

#### Children

Nellhaus, 1968  
Roche & Himes, 1980  
Roche et al., 1987

#### Adults

Churchill et al., 1977  
White & Churchill, 1971

## Minimal Neck Circumference

### Recommended Technique

The subject does not wear any clothes around the neck and sits or stands erect with the head in the Frankfort Horizontal Plane (see Figure 2). The measurer stands facing the left side of the subject. A self-retracting inelastic tape is applied around the neck just inferior to the laryngeal prominence (Adam's Apple; see Figure 2). The minimal circumference is measured to the nearest 0.1 cm, with the tape perpendicular to the long axis of the neck. The tape will not necessarily be horizontal. The zero mark on the tape should be inferior to the value that will be recorded. The pressure of the tape on the skin should be minimal while maintaining complete contact. The measurement should be made in less than 5 s to avoid discomfort.

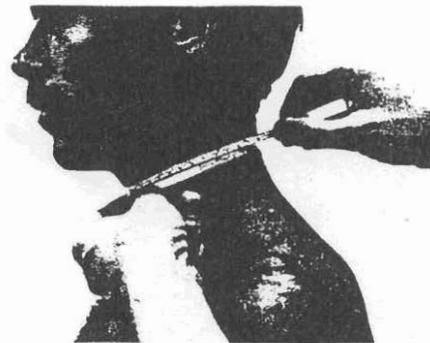


Figure 2 Measurement of minimal neck circumference.

### Purpose

Minimal neck circumference can be used in the study of growth, motor and athletic performance, obesity, and aging. The measurement can have useful medical and engineering applications.

### Literature

The general consensus is that neck circumference should be measured with the head in the Frankfort Horizontal Plane and should be performed

similarly in children and in adults. It has been recommended that neck circumference be measured with the subject standing (Behnke & Wilmore, 1974), but others have recommended a sitting position (Anthropology Research Project, 1978).

In the 1978 Anthropology Research Project "Anthropometric Source Book," the measurement is defined as "the maximum circumference of the neck at a point just inferior to the bulge of the thyroid cartilage" (Volume I: *Anthropometry for Designers*) and later as "the maximum circumference of the neck, including the Adam's Apple" (Volume II: *A Handbook of Anthropometric Data*). Wilmore and Behnke (1969) suggested that this circumference be measured "just inferior to the larynx."

Most have measured at right angles to the long axis of the neck, as is recommended, but some have described the measurement as "taken in the horizontal plane, just below the level of the thyroid cartilage" (Weiner & Lourie, 1981).

### Reliability

There are few reliability data. Wilmore and Behnke (1969), from test-retest data for college-aged males, reported that neck circumference was a reliable measurement with an interclass correlation of .95. Gavan (1950) concluded that neck circumference was a measurement of medium reliability.

### Sources of Reference Data

#### Children

Pieper & Jürgens, 1977  
Snyder et al., 1975

#### Adults

Clauser et al., 1972  
White & Churchill, 1971

## Shoulder Circumference

### Recommended Technique

The measurement of shoulder circumference requires that the subject be dressed so that the appropriate landmarks can be located. The subject stands, head erect and looking ahead with weight evenly distributed between both feet, which are about 5 cm apart, and with shoulders back and the arms by the sides (see Figure 3). The measurement



Figure 3 Subject position for shoulder circumference measurement.

is made at the end of a normal expiration. This can be accomplished easily by engaging the subject in light conversation, or by asking that the subject count to 10 during the measurement. The tape is positioned over the maximum muscular bulges (deltoid muscles) inferior to each acromion (see Figure 4). A mirror, or assistant, helps to ensure that the tape is horizontal. The tape is held snug, in contact with the skin, without compressing the tissue. The measurement is recorded to the nearest 0.1 cm.

### Purpose

Shoulder circumference reflects muscular development of the shoulder regions and upper thorax.



Figure 4 Measurement of shoulder circumference.



Figure 6 Measurement of chest circumference.

### Purpose

In infants and children, chest circumference serves as a screening variable for malnutrition. In children and adults, it can be used as an index of frame size.

### Literature

The tape measure should be divided to metric units with unequivocal identification of millimeters and centimeters. There should be a free space between the end of the tape and the zero line to facilitate handling. Spring-loaded tapes are not recommended because they may indent the soft tissues.

Chest circumference has been measured at various sites and at various phases of the respiratory cycle (Behnke & Wilmore, 1974; De Garay et al., 1974; Hrdlička, 1920; Simmons, 1944; Weiner & Lourie, 1981). Consideration was given to the possibility of measuring chest circumference at maximum inspiration and at maximum expiration, which would provide an index of respiratory functional capacity. This is not recommended for general use because it is not applicable to the very young and the elderly, and it does not match the recommended techniques for other thoracic and abdominal dimensions. If all these dimensions were measured at both maximum inspiration and at maximum expiration, many additional measurements would be necessary.

The most frequently mentioned anatomical landmark on the anterior aspect of the thorax is the nipple, which corresponds approximately to the fourth intercostal space (Bailey, 1967; Behnke & Wilmore, 1974; De Garay et al., 1974; Osborne & De George, 1959; Ross & Marfell-Jones, 1982; Singh & Bhasin, 1968). Weiner and Lourie (1981) suggested that the tape be placed at the level of the third and fourth sternbrae, whereas Olivier (1960) recommended a level superior to the nipples.

The position of the tape on the posterior aspect of the thorax is described generally as either crossing the lower angles of the scapulae or passing just distal to them (Bailey, 1967; De Garay et al., 1974; Singh & Bhasin, 1968). Note that when a tape is placed anteriorly at or superior to the nipples and distal to the inferior angles of the scapulae posteriorly, the plane of measurement slopes postero-inferiorly. Alternative levels described in the literature include the xiphoid process (Hrdlička, 1920; Osborne & De George, 1959; Simmons, 1944) and the axilla (Snyder et al., 1975). Ross et al. (1982) recommended that measurements of the chest be made at a midsternal level in a horizontal plane without reference to anatomical landmarks on the posterior aspect of the thorax.

The time of measurement within the respiratory cycle ranges from maximum inspiration and expiration (De Garay et al., 1974; Hrdlička, 1920; Simmons, 1944) to normal or quiet inspiration and expiration (Weiner & Lourie, 1981) and to mid-respiration (Behnke & Wilmore, 1974).

### Reliability

Intermeasurer and intertrial reliability coefficients are generally slightly lower than those for limb measures but are well within acceptable ranges. Weltman and Katch (1975) reported intertrial and intermeasurer correlations between .94 and .99. Slaughter, Lohman, and Boileau (1978) reported intertrial correlations greater than .90 for chest circumferences of children from 7 to 12 years of age.

### Sources of Reference Data

#### Children

Meredith, 1970  
Malina et al., 1973  
Slaughter et al., 1978

#### Adults

Stoudt et al., 1970  
Weltman & Katch, 1975

## Waist Circumference

### Recommended Technique

The subject wears little clothing so that the tape may be correctly positioned. The measurement should not be made over clothing. If clothing must be worn, subjects should undress to light underwear and wear only a cloth or paper smock dur-

ing the measurement. The subject stands erect with the abdomen relaxed, the arms at the sides and the feet together. The measurer faces the subject and places an inelastic tape around the subject, in a horizontal plane, at the level of the natural waist, which is the narrowest part of the torso, as seen from the anterior aspect (see Figure 7). An assistant is needed to help position the tape in a horizontal plane. In some obese subjects, it may be difficult to identify a waist narrowing. In such cases, the smallest horizontal circumference should be measured in the area between the ribs and iliac crest. The measurement should be taken at the end of a normal expiration, without the tape compressing the skin. It is recorded to the nearest 0.1 cm.



Figure 7 Measurement of waist circumference.

### Purpose

Waist circumference is an index of deep adipose tissue (Borkan et al., 1983), and it is related to fat-free mass (Jackson & Pollock, 1976). When used in a ratio with the thigh or buttock (hip) circumference, waist circumference is an indicator of the degree of masculine distribution of adipose tissue: The higher the waist to the thigh or buttock (hip) ratio, the more masculine the pattern of adipose tissue distribution and the greater the risk of diseases such as noninsulin-dependent diabetes mellitus (Hartz et al., 1984; Krotkiewski et al., 1983). Waist circumference is highly correlated with weight/stature<sup>2</sup> (Kannel & Gordon, 1980), which is an index of general obesity. Waist circumference has important applications in human engineering.

### Literature

Waist circumference has usually been measured at the smallest circumference of the torso, which is at the level of the natural waist (Garrett & Kennedy, 1971). Some measure "waist circumference" at the level of the umbilicus, but this leads to recording larger values.

### Reliability

The technical error of measurement in adolescents is 1.31 cm for intrameasurer errors and 1.56 cm for intermeasurer errors (Malina et al., 1973). The technical error of measurement in the elderly is 0.48 cm in men and 1.15 cm in women (Chumlea et al., 1984b). Thus, the "true" measurement of an individual would typically be within  $\pm 1$  cm of the measured value in most cases.

### Sources of Reference Data

#### Children

Huenemann et al., 1974  
Roche & Malina, 1983

#### Adults

National Aeronautics and Space Administration, 1978  
Stoudt et al., 1970

## Abdominal Circumference

### Recommended Technique

If clothing must be worn, subjects should undress to light underwear and wear only a cloth or paper smock during the measurement. The measurer faces the subject. The subject stands with the arms by the sides and the feet together. The procedures are the same as those to be followed for the waist circumference, except that the tape is placed around the subject at the level of the greatest anterior extension of the abdomen in a horizontal plane. This level is usually, but not always, at the level of the umbilicus (see Figure 8). An assistant is needed to position the tape behind the subject. The tape is held snug against the skin without compressing the tissues and with its zero end below the value to be recorded. The measurement is made at the end of a normal expiration to the nearest 0.1 cm.

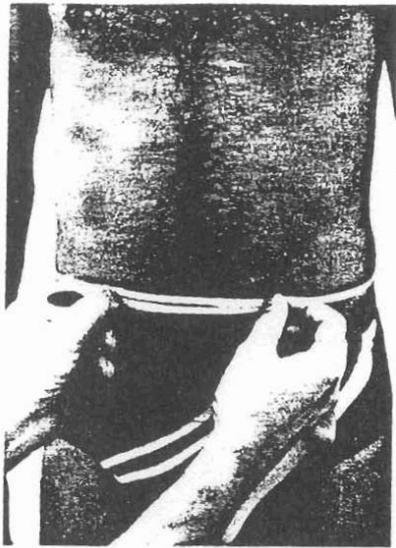


Figure 8 Measurement of abdominal circumference.

### Purpose

The abdominal circumference, like the waist circumference, is an anthropometric indicator of subcutaneous and deep adipose tissue. It differs from the waist circumference in being the maximum circumference of the abdomen and, therefore, may be a better indicator of adipose tissue. It is probable that the waist and abdominal circumferences are highly correlated, although the extent is unknown because in most studies one or the other measurement is recorded.

### Literature

The recommended procedure is the one used commonly (Behnke, 1963; Hertzbert et al., 1963; Huenemann et al., 1974; Wilmore & Behnke, 1969).

### Reliability

Wilmore and Behnke (1969) reported a test-retest correlation of .99 in young men measured 1 day apart.

### Sources of Reference Data

#### Children

Huenemann et al., 1974

#### Adults

National Aeronautics and Space Administration,  
1978

Clauser et al., 1972

Hertzberg et al., 1963

## 3 Buttocks (Hip) Circumference

### Recommended Technique

The subject should wear only nonrestrictive briefs or underwear, or light smock over underwear. The subject stands erect with arms at the sides and feet together. The measurer squats at the side of the subject so that the level of maximum extension of the buttocks can be seen. An inelastic tape is placed around the buttocks in a horizontal plane at this level without compressing the skin (see Figure 9). An assistant is needed to help position the tape on the opposite side of the subject's body. The zero end of the tape should be below the measurement value. The tape is in contact with the skin but does not indent the soft tissues. The measurement is recorded to the nearest 0.1 cm.

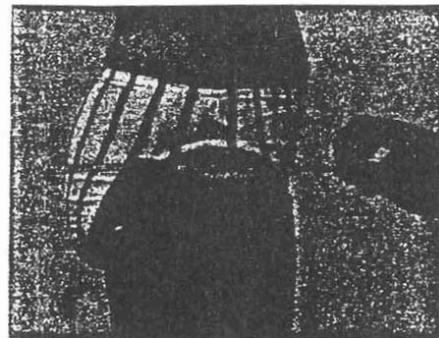


Figure 9 Measurement of buttocks (hip) circumference.

### Purpose

Buttocks (hip) circumference is a measurement of external pelvic size that reflects the amount of adipose tissue in the region. As defined, it is more properly called "buttocks circumference" than "hip circumference." Adipose tissue in this region is largely subcutaneous and relates to the lower segment of the body. Hence, buttocks circumference is an indicator of lower body fatness. Used in conjunction with waist circumference, in the waist-to-hip (buttocks) circumference ratio, it is an indicator of the pattern of subcutaneous adipose tissue distribution, with low values being characteristic of women. This type of adipose tissue distribution is associated with a decreased risk of diabetes mellitus in men and in women (Krotkiewski et al., 1983; Hartz et al., 1984). In addition, the buttocks circumference has important applications in human engineering.

## Literature

There are many ways in which a circumference around the hip region has been measured (Garrett & Kennedy, 1971). These can be reduced to two basic methods, plus a combination of the two. In the first, usually called "buttocks circumference," the measurement is made horizontally at the level of maximum extension of the buttocks posteriorly, as recommended. In the second, the circumference is measured horizontally at the level of the greatest lateral extension of the hips, the usual landmark being the greater trochanter. The buttocks level is recommended because it is easier to locate than the trochanteric level, because buttocks adipose tissue is related to lower limb adipose tissue (Mueller & Wohlleb, 1981), and because the buttocks circumference is generally the maximum circumference of the hip area in a horizontal plane.

Usually the trochanteric level is inferior to the level of the maximum extension of the buttocks posteriorly. Hence, when a circumference is measured at the trochanteric level, the tape tends to slip down over the buttocks. In very obese subjects, the anterior abdominal wall may sag and be included in the measurement. This is a potential problem with either of the two main methods for measurement.

Some pass the tape around both the trochanteric and buttock areas (Montagu, 1960). With this technique, the circumference is measured in an oblique plane leading to a less well-defined circumference and larger measurement errors. In the epidemiological literature, the method for the measurement of buttocks circumference is often omitted (Kalkhoff et al., 1983), or it deviates considerably from usual procedures. Some have measured this circumference at the level of the iliac crest, which is virtually the same as waist circumference (Ohlson et al., 1985).

## Reliability

Little is known about the reliability of buttock circumference measurements. In a U.S. National Survey of adolescents, the technical error of measurement was 1.23 cm for intrameasurer errors and 1.38 cm for intermeasurer errors (Malina et al., 1973). Thus, the true value for an individual will be within approximately 1 cm of that recorded in most determinations. Using a slightly different measurement technique, Behnke and Wilmore (1969) found a correlation of .99 between measurements 1 day apart in young men.

## Sources of Reference Data

### Children

Huenemann et al., 1974  
Roche & Malina, 1983

### Adults

National Aeronautics and Space Administration, 1978  
Clauser et al., 1970  
White & Churchill, 1971

## Thigh Circumference

### Recommended Technique

The subject wears a bathing suit or other minimal clothing so that the appropriate landmarks can be located. Measurement of the proximal and distal thigh circumferences requires only a measuring tape. Measurement of midthigh circumference requires a grease pencil and a bench. The subject places the left foot flat on the top of the bench so that the knee is flexed to about 90°. An alternative positioning for the measurement of midthigh circumference is for the subject to sit erect with the knees flexed to about 90°. Each of the measurements is made with the subject standing, with the heels about 10 cm apart and the weight evenly distributed between both feet. The three locations are illustrated in Figures 10 and 11.

**Proximal Thigh Circumference.** A tape is passed horizontally around the thigh, immediately distal

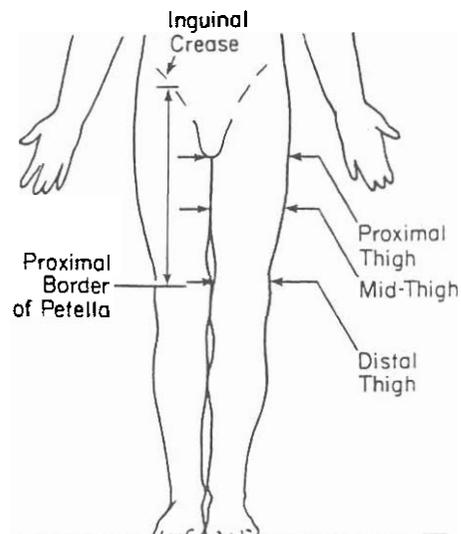


Figure 10 Anterior view of locations for thigh circumferences.