Part II

Diagnosis
Anthropometric Indices of Obesity and Regional Distribution of Fat Depots

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INTRODUCTION AND BACKGROUND

Body fatness and body shapes have been topics of interest to people over the ages because of health considerations, but scientific assessment and presentation have been complicated by changing fashions and a range of myths. Many methods of measuring body fatness have been developed for epidemiological field studies or clinical use, based on laboratory methods such as underwater weighing as a conventional ‘gold standard’. This two-compartment model estimates body composition with the assumption that the densities of lean (1.1 kg/L) and adipose (0.9 kg/L) tissues are constant (1). Indices of obesity have been derived to assess body composition and health at the present, and to predict future health. Rarely a method has been developed specifically for self-monitoring by lay people. One of the tantalizing features of research in body composition is the lack of any true gold standard from which to calibrate other methods. Direct measurement by chemical analysis, either by macroscopic dissection or by lipid extraction, is of limited value as it cannot be related to measurements \textit{in vivo}.

PURPOSES AND APPLICATIONS OF ANTHROPOMETRY

Simple and cheap anthropometric methods are useful for epidemiological surveys of large numbers of subjects across the population. For clinical use, anthropometric methods are useful tools for diagnosis and monitoring patients. The most appropriate methods may vary depending on whether the need is for cross-sectional or longitudinal assessment. In research studies, physiological characterization of individuals is assessed by a range of anthropometric measurements. One of the most fundamental issues in employing anthropometric measurements to assess body fat is that the prediction equations must be validated in a similar population to that to which the equations are being applied.

METHODS COMMONLY USED TO MEASURE BODY FATNESS

Laboratory Standard Methods

For small studies, total body fat is estimated by standard methods (Table 4.1) such as underwater...
Table 4.1  Methods of measuring body fat and fat distribution

<table>
<thead>
<tr>
<th>Methods</th>
<th>Accuracy</th>
<th>Practicality</th>
<th>Sensitivity to change</th>
<th>Cheapness</th>
<th>Fat distribution detection</th>
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</thead>
<tbody>
<tr>
<td>Laboratory: ‘standard’ methods</td>
<td></td>
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<tr>
<td>Underwater weighing</td>
<td>++</td>
<td>++</td>
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<td>++</td>
<td>-</td>
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<tr>
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<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Dual-energy X-ray absorptiometry</td>
<td>+</td>
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<tr>
<td>Computerized tomography</td>
<td>++</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Magnetic resonance imaging</td>
<td>+++++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Multi-compartment models</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Air displacement (BOD POD)</td>
<td>?</td>
<td>+</td>
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<td>++</td>
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</tbody>
</table>

Field: anthropometric methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Accuracy</th>
<th>Practicality</th>
<th>Sensitivity to change</th>
<th>Cheapness</th>
<th>Fat distribution detection</th>
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<tr>
<td>Skinfold thickness</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Circumference</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++++</td>
<td>+</td>
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<tr>
<td>Body mass index</td>
<td>++</td>
<td>++</td>
<td>+++</td>
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Figure 4.1  Measuring total body fat by underwater weighing

weighing (Figure 4.1), potassium-40 ($^{40}$K) counting, or more recently by imaging techniques such as dual-energy X-ray absorptiometry (DEXA) (which was itself calibrated against underwater weighing), computerized tomography (CT) scan and magnetic resonance imaging (MRI) (Figure 4.2). All these methods make assumptions about composition of ‘average’ tissues, e.g. density of fat, constant $^{40}$K of
magnetic resonance imaging scanner used to image body tissues

**Figure 4.2** Magnetic resonance imaging scanner used to image body tissues

Depend on the resolution of imaging, and they also fail to detect fat within organs such as liver, muscles and bones. Cadaver dissection, coupled with chemical analysis, should theoretically overcome this problem, but there is a very real practical limitation through the time required for dissection and alteration in tissue hydration.

### Field Anthropometric Methods

Using an underwater weighing method to predict body fat is impractical for large field studies, requiring facilities and the cooperation of subjects and expertise of the investigators. Proxy anthropometric methods (Table 4.1) have been employed including skinfolds (2), body mass index (BMI) (3), and skinfolds combined with various body circumferences (4–6) to predict body fat estimated by underwater weighing. Body fat predicted from these equations shows high correlations with body fat measured by underwater weighing and relatively small errors of prediction. However, there have been few major validations of these equations in independent populations to test their generalizability or applicability in special population subgroups.

The most widely used field method for total fat has been the four-skinfold methods (Figure 4.3), derived from underwater weighing (2). Recognizing possible errors of predicting body fat in subpopulations with altered fat distribution, regression equations including waist circumference (Figure 4.4) appear to have advantages in predicting total body fat by taking some account of this variation in fat distribution (6).

Waist circumference, alone, predicts health (7) as well as body composition and is recommended for public health promotion (8,9).

Previously, little attention has been paid to developing an index of adiposity that could be used by lay people. The BMI has been the traditional index of obesity, but its concept and calculations are not readily understood by many. Criteria for classification of overweight and obesity have been inconsistent. Conventional classification of BMI, using the same criteria for both men and women, is based on life insurance and epidemiological data. Waaler (10) has shown a U-shaped relationship between BMI and mortality rates, with exponential increases of mortality in adult subjects with high BMI \(( > 30\, \text{kg/m}^2)\) or low BMI \(( < 20\, \text{kg/m}^2)\). These cri-
Figure 4.3 Measuring subcutaneous skinfold thicknesses at the sites of biceps, triceps, subscapular and suprailliac using skinfold calipers

Criteria for interpreting BMI do not apply to children, whose BMI is normally much lower than that of adults. The arbitrary cut-offs for overweight at BMI 25 and for obesity at BMI 30 kg/m² have now been adopted by the National Institutes of Health (8) in America and World Health Organization (11). These cut-offs have been used widely in Europe for many years.

MEASURING BODY COMPOSITION IN SPECIAL GROUPS

There are major effects of age on body composition which mean that anthropometric methods may not always be valid. A major pitfall is the unquestioning use of equations to predict body fat derived from one population group, without subsequent validation in another specific population group.

Infants and Children

For infants, the 'reference' methods used to determine body composition in infants include ¹⁸O isotope dilution (12) and DEXA (13). The ponderal index (weight divided by height cubed) has been used as an anthropometric method to assess body fatness. Measuring children's body composition is problematic, as their tissue composition varies with growth, the rate and timing of growth vary widely, and physical activity influences the composition of fat free mass (14). Several studies have used doubly labelled water to monitor children's growth and estimate their total body water, and thus body composition. Reference values for body weight and triceps skinfold thickness of British children have been provided by Tanner and co-workers (15–17), although the Tanner reference values for weight are no longer appropriate in the UK. In a validation study, Reilly et al. (18) have shown that the skinfold method produces large errors in predicting body fat.
of 9-year-old children. These workers used underwater weighing as the reference method and found it acceptable even to very young children. As a generalization, anthropometric methods to estimate body fat are not reliable in children. BMI can be used, but with caution in its interpretation because of variable stages of development at the same age. There are standard BMI reference curves (Figure 4.5) developed by Cole et al. (19) for the Child Growth Foundation.

Ageing and Elderly

Intra-abdominal fat increases with age and immobility, and thereby tends to invalidate the subcutaneous skinfold methods. In postmenopausal women, body fat may accumulate intra-abdominally as a result of hormonal changes. Consequently, subcutaneous skinfold methods may underestimate their total body fat.

Athletes

In athletes, BMI does not reflect body fat very well, particularly in power athletes who have large muscle mass. Inaccuracies in anthropometric prediction equations stem from the reference methods, such as underwater weighing, from which they are derived since the density of these subjects’ lean tissues is considerably higher than the 1.1 kg/L value (1) used for estimating body composition in the ‘normal’ population. Muscle varies considerably as a proportion of total lean body mass.

Illness

Conventional anthropometric prediction equations break down with altered relative body composition. For example, patients with advanced tuberculosis and cancer or with benign oesophageal stenosis may have similar BMIs as a result of weight loss, but muscle loss is likely to be greater in a cachectic inflammatory condition. Errors will therefore result from using the same body composition prediction equations. Illnesses that result in considerable loss of minerals or specific tissues, e.g. muscle wasting in patients with acquired immune deficiency syndrome (AIDS), may result in an overestimation of body fat using conventional prediction equations. In contrast, in patients with non-insulin-dependent diabetes mellitus (NIDDM) (Type 2 diabetes) who have increased intra-abdominal fat, there is underestimation of body fat using skinfold methods, which increases with the amount of central fat deposition (20). There is a problem in measuring body composition of amputees whose substantial absence of muscle mass gives unrealistic BMI values. In bed- or chair-bound patients, height measurement is not available for calculation of BMI. Alternative methods including arm span and lower leg length can be used to predict height with an accuracy within 4 cm (21).

ANTHROPOMETRIC ASSESSMENT OF OBESITY

Predicting Total Body Fat from Skinfold Thicknesses

Four skinfold thicknesses are conventionally meas-
Figure 4.5 Standard body mass index curves from birth to 20 years for boys (a, above) and girls (b, opposite). Copyright © Child Growth Foundation. Reproduced by permission. Copies of the CGF BMI charts are available from Harlow Printing, Maxwell Street, South Shields NE33 4PU, UK.

ured (Figure 4.3), using calipers at biceps, triceps, subscapular and suprailiac, and the sum of all four skinfolds (equation 1), or just the triceps skinfold (equation 2), with subjects’ age, are used in linear multiple regression to predict total body fat. The original equations for use in adults (2) have been cross-validated in a separate sample and found to be robust in adults aged 20–60 years (6), but tend to underestimate substantially the total fat in the elderly, particularly women (6,22) (Figure 4.6).

Body fat % (men) = \[30.9 \times \log_{10} \sum \text{skinfolds (mm)} + [0.271 \times \text{Age (years)}] - 39.9\] (1)

Body fat % (women) = \[30.8 \times \log_{10} \sum \text{skinfolds (mm)} + [0.274 \times \text{Age (years)}] - 31.7\]
Body fat % (men) = (1.31 \times \text{Triceps}) + (0.430 \times \text{Age}) - 9.2 \\
Body fat % (women) = (0.944 \times \text{Triceps}) + (0.279 \times \text{Age}) + 4.6

**Predicting Total Body Fat from Waist Circumference and Triceps Skinfold**

Han and Lean (20) have observed a systematic underestimation of body fat by equations using subcutaneous skinfold thicknesses (2) in subjects with increased intra-abdominal fat mass, reflected by a high waist circumference or waist-to-hip ratio, including the elderly and those with type 2 diabetes. Waist circumference (Figure 4.4) has been found to correlate highly with both intra-abdominal and total fat masses (6,23), and was used on its own and with skinfold thicknesses to develop new regression equations to correct for the intra-abdominal fat mass (6). These equations were validated in a large Dutch sample from previous study of body fat distribution (3).
Equations using waist circumference alone, adjusted for age (equation 3), showed good prediction of body fat in the independent Dutch sample ($r^2 = 78\%$) with similar error of prediction as other equations. These equations are particularly good for estimating body fat in the elderly without the systematic underestimation of body fat that occurs in the subcutaneous skinfold method (Figure 4.6).

Body fat % (men) = \[0.567 \times \text{Waist circumference (cm)} + [0.101 \times \text{Age (years)}] - 31.8 \] \hspace{1cm} (3)

Body fat % (women) = \[0.439 \times \text{Waist circumference (cm)} + [0.221 \times \text{Age (years)}] - 9.4 \]

Equations combining waist circumference and triceps skinfold, adjusted for age (equation 4), have been shown to improve predictive power of body fat estimation without systematic errors over equations employing subcutaneous skinfolds alone in subjects with type 2 diabetes who had increased intra-abdominal fat mass (20).

Body fat % (men) = \[0.353 \times \text{Waist (cm)} + [0.756 \times \text{Triceps (mm)}] + 0.235 \times \text{Age (years)}] - 26.4 \] \hspace{1cm} (4)

Body fat % (women) = \[0.232 \times \text{Waist (cm)} + [0.657 \times \text{Triceps (mm)}] + 0.215 \times \text{Age (years)}] - 5.5

**Calculations of Body Mass Index (Quetelet Index), and its Use to Predict Body Fat**

Bigger people—both taller and fatter—are heavier than small people. Body weight includes fat, muscle and all other organs. For people of the same height, most of the variation in weight is accounted for by different amounts of body fat. BMI aims to describe weight for height in a way which will relate maximally to body weight (or body fat) with minimal relation to height (24). BMI is calculated as the ratio of weight in kilograms divided by height squared ($m^2$). Since BMI uses height, the height measurement needs to be very accurate. Classification of BMI (Table 4.2) uses the same criteria for both men and women is now adopted by both the NIH (8) and WHO (25). A BMI of 18.5 to 24.9 kg/m$^2$ is considered as in the normal range, above 25 kg/m$^2$ as overweight and above 30 kg/m$^2$ as obese. For some purposes, the obese category is subclassified by the WHO (25) as 30–34.9 (moderately obese), 35–39.9 (severely obese), and greater than 40 (very severely obese) kg/m$^2$.

BMI can be used to predict body fat from underwater weighing from equations using waist circumference ($r^2 = 79\%$) with age and sex corrections (3). Our derived equations using BMI to predict body fat were validated in the independent sample provided by Deurenberg et al. (3) and showed similarly good prediction of body fat as other equations currently in use (equation 5).

Body fat % (men) = \[1.33 \times \text{BMI (kg/m}^2\text{)} + [0.236 \times \text{Age (years)}] - 20.2 \] \hspace{1cm} (5)

Body fat % (women) = \[1.21 \times \text{BMI (kg/m}^2\text{)} + [0.262 \times \text{Age (years)}] - 6.7

**ANTHROPOMETRIC ASSESSMENT OF BODY FAT DISTRIBUTION**

People with central fat distribution in both sexes
tend to have a distinct body shape, said to resemble that of an apple (Figure 4.7), a physical characteristic of men (termed ‘android’ by Vague) which tends to be associated with metabolic abnormalities and chronic diseases (26–31).

Body circumferences and their ratios are used to indicate the distribution of body fat. The most important variations, in terms of health associations, are between the amounts of fat in internal, mainly intra-abdominal sites, as distinct from subcutaneous sites (Figure 4.8). The ‘gold standard’ for measuring fat depots in these sites is scanning by MRI (Figure 4.2). CT gives almost equal information but the small radiation exposure limits its acceptability.

### Waist-to-hip Ratio

The ratio of waist-to-hip circumferences (Figure 4.4) was the first anthropometric method developed from epidemiological research as an indicator of fat distribution in relation to metabolic diseases. Waist-to-hip ratio is related more closely to the ratio of intra-abdominal fat/extra-abdominal fat mass than the absolute amount of intra-abdominal fat mass (32), and has been shown to relate to mortality from coronary heart disease and type 2 diabetes independent of BMI (28,29). Most of the value in indicating body fat is derived from waist circumference, the hip circumference probably reflecting several other body tissues such as bones and muscles. The waist-to-hip ratio may have some particular value in reflecting diseases which involve muscle reduction as well as fat deposition, e.g. type 2 diabetes (33).

### Waist-to-thigh Ratio

In some studies waist-to-thigh ratio has been used as an index for fat distribution to relate to metabolic risk factors (34). This ratio is also influenced by abdominal fat as well as fat mass, muscle mass and bone structures of the thigh, which may be a strong indicator of certain health conditions involving both abdominal fat accumulation and skeletal muscle wasting such as NIDDM.

### Conicity Index

The conicity index was formulated by Valdez (35) to estimate abdominal fat, based on the theory that leaner subjects have a body shape similar to a cylinder, but as fat is accumulated around the abdomen, the body shape changes towards that of a double cone (two cones with a common base at the waist). With the assumption that the average human body density is 1.05 kg/m³, the equation was derived as:

\[
\text{Conicity index} = \frac{\text{Waist}}{0.109 \times \sqrt{\frac{\text{weight}}{\text{height}}}}
\]

The conicity index is theorized to have a built-in adjustment for height and weight so that abdominal adiposity can be compared across different populations of varying heights and weights (36). The index is related to the ratio of intra-abdominal fat/extra-abdominal fat mass similarly to waist-to-hip ratio, and may be useful when hip measurement is not available. Valdez et al. (36) found the conicity index to be correlated to cardiovascular risk factors similarly to that of waist-to-hip ratio in different countries. A drawback is that the index has not been cross-validated to ensure applicability.

### Sagittal Abdominal Diameter

The use of sagittal diameter of the waist has been proposed as an index of abdominal fatness based on a theory that fat deposition in the anteroposterior axis is more ‘dangerous’ than lateral fat deposition. This index has not been validated in an independent population. Sagittal diameter can be measured using a pelviometer in the standing position, or a more sophisticated instrument that is modified from a sliding stadiometer in the supine position (37). Gadgets are on sale with a back plate which is...
flexible, thereby introducing enormous errors. The measurement of sagittal diameter of the waist has not been used very widely. This method has recently been validated by CT scanning and found to have high reproducible results.

**Abdominal Cross-sectional Area**

Abdominal cross-sectional area (CSA_A) has also been proposed by van der Kooy et al. (38) as an index of abdominal fat and is calculated from waist sagittal (WSD) and waist transverse diameters (WTD) as: \( CSA_A = \frac{4 \times WSD \times WTD}{\pi} \), but this more complicated method is not likely to be much different from a circumference or a single measurement of waist diameter.

**Waist Circumference**

Recent proposals for the use of waist circumference as a single measurement of body fat and fat distribution have now been adopted by several major public health promotion agencies and organizations (8,9,21).

Waist circumference has been suggested as a simple measurement to identify individuals with high BMI or high waist-to-hip ratio. Waist circumference correlates significantly with BMI (both men and women: \( r = 0.89; P < 0.001 \)). Lean et al. (39) have derived the ‘action levels’ for weight management based on the waist circumference of over 2000 men and women (Table 4.3). Action level 1: Waist circumference of \( \geq 94 \) cm in men or \( \geq 80 \) cm in women identifies as overweight with increased health risks, those with BMI \( \geq 25 \) kg/m\(^2\) and high waist-to-hip ratio ( \( \geq 0.95 \) for men; \( \geq 0.80 \) for women). These subjects are advised not to gain further body weight and to increase physical activity. Action level 2: Waist circumference of \( \geq 102 \) cm in men or \( \geq 80 \) cm in women identifies as overweight with high health risks, those with BMI \( \geq 30 \) kg/m\(^2\) and high waist-to-hip ratio ( \( \geq 0.95 \) in men and \( \geq 0.80 \) in women). Weight loss and consultation of health professionals are recommended for these individuals. These action levels for weight management have a sensitivity (correctly identifies individuals who need weight management by waist circumference above action levels) and a specificity (correctly identifies individuals who do not need weight management by waist circumference below action levels) of more than 96% for identifying overweight and obese subjects with high waist-to-hip ratio. Waist circumference is not importantly influenced by height (40) (Figure 4.9), thus it is not necessary to divide waist by height when using waist circumference as an index of adiposity. To avoid problems with over-tightening during waist measurement, a specially designed ‘Waist Watcher’ spring-loaded tape measure has been produced with three colour bands based on cut-offs of the waist circumference action levels (Figure 4.10).
Table 4.3  Action levels to identify overweight and obese men and women with increased abdominal fat

<table>
<thead>
<tr>
<th>Waist circumference</th>
<th>Approximate equivalents</th>
<th>Classification of health risks</th>
<th>Weight management</th>
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<tr>
<td></td>
<td>cm</td>
<td>Body mass index</td>
<td>Waist-to-hip ratio</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action level 1</td>
<td>≥ 94</td>
<td>≥ 25</td>
<td>≥ 0.95</td>
</tr>
<tr>
<td>Action level 2</td>
<td>≥ 102</td>
<td>≥ 30</td>
<td>≥ 0.95</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action level 1</td>
<td>≥ 80</td>
<td>≥ 25</td>
<td>≥ 0.80</td>
</tr>
<tr>
<td>Action level 2</td>
<td>≥ 88</td>
<td>≥ 30</td>
<td>≥ 0.80</td>
</tr>
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</table>

**METHODS FOR ANTHROPOMETRIC MEASUREMENTS**

**Body Weight**

Weight is measured by digital scales or beam balance to the nearest 100 g. For those unable to stand, electronic chair scales (Weighcare C, Marsden Ltd, London) are available. For field work, portable scales are used. Equipment is calibrated regularly by standard weights (4 × 10 kg and 8 × 10 kg), and the results of test weighing recorded in a book. Subjects are weighed in light clothing, fasting and with an empty bladder, preferably at the same time of day.

**Height**

Height is measured by stadiometer to the nearest millimetre, which is calibrated by meter rule before use. When possible, a wall mounted stadiometer is preferred. For field work, a portable stadiometer (Leicester Height Measure, Child Growth Foundation, London, UK; Holtain, Crymych, UK) is available. Subjects stand in bare feet which are kept together and pointing forward. The head is level with horizontal Frankfurt plane (line from lower border of the eye orbit to the auditory meatus). Subjects are encouraged to stretch upwards by applying gentle pressure at the mastoid processes and height is recorded with subjects taking in a deep breath for maximum measurement.

**Limb Lengths**

When height measurement is not available in bed- and chair-bound patients. Height can be predicted from arm span or lower leg length (21). Arm span is measured between finger tips with subjects standing against the wall, and both arms fully stretch horizontally. Demi-arm span is measured as the horizontal distance from the web space between middle and fourth fingers to the midpoint of the sternal notch to the nearest millimetre, in the sitting position. Lower leg length is measured with subjects sitting in a chair adjusted to about their knee height, and the lower legs and bare feet flexed at 90°. The lower legs, 25–30 cm apart, are adjusted to vertical position both side and front views. A ruler standing on its edge is placed on top of the patellae. Lower leg length is taken to the nearest millimetre from the midpoint of the ruler to the floor with a wooden metre rule.

**Waist Circumference**

Waist circumference is measured midway between the lower rib margin and iliac crest, with a horizontal tape at the end of gentle expiration (Figure 4.4), with feet kept 20–30 cm apart. Subjects should be asked not to hold in their stomach, and a constant tension spring-loaded tape device reduces errors from over-enthusiastic tightening during measurement. Waist circumference measurement reflects body fat and does not include most of the bone
Figure 4.8 Subcutaneous and intra-abdominal fat images obtained from magnetic resonance imaging. (a, above) Male; (b, opposite) female. Light areas indicate fat structure (only the spine) or large muscle masses, whose variations between subjects might otherwise introduce errors.

**Hip Circumference**

Maximum hip circumference is measured with a horizontal steel tape at the widest part of the trochanter at horizontal position (Figure 4.4) with feet kept 20–30 cm apart. It is related more closely to subcutaneous fat than to intra-abdominal fat mass. Hip circumference has limited value on its own in body composition estimation. The circumference of the hip is influenced by gluteal muscle mass and pelvic size, which vary between subjects, as well as by fat.

**Thigh Circumference**

Thigh circumference is measured at the level of gluteal fold with the leg being measured relaxed by placing it forward and slightly bent, with body weight transferred to the other leg. It estimates fat on the thigh but will also be altered by muscle mass.

**Waist Diameter**

Abdominal fat deposition is further classified into medial (fat is accumulated at the middle of the abdomen) and lateral (fat is accumulated at the sides of the abdomen). Waist diameters are measured using a pelviometer or a more expensive device that measures the supine sagittal abdominal diameter (37). The pelviometer is a cheaper instrument.
that looks like a pair of large calipers and measures the waist diameter at the level between the lower rib margin and iliac crest. Waist sagittal diameter is taken as the distance from the back to the front of the abdomen measured with the subject standing. Waist transverse diameter is taken as the distance from the sides of the abdomen.

**Skinfold Thickness**

Skinfold thicknesses are measured on the left side of the body with calipers (Holtain Ltd, Crymych, UK) in triplicate, to the nearest 0.2 mm. All the sites intended for measurements should be marked clearly on the skin after making measurements from bony landmarks (Figure 4.3). When the subjects relax their muscles, the subcutaneous fat layer (commonly referred to as skinfold thickness) covering the muscles is relatively loose and can usually be pinched easily by two fingers (thumb and index finger) which hold the skinfold firmly throughout the measurement (11). The pinch is made at about 1 to 2 cm above the ink mark so that the jaw of the calipers can be applied at the mark. The thickness of the skinfold is read about 2 seconds after closing the jaw of the calipers.

Biceps and triceps skinfold thicknesses are made at the midpoint of the upper arm, between the acromion process and the tip of the bent elbow. Subscapular skinfold thickness is picked up at the natural fold about 2–3 cm below the shoulder blade in an oblique angle. Suprailiac skinfold is pinched at about 2–3 cm above the iliac crest, in either a vertical or oblique angle on the lateral side and mid-axillary line. The upper limit of skinfold calipers is 50 mm, which is exceeded for the subscapular site when BMI is greater than 40 kg/m². Thus for very overweight people, other methods are required.
Figure 4.9 The relationship between waist circumference and height in 2183 men (a) and 2698 women (b) showing regression line (solid) and the line of zero correlation (dashed).

REFERENCES


