4 STANDARDS FOR ANTHROPOMETRY ASSESSMENT

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4.1 INTRODUCTION

Anthropometry is the measurement of human body dimension such as lengths, breadths, girths, and skinfolds using surface landmarks for reference. Like other areas of science the procedures and processes depend upon adherence to the particular rules of measurement as determined by national and international standards bodies. The definitions and instructions in this chapter are consistent with the international anthropometric standards body called the International Society for the Advancement of Kinanthropometry (ISAK). It should be recognised, however, that other groups exist that also have their own standards. These include the World Health Organization (1), International Organization for Standardization (ISO) (2), and those used in very large surveys such as the National Health Examination surveys (NHANES) (3, 4).

The anthropometric sites and profile descriptions in this chapter are based on those by Norton and colleagues (5, 6) and subsequently published by ISAK (2001–2011). Within Australia these anthropometry guidelines have been endorsed by the Australian Sports Commission (ASC) and Exercise and Sports Science Australia (ESSA; originally AAESS). The publication of these anthropometry guidelines in *Anthropometrica* (7) were released to coincide with the inaugural ISAK accreditation system (8) which has continued to be the basis of international anthropometry training since.

This chapter introduces practitioners to techniques required to obtain a comprehensive anthropometric profile on a person. The procedure should take an experienced anthropometrist about 25 min, while an inexperienced person might require about 1 hr or more to complete the task. The measurement sites included are those which are regularly taken for monitoring purposes on athletes (see 9), tracking growth, development, ageing and mobility, and linking physical activity and nutrition interventions to changes in body size, shape, and composition. Measurements which are known to be predictive of health status in the general population are also included (10, 11).

There are many reasons why measurements of body dimensions are taken. This chapter describes a single 'core' of body sites that are most often included in an anthropometric profile. Adoption of a standard profile and methodology allows comparisons to be made locally, nationally and internationally between sample groups and also to pool data for research purposes. However, there will occasionally be the need where specific and perhaps unusual anthropometric measurement sites are required. Anthropometrists should not feel constrained by the specific list of sites contained in this chapter.

4.2 SUBJECT MEASUREMENT

The 'subject' is the person being measured. They must always be informed as to what measurements are to be taken and also complete a consent form as part of the preliminaries of the test protocol. There should be no pressure on any person to participate and measurements should not be taken if they compromise the physical or emotional well-being of the subject.

Throughout the marking and measurement session, the subject stands relaxed, arms comfortably to the side and feet slightly apart. Some measurements require the subject to place the feet together. These have been identified throughout the chapter. The measurer should be able to easily move around the subject and manipulate the equipment. This will be facilitated by setting aside adequate space for these measurement procedures. For measurements to be made as quickly and efficiently as possible the subjects should be asked to present themselves in minimal clothing. Swimming costumes (two-piece for females) are ideal for ease of access to all measurement sites although the anthropometrist should be sensitive to the cultural beliefs and other traditions of the subject. This may include the type of clothing worn, the sex of the anthropometrist, and need for privacy during measurement. The measurement room should be at a comfortable temperature for the subject.

4.3 DATA COLLECTION

Where possible a recorder should be used to assist the measurer and enter data. Ideally the recorder will be knowledgeable in measurement techniques. The recorder will be able to verify accuracy of site location and ensure the correct sequence of measurement sites. Despite careful attention to the standards there is still the possibility that errors will occur in the recording of data. This may occur due to poor pronunciation by the measurer, inattention by the recorder, or the recorder's failure to follow steps that are designed to eliminate such errors. Ideally, data collection should involve one measurer and one recorder to minimise measurement error but in large surveys a team of anthropometrists may be used to expedite data collection.

It must be remembered that the measurer and the recorder work as a team and it is the responsibility of the recorder to help the measurer wherever necessary. The recorder repeats the value as it is being recorded thereby enabling the measurer to do an immediate check. Where possible, measurements should be repeated or even taken a third time. When duplicate measures are taken the average value is used. When three measures are taken the median value is used for data analysis.

4.4 ANTHROPOMETRY EQUIPMENT

The following equipment items are essential tools for the anthropometrist.

4.4.1 Stadiometer

This is the instrument used for measuring stature and sitting height. It is usually attached to a wall so that the subjects can be aligned vertically in the appropriate manner. A sliding headpiece with at least 6 cm width is lowered to the vertex of the head. It is recommended that the headpiece be constructed with a locking device. The range should be from 60–220 cm with a measurement resolution of 0.1 cm. The floor surface should be hard and solid. See Figure 4.1.

4.4.2 Weighing scale

The traditional instrument of choice was a beam balance accurate to the nearest 100 g. However, modern quality electronic scales incorporating load cells are now more common. The accuracy of these instruments is to within 50 g. They are easily transported and can therefore be used in the laboratory and the field. Calibration weights, certified by a government department of weights and measures and totalling at least 150 kg, are required as standard equipment.

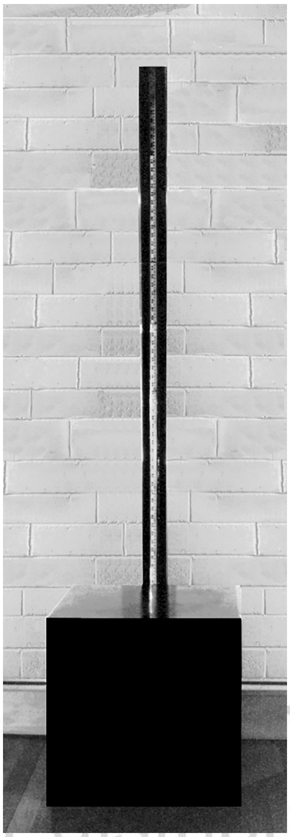

Figure 4.1 A stadiometer and anthropometry box

4.4.3 Anthropometry tape

A flexible steel tape calibrated in centimetres with millimetre gradations is recommended for girths. Anthropometrists often prefer the Lufkin metal tape as illustrated. If fibreglass tapes are used regular calibration against a steel tape is required as these non-metal tapes may stretch over time. If any other type of tape is to be used it should be non-extensible, flexible, no wider than 7 mm and have a stub (blank area) of at least 4 cm before the zero line. In addition to assessing girth measurements an anthropometric tape is also required to accurately locate a number of skinfold sites and mark distances from bony landmarks. It is preferable that the tape is enclosed in a case with automatic retraction. See Figure 4.2.

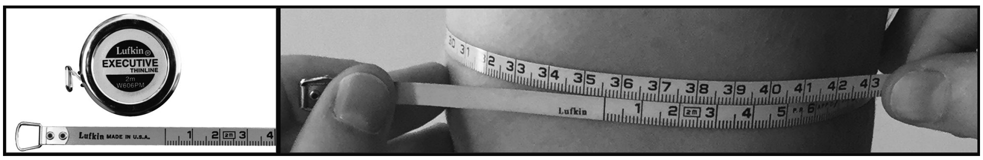

Figure 4.2 Anthropometry tapes are shown on the left. The right image shows how to read the tape where the zero mark is aligned with the top scale: here reading 35.6 cm

4.4.4 Skinfold calliper

The Harpenden caliper has been used as the criterion instrument by anthropometrists but other less-expensive types are also available. The manufacturers of the Harpenden caliper report a compression of 10 g/mm^2 in new calipers. They should be calibrated to approximately 50 mm in 0.2 mm divisions but may be accurately interpolated to the nearest 0.1 mm. Some can measure accurately to 80 mm. Annual calibration checks should also be performed. This is important since springs may deteriorate over time (12). It should be pointed out that the application of skinfold data to any body density regression equation or when comparisons are performed should be made with additional caution if calipers are used which are different to the original. See Figure 4.3.

Figure 4.3 Harpenden skinfold caliper

4.4.5 Anthropometer

An anthropometer is used to measure heights and lengths either directly or indirectly. The instrument is used to measure the vertical heights between specific anatomical landmarks on the subject and the floor or sitting surface. Estimates of segment lengths using the differences between pairs of heights are called projected segment lengths. For example, Acromiale-Radiale length can be obtained by subtraction of Acromiale height minus Radiale height. More recent techniques allow direct measurement of segment lengths using a segmometer. The upper segment of an anthropometer such as the Siber-Hegner GPM anthropometer is referred to as a large sliding caliper. It is used to measure direct segment lengths (e.g., Radiale-Stylion), large bone breadths (e.g., Biacromial) and non-bone breadths (e.g., Bideltoid) as well as Stature and Sitting height. See Figure 4.4.

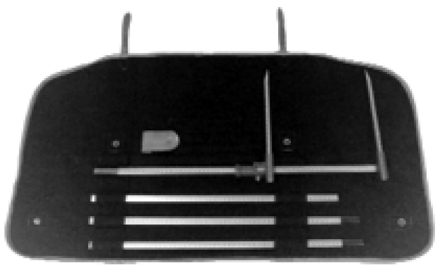

Figure 4.4 Siber-Hegner GPM anthropometer

4.4.6 Segmometer

This instrument is manufactured from a steel tape approximately 100 cm in length and 15 cm in width. Two straight branches are attached, each approximately 7–8 cm in length. It is used to measure segment lengths directly. Selected heights (e.g., Iliospinale and Trochanterion heights) which can be measured from landmarks on the subject to the anthropometry box (the box height is then added to this length) can also be made using a segmometer. The segmometer is designed as a cost-effective alternative to the anthropometer (13), although it is not appropriate for measuring large bone breadths. See Figure 4.5.

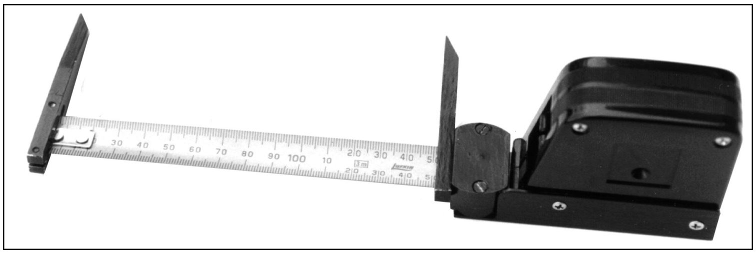

Figure 4.5 Segmometer

4.4.7 Large sliding calliper

This instrument is usually the upper segment of the anthropometer. It has two straight branches that allow measurements of large bone breadths such as the Biiliocristal and Biacromial breadths. These branches are attached to a rigid metal scale which is important since considerable pressure must be exerted when bony dimensions are measured. The distance between the branches should be verified to ensure it has been assembled correctly. See Figure 4.6.

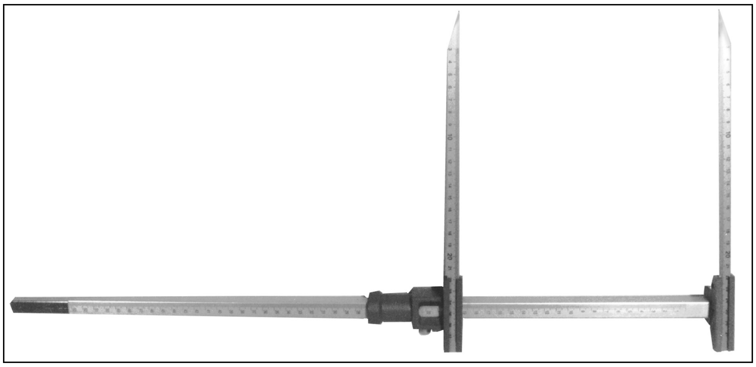

Figure 4.6 Large sliding caliper

4.4.8 Small sliding caliper

This caliper is used for Biepicondylar humerus and Femur breadths. Engineering vernier calipers can be adapted and are an ideal instrument for these measurements. These calipers have added longer arms which are able to encompass the biepicondylar breadth of the femur and

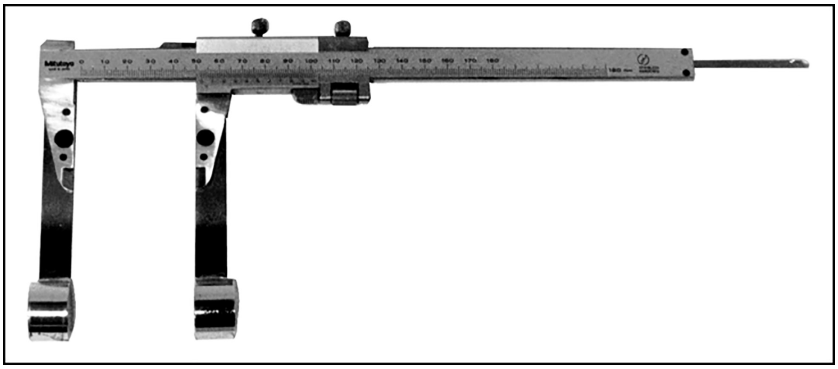

Figure 4.7 Small bone caliper

humerus and are highly accurate (to within 0.1 mm). Branch lengths should be at least 10 cm and an application face of 1.5 cm. See Figure 4.7.

4.4.9 Wide-spreading caliper

The measurement of anterior-posterior chest depth requires this instrument which has two recurved branches or arms. These should extend at least 25 cm beyond the measurement scale to allow the caliper branches to be placed over the shoulder to the correct anatomical landmarks. See Figure 4.8.

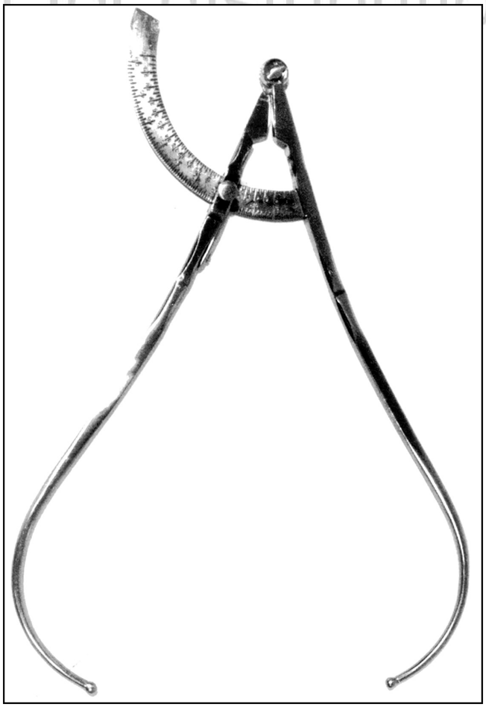

Figure 4.8 Wide-spreading caliper

4.4.10 Anthropometry box

This box should be stable and robust with all side lengths of approximately 40–50 cm. The actual height of the box used in any laboratory should be known exactly. It is useful to have a cut-out section on one side of the box which enables the subject's feet to be positioned under the box during measurement of the Iliospinale height. The box is particularly useful for assisting in the measurement of heights such as Iliospinale and Trochanterion using a segmometer. In these cases the measured height from the box to the landmark is added to the height of the box. This gives the true landmark height from the floor and is more efficient for the anthropometrist who need not bend to the floor but only to the top of the box. The box is also useful when measuring other lengths and breadths where the subject is required to be seated. See Figure 4.9.

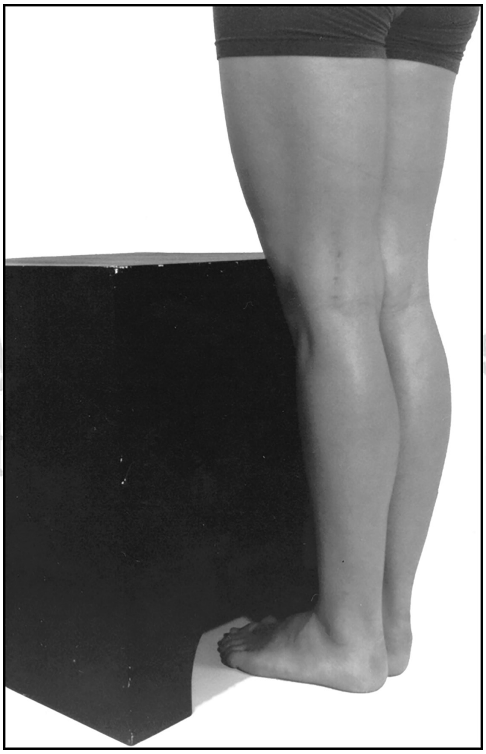

Figure 4.9 Anthropometry box with cut-out section

4.5 THE ANTHROPOMETRIC PROFILES

There are two general 'profiles' adopted by ISAK and commonly used for anthropometric assessment, the **Restricted** and **Full** profiles (5, 6). These are shown in more detail in Tables 4.1 and 4.2. Both profiles can be entered onto the same proforma (Figure 4.10). Throughout this chapter the anthropometric sites are numbered in a way that correspond to the site ID number on the proforma. The 17 shaded ID numbers on the proforma refer to variables included in the Restricted anthropometric profile. The 25 other variables listed are required to complete a full anthropometric profile, giving a total of 42 measurements. Additional sport- or population-specific variables measured during profiling of specific individuals or groups can be added as required.

Table 4.1 The 17 measures of the Restricted anthropometric profile

Basic	*Skinfolds*	*Girths*	*Breadths*
Mass®	Triceps®	Arm (relaxed)®	Humerus®
Stature®	Subscapular®	Arm (flexed and tensed)®	Femur®
	Biceps®	Waist (minimum)®	
	Iliac crest®	Gluteal (hips)®	
	Supraspinale®	Calf (maximum)®	
	Abdominal®		
	Front thigh®		
	Medial calf®		

Table 4.2 The 42 measures of the Full anthropometric profile

Basic	*Skinfolds*	*Girths*	*Lengths*	*Breadths*
Mass®	Triceps®	Head	Acromiale-Radiale	Biacromial
Stature®	Subscapular®	Neck	Radiale-Stylion	A-P abdominal depth
Sitting height	Biceps®	Arm (relaxed)®	Mid-stylion-dactylion	Biiliocristal
Arm span	Iliac crest®	Arm (flexed and tensed)®	Iliospinale height	Foot length
	Supraspinale®	Forearm (maximum)	Trochanterion height	Transverse chest
	Abdominal®	Wrist (distal styloids)	Trochanterion-tibiale-laterale	A-P chest depth
	Front thigh®	Chest (mesosternale)	Tibiale laterale height	Humerus®
	Medial calf®	Waist (minimum)®	Tibiale mediale-sphyrion tibiale	Bi-styloid
		Gluteal (hips)®		Femur®
		Thigh (1 cm gluteal)		
		Thigh (mid tro-tib-lat)		
		Calf (maximum)®		
		Ankle (minimum)		

4.5.1 Restricted anthropometric profile

In addition to Mass and Stature, the short or Restricted profile consists of eight skinfolds, five girths and two breadths: For efficient profiling these Restricted sites are identified in this chapter with an ® symbol. The anatomical landmarks required for exact location of these sites are also identified with this ® symbol. Measurement of these sites will enable computations to be made for somatotype, proportionality, relative body fat (using a restricted number of prediction equations), indices of body surface area, Body Mass Index, waist-to-hip ratio, fat patterning, and skinfold-corrected girths. Other comparisons such as obesity estimates and proportional mass rankings relative to other populations of interest can also be performed for the Restricted profile measurements.

4.5.2 Full anthropometric profile

In addition to Mass and Stature, the long or Full anthropometric profile consists of 8 skinfolds, 13 girths, and 19 lengths, breadths and basic measures as shown in Table 4.2.

Measurement of the sites in the Full profile will enable additional computations to be made, including relative body fat (using a large number of prediction equations), and estimates of bone, muscle, fat, and residual masses using the fractionation of body mass technique (14, 15).

Anthropometry Proforma				
Test ID:	**Lab ID:**			
Name:	Sport:			
DoB:	Test date:			
Postcode:	Gender:	Male	Female	
Country:	Box Ht:			

	ID No.	Site	Trial 1	Trial 2	Trial 3	Median
Basic	1	Mass (kg)				
	2	Stature (cm)				
	3	Sitting height (cm)				
	4	Arm span (cm)				
Skinfolds	5	Triceps				
(mm)	6	Subscapular				
	7	Biceps				
	8	Iliac crest				
	9	Supraspinale				
	10	Abdominal				
	11	Front thigh				
	12	Medial calf				
		Mid-axilla				
Girths	13	Head				
(cm)	14	Neck				
	15	Arm (relaxed)				
	16	Arm (flexed and tensed)				
	17	Forearm (maximum)				
	18	Wrist (distal styloids)				
	19	Chest (mesosternale)				
	20	Waist (minimum)				
	21	Gluteal (hips)				
	22	Thigh (1 cm gluteal)				
	23	Thigh (mid-troch-tib-lat)				
	24	Calf (maximum)				
	25	Ankle (minimum)				
Lengths	26	Acromiale-radiale				
(cm)	27	Radiale-stylion				
	28	Mid-stylion-dactylion				
	29	Iliospinale height				
	30	Trochanterion height				
	31	Trochanterion-tibiale laterale				
	32	Tibiale laterale height				
	33	Tibiale mediale-sphyrion tibiale				
Breadths	34	Biacromial				
(cm)	35	A-P abdominal depth				
	36	Biiliocristal				
	37	Foot length				
	38	Transverse chest				
	39	A-P chest depth				
	40	Humerus				
	41	Bi-styloid				
	42	Femur				
		Bideltoid				
		Bitrochanteric				

* site used in Restricted profile

Figure 4.10 Anthropometry proforma

4.6 ANATOMICAL LANDMARKS

There are two types of landmarks or sites on the surface of the body that are important for measurement protocols. These are non-marked reference landmarks and marked landmarks.

4.6.1 Reference anthropometric landmarks

The following are landmarks that help guide the anthropometrist to the correct measurement site but which are not physically marked:

Akropodion

Definition: The most anterior point on the toe of the foot when the subject is standing. It is usually either the first or second phalanx.

Dactylion

Definition: The tip of the middle (third) finger. Fingernails should not be used as landmarks for the end of fingers.

Glabella

Definition: The mid-point between the brow ridges of the forehead.

Ilio-axilla line®

Definition: The imaginary line on the longitudinal axis of the body joining the observed mid-point of the armpit with the lateral superior edge of the ilium. The subject's arm is placed horizontally in a lateral position.

Inguinal fold®

Definition: The crease at the angle of the trunk and the anterior thigh while the subject is in a seated position.

Inguinal point®

Definition: The point at the intersection of the Inguinal fold® and a line from the Patellare along the superior aspect of the thigh while the subject is seated on the edge of the box.

Orbitale®

Definition: The lower bony margin of the eye socket.

Pternion

Definition: The most posterior point on the calcaneus of the foot when the subject is standing.

Tragion®

Definition: The notch immediately superior to the tragus of the ear. See Figure 4.11.

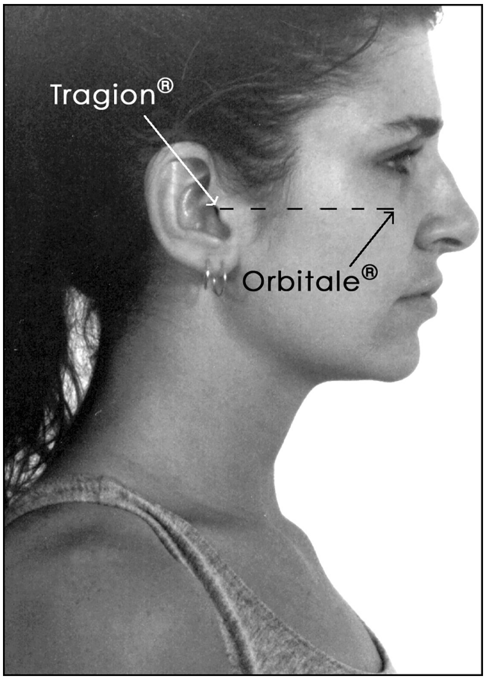

Figure 4.11 The head in the Frankfort plane with horizontal alignment of the Orbitale® and Tragion®

Vertex®

Definition: The most superior point on the skull when the head is positioned in the Frankfort plane.

4.6.2 Marked anthropometric landmarks

Landmarks are identifiable skeletal points which generally lie close to the body's surface and are the 'markers' which identify the exact location of the measurement site, or from which a soft tissue site is located, for example, subscapular skinfold and arm girth. All landmarks are found by palpation. For the comfort of the subject, the measurer's fingernails should be kept trimmed.

The landmark is identified with the thumb or index finger. The site is released to remove any distortion of the skin, then is relocated and marked using a fine-tipped felt or dermographic pen. The site is marked directly over the landmark with a dot or short line. The mark is then re-checked to ensure that there has been no displacement of skin relative to the underlying bone.

The landmarks described here are those required for the measurement sites included in this chapter. All landmarks are identified before any measurements are made. The order of their identification is as listed here. These sites represent only a small portion of the potentially infinite number of sites over the surface of the body. They are included since they are the sites typically referenced when profiling individuals and are consistent with the recommendations of the ISAK working group on standards and instrumentation. It should be pointed out however that other sites are often required for analyses in ergonomics, child growth and development, and specific sporting populations. Landmarks essential for the restricted profile are identified by the symbol®.

Acromiale®

Definition: The point on the superior aspect of the most lateral part of the acromion border

Location: Standing behind and on the right-hand side of the subject palpate along the spine of the scapula to the corner of the acromion. This represents the start of the lateral border which usually runs anteriorly, slightly superiorly and medially. Apply the straight edge of a pencil to the lateral aspect of the acromion to confirm the location of the most lateral part of the border.

The landmark is a point on the most lateral *and* superior part of the border so palpate superiorly to the top margin of the acromion border in line with the most lateral aspect. See Figure 4.12.

Figure 4.12 The Acromiale® landmark

Radiale®

Definition: The point at the proximal and lateral border of the head of the radius.

Location: The subject stands in a relaxed position with the arm hanging by the side in the mid-prone position. Palpate downward into the lateral dimple of the right elbow. It should be possible to feel the space between the capitulum of the humerus and the head of the radius. Mark with a short line perpendicular to the long axis of the forearm. Slight rotation of the forearm is felt as rotation of the head of the radius. See Figure 4.13.

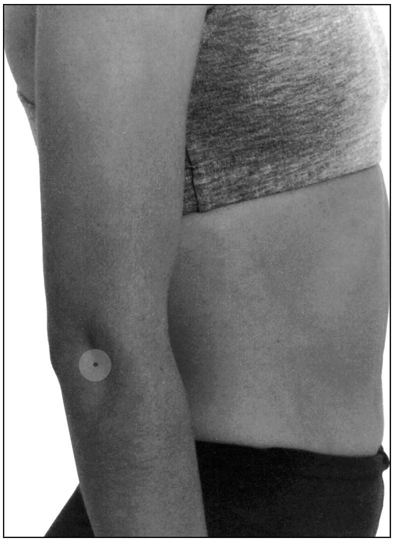

Figure 4.13 The Radiale® landmark

Mid-acromiale-radiale®

Definition: The horizontal line mid-way between the Acromiale® and Radiale® landmarks.

Location: The subject stands in a relaxed position with the arms hanging by the side. Measure the linear distance between Acromiale® and Radiale® with the arm relaxed and extended by the side. Place a small mark at the level of the mid-point between these two landmarks. Project this mark around to the posterior and anterior surfaces of the arm as a horizontal line. This is required for locating the Triceps® and Biceps® skinfold sites. See Figure 4.14.

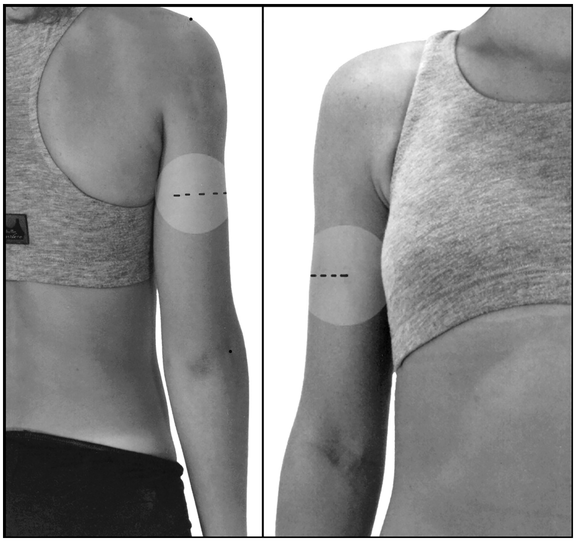

Figure 4.14 The Mid-acromiale-radiale® landmark from back and front views

Triceps skinfold site®

Definition: The point on the posterior surface of the arm, in the mid-line, at the level of the marked Mid-acromiale-radiale® landmark.

Location: The subject stands in a relaxed position with the arm hanging by the side in the mid-prone position. The skinfold site is located by projecting the Mid-acromiale-radiale® site perpendicularly to the long axis of the arm around the posterior surface of the triceps. The site is where intersection of this line occurs with an imaginary vertical line in the middle of the arm when viewed from behind. See Figure 4.15.

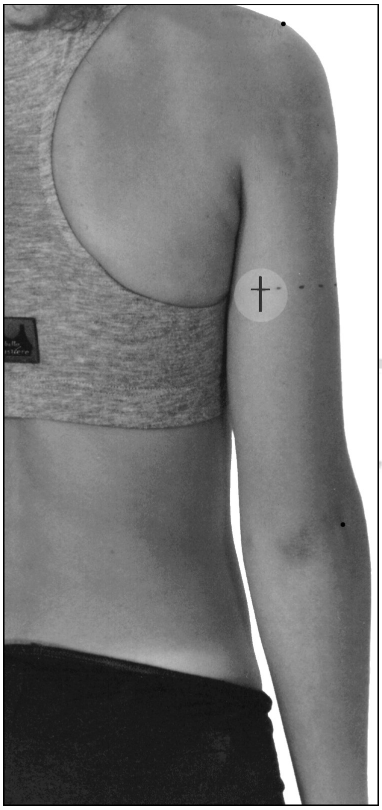

Figure 4.15 Triceps skinfold site®

Biceps skinfold site®

Definition: The point on the anterior surface of the arm at the level of the marked Mid-acromiale-radiale® landmark, in the middle of the biceps muscle.

Location: The subject stands in a relaxed position with the arm hanging by the side in the mid-prone position. The skinfold site is located by projecting the Mid-acromiale-radiale® site perpendicularly to the long axis of the arm around the anterior aspect of the biceps. The site is where intersection of this line occurs with an imaginary vertical line in the middle of the biceps muscle belly when viewed from the front. See Figure 4.16.

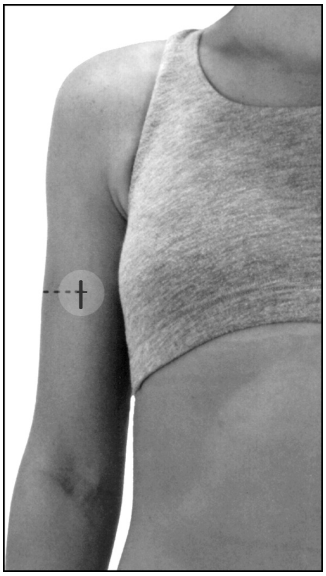

Figure 4.16 Biceps skinfold site®

Stylion

Definition: The most distal point on the lateral margin of the inferior head of the radius.

Location: The subject stands in a relaxed position with the arms hanging by the side. The anthropometrist lifts the wrist of the subject to locate the landmark. Using a thumbnail the anthropometrist palpates in the triangular space identified by the muscle tendons of the wrist immediately above the thumb. This site is also called the anatomical 'snuff box'. Once the snuff box has been identified, palpate in the space between the distal radius and the most proximal aspect of the first metacarpal in order to correctly identify the tip of the styloid process. See Figure 4.17.

Figure 4.17 The Stylion landmark

Mid-stylion

Definition: The midpoint, on the anterior surface of the wrist, of the horizontal line at the level of the Stylion.

Location: The subject stands in a relaxed position with the arms hanging by the side. The anthropometrist lifts the wrist of the subject to locate the landmark. The tape is aligned with the Stylion landmark and a line perpendicular to the long axis of the forearm is drawn close to the mid-point of the wrist. The mid-point is estimated between the medial and lateral edges of the wrist. A line is drawn at this position which intersects the perpendicular line. See Figure 4.18.

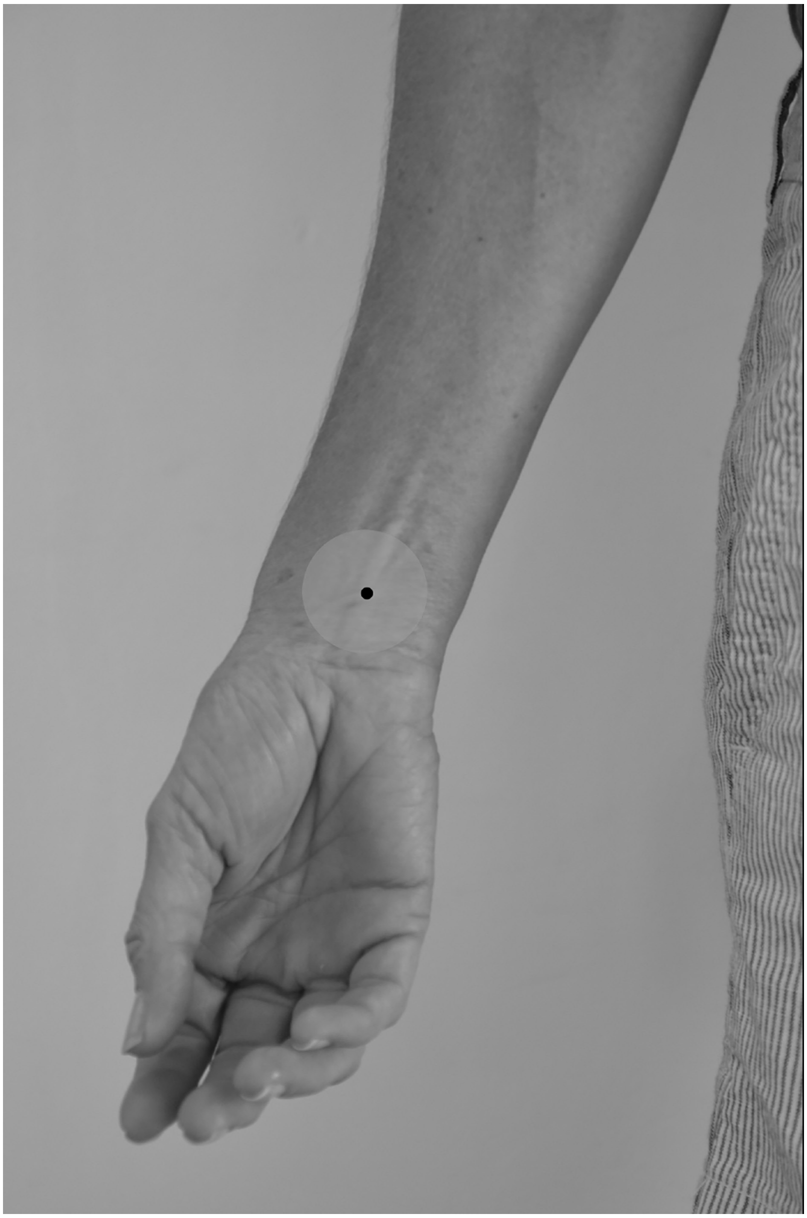

Figure 4.18 The Mid-stylion landmark

Subscapulare®

Definition: The undermost tip of the inferior angle of the scapula.
Location: The subject stands in a relaxed position with the arms hanging by the side. Palpate the inferior angle of the scapula with the left thumb. If there is difficulty locating the inferior angle of the scapula, the subject should slowly reach behind the back with the right arm. The inferior angle of the scapula should be felt continuously as the hand is again placed by the side of the body. A final check of this landmark should be made with the hand by the side in the relaxed position. See Figure 4.19.

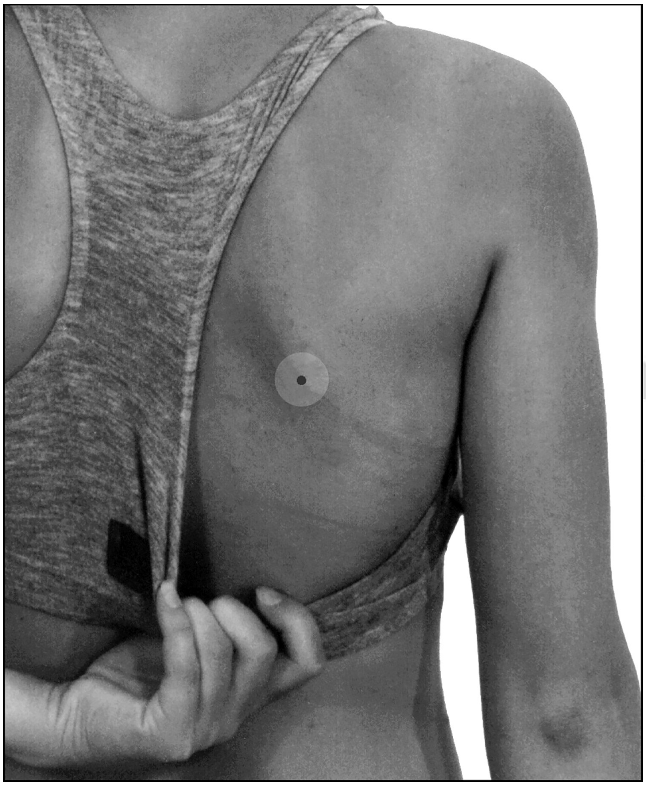

Figure 4.19 The Subscapulare® landmark

Subscapular skinfold site®

Definition: The site 2 cm along a line running laterally and obliquely downwards from the Subscapulare® landmark at a 45° angle.
Location: The subject should be standing in a relaxed position with the arms hanging by the side. A line is drawn from the marked Subscapulare® landmark downwards at an angle of 45°. At a point 2 cm from the Subscapulare® landmark a second line is drawn perpendicular to the first. This line indicates the alignment of the finger and thumb when picking up the skinfold. The line of the skinfold is determined by the natural fold of the skin. See Figure 4.20.

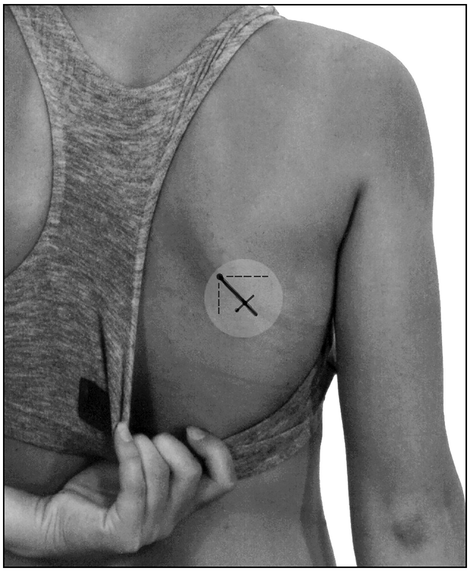

Figure 4.20 The Subscapular skinfold site® is the intersection of the two oblique lines. The top left-hand dot is the marked Subscapulare® site.

Mesosternale

Definition: The midpoint of the sternum at the level of the centre of the articulation of the fourth rib with the sternum (chondrosternal articulation).

Location: The subject assumes a relaxed standing position with the arms hanging by the side. The landmark is located by palpation beginning from the top of the clavicles. Using the thumb the anthropometrist should roll down from the clavicle to the first costal space (i.e., between the first and second ribs). The thumb is then replaced by the index finger and the procedure is then repeated down to the second, third and fourth intercostal spaces. The fourth rib is between the last two spaces. See Figure 4.21.

Figure 4.21 The Mesosternale landmark

Iliocristale®

Definition: The most superior point on the iliac crest where the Ilio-axilla line® meets the ilium.

Location: The subject assumes a relaxed standing position with the right arm folded across the chest. The left hand is used to stabilise the body by providing resistance on the left side of the pelvis. Find the superior aspect of the iliac crest by horizontal palpation with the tips of the fingers. The landmark is made at the identified edge of the ilium which is intersected by the imaginary vertical line from the mid-point of the axilla. See Figure 4.22.

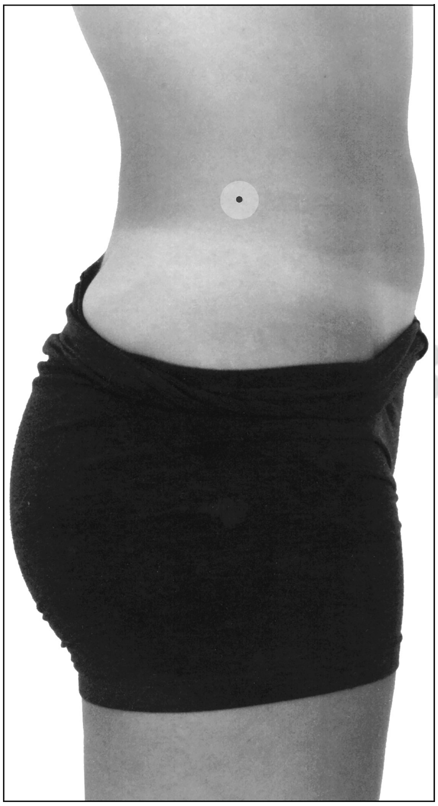

Figure 4.22 The Iliocristale® landmark

Iliac crest skinfold site®

Definition: The site at the centre of the skinfold raised immediately superior to the marked Iliocristale® on the Ilio-axilla line®.

Location: The subject assumes a relaxed position and places the right arm across the chest. Align the fingers of the left hand on the Iliocristale® landmark and exert pressure inwards so that the fingers roll over the iliac crest. Substitute the left thumb for these fingers and relocate the index finger a sufficient distance superior to the thumb so that this grasp becomes the skinfold to be measured. The fold runs slightly downwards anteriorly as determined by the natural fold of the skin. [Note: This skinfold is equivalent to that described by Durnin and Womersley (16) as the suprailiac skinfold.] See Figure 4.23.

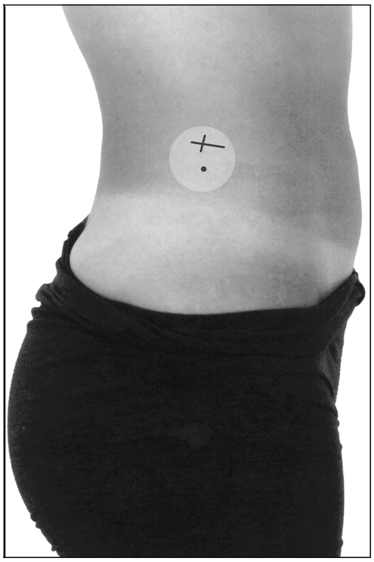

Figure 4.23 The Iliac crest skinfold site®

Iliospinale®

Definition: The most inferior or undermost tip of the anterior superior iliac spine.

Location: The subject assumes a relaxed position and places the right arm across the chest. To locate the Iliospinale®, palpate the superior aspect of the ilium and follow anteriorly and inferiorly along the crest until the prominence of the ilium runs posteriorly. The landmark is the lower margin or edge where the bone can just be felt. Difficulty in appraising the landmark can be assisted by the subject lifting the heel of the right foot and rotating the femur outward. Because the sartorius muscle originates at the site of the Iliospinale®, this movement of the femur enables palpation of the muscle and tracing to its source. See Figure 4.24.

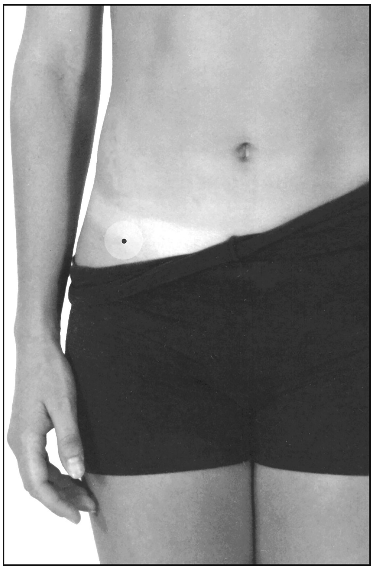

Figure 4.24 The Iliospinale® landmark

Supraspinale skinfold site®

Definition: The point where an imaginary line from the marked Iliospinale® to the anterior axillary border intersects with the horizontal line of the superior border of the ilium at the level of the marked Iliocristale®.

Location: The subject assumes a relaxed position with the arms hanging by the side to facilitate the location of the anterior axillary border. The subject places the right arm across the chest after the anterior axillary border has been identified. Run a tape from the anterior axillary border to the marked Iliospinale® and draw a short line at the level of the marked Iliocristale®. Next run the tape horizontally from the marked Iliocristale® to intersect with the first line. The fold runs medially downward at about a 45° angle and is determined by the natural ford of the skin. This skinfold was originally named suprailiac by Heath and Carter (17), but is now known as the Supraspinale® (18). It is the skinfold used when the Heath-Carter somatotype is being determined. See Figure 4.25.

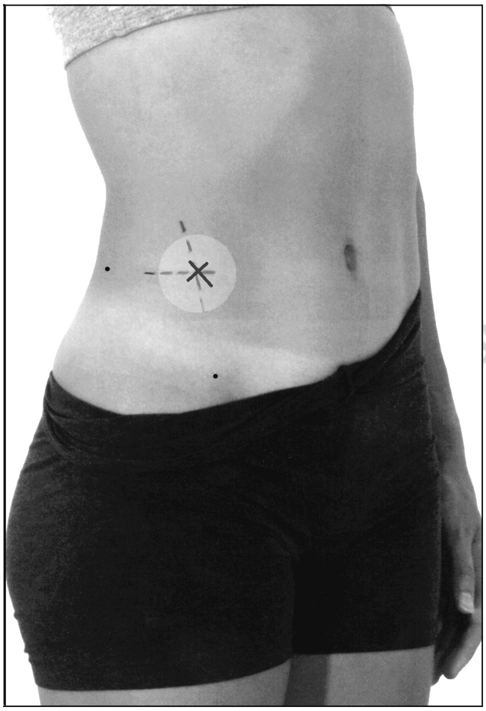

Figure 4.25 The Supraspinale skinfold site®. The oblique dashed line is from the marked Iliospinale® towards the anterior axillary border and the horizontal dashed line is at the level of the marked Iliocristale®

Abdominal skinfold site®

Definition: The point 5 cm horizontally from the right hand side of the omphalion (midpoint of the navel).

Location: The subject assumes a relaxed position with the arms hanging by the side. The site is marked 5 cm horizontally from the omphalion. The skinfold orientation at this site is a vertical fold. See Figure 4.26.

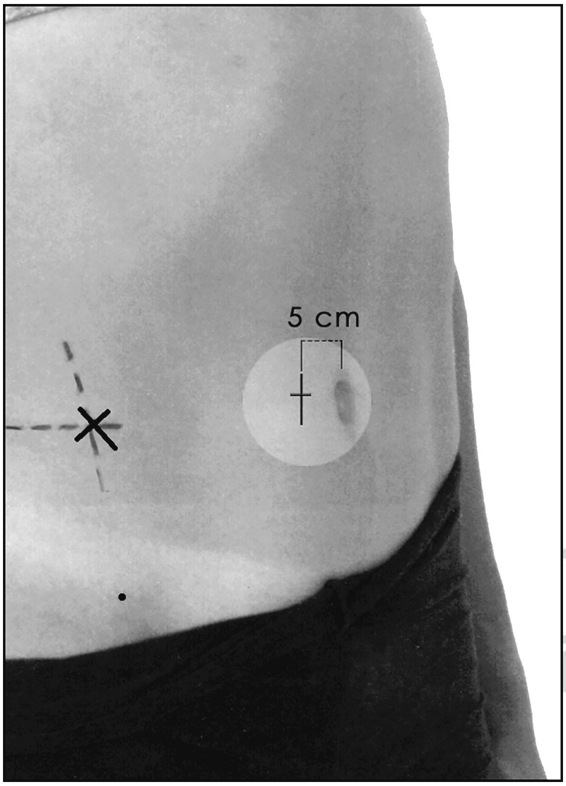

Figure 4.26 Abdominal skinfold site®

Trochanterion

Definition: The most superior point on the greater trochanter of the femur, not the most lateral point.

Location: The subject assumes a relaxed standing position and places the right arm across the chest. The site is identified by palpating the lateral aspect of the gluteal muscle with the heel of the hand while standing behind the subject. It is advisable to support the left side of the subject's pelvis with the left hand while applying pressure with the right hand. Once the greater trochanter has been identified, the measurer should palpate upwards to locate the lowest point on the thigh where the superior surface of the trochanter can be felt when strong pressure is applied. (Note: This site can be difficult to locate in persons with thick adipose tissue over the greater trochanter.) See Figure 4.27.

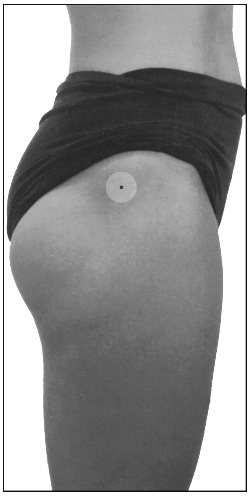

Figure 4.27 The Trochanterion landmark

Tibiale laterale

Definition: The most superior point on the lateral border of the head of the tibia.

Location: The subject assumes a relaxed standing position with the arms hanging by the side. This is often a difficult landmark to correctly locate due to thick lateral ligaments that run across the knee joint. Palpate the site using a thumb or fingernail and the following guidelines. Locate the joint space bounded by the lateral condyle of the femur and the antero-lateral portion of the head of the tibia. Press inwards firmly in order to locate the superior and lateral border of the head of the tibia. It is often useful to have the subject flex and extend the knee several times to ensure that the correct position has been located. The mark should be made approximately one-third of the distance along the border moving in an anterior-posterior direction. See Figure 4.28.

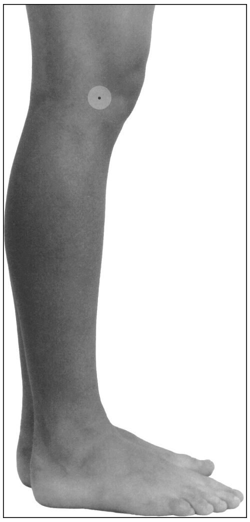

Figure 4.28 The Tibiale laterale landmark

Mid-trochanterion-tibiale laterale

Definition: The mid-point of the straight line joining the marked Trochanterion and Tibiale laterale landmarks.

Location: The subject assumes a relaxed standing position and places the right arm across the chest. The distance between the marked Trochanterion and Tibiale laterale landmarks is measured. A short horizontal line is drawn at the mid-point between these two landmarks. See Figure 4.29.

Figure 4.29 The Mid-trochanterion-tibiale laterale landmark

Medial calf skinfold site®

Definition: The point on the most medial aspect of the calf at the level of the maximal girth.

Location: The subject assumes a relaxed standing position on the box with the arms hanging by the side. The subject's feet should be separated with the body weight evenly distributed. The maximal girth of the calf is determined by trial and error. It is found by using the middle fingers to manipulate the position of the tape in a series of up or down measurements to identify the maximal girth. Once the maximal level is located it is marked on the medial aspect of the calf with a short horizontal line. A vertical line is then marked on the medial aspect of the calf to indicate the skinfold site. See Figure 4.30.

Figure 4.30 The Medial calf skinfold site®

Patellare®

Definition: The midpoint of the posterior superior border of the patella.
Location: The subject sits on the edge of the box with the leg straight out and heel on the ground. The measurer palpates the patella from both the lateral and medial sides. The posterior surface is palpated through the patella tendon. The subject then slowly flexes the knee to 90° while the measurer's thumbnail maintains contact with the posterior superior border. The site is marked when the knee is at a 90° angle. See Figure 4.31.

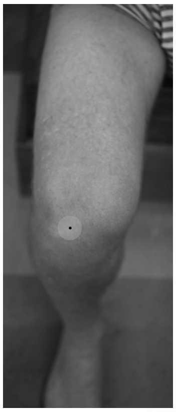

Figure 4.31 The Patellare® landmark

Front thigh skinfold site®

Definition: The mid-point of a line between the Inguinal point and marked Patellare®.
Location: The subject sits on the edge of the box with an erect torso and arms hanging by the side. The knee of the right leg is bent at 90°. The measurer stands facing the right side of the seated subject on the lateral side of the thigh. The distance between the Inguinal point® and marked Patellare® is measured and a small horizontal mark is made at the level of the mid-point. A perpendicular line located in the midline of the thigh is then drawn to intersect the horizontal line. See Figure 4.32.

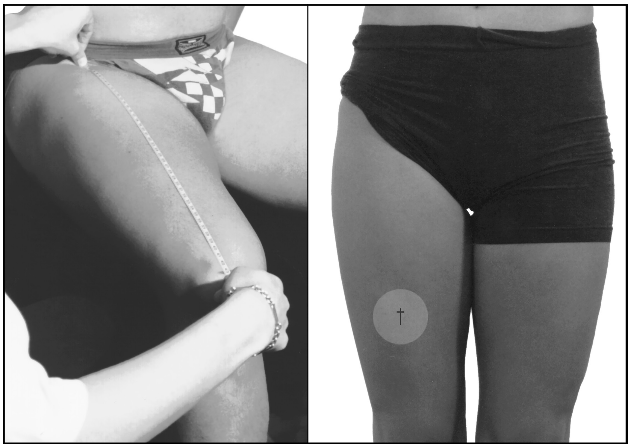

Figure 4.32 The Front thigh skinfold site® being located (left panel) and after marking

Tibiale mediale

Definition: The most superior point on the medial border of the head of the tibia.
Location: The subject is seated on the box with the right leg resting over the left knee so that the medial aspect of the lower leg is more readily marked. The Tibiale mediale is approximately in the same transverse plane as the Tibiale laterale. The specific location is found by palpating the site bounded by the medial femoral condyle and the medial tibial condyle with a thumb or fingernail. Move distally to locate the superior medial border of the tibia. A short mark should be made at the superior medial border while the leg is held in this position.

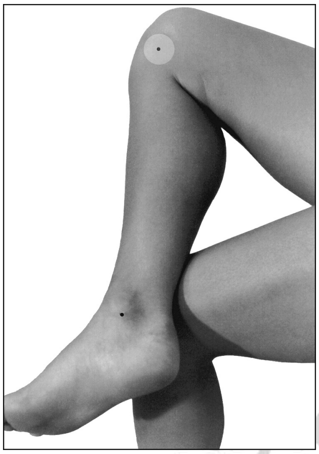

Figure 4.33 The Tibiale mediale landmark

Sphyrion tibiale

Definition: The inferior aspect of the distal tip of the medial malleolus.
Location: The subject is seated on the box with the right leg resting over the left knee so that the medial aspect of the lower leg is more readily marked. This landmark may be located most easily by palpation with the thumbnail from beneath the medial malleolus. It is the distal tip, not the outermost point, of the medial malleolus of the tibia. Once located, it is marked with a short line perpendicular to the long axis of the leg. See Figure 4.34.

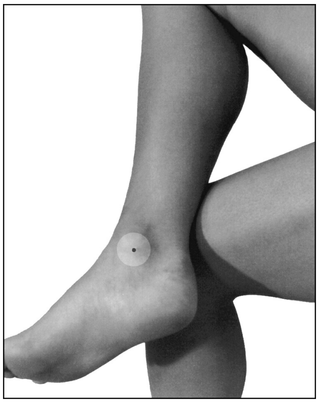

Figure 4.34 The Sphyrion tibiale landmark

4.7 BASIC MEASUREMENTS OF AN ANTHROPOMETRY PROFILE

The four basic anthropometry measurements are listed below. For each site there is a definition, details of the equipment required, and description of measurement method. They are also listed according to their ID No. on the Anthropometry proforma.

4.7.1 General instructions

Anthropometrists should strive to minimise systematic errors and this is demonstrated by low technical errors of measurements and close agreement with criterion measurers. It is essential, therefore, that the standard protocols outlined in this chapter are followed strictly.

The precise assessment of anthropometric measurements can be difficult and therefore extreme care is required. In general there is not enough attention paid to an accurate measurement technique and consequently reproducibility cannot be obtained. The description of the measurement procedures seems quite simple but a high degree of technical skill is essential for consistent results, especially when applied under field test conditions.

- Prior to measuring, the anthropometrist should develop the appropriate technique. This has been shown to reduce the level of error in repeated measurements and among investigators (19, 20, 21). Repeated measures on at least 20 subjects should be made in order to establish reproducibility and comparison of measurements against an experienced anthropometrist will help to establish accuracy and expose any weaknesses in technique (8).
- The right side of the body is typically used for unilateral measurements irrespective of the preferred side of the subject (22). It is sometimes impracticable to use the right side due to injury (swelling, casts, etc.) and at other times it is desirable to compare the two sides of the body following injury and/or rehabilitation, in which case the left side may be used. Comparisons between the left and right sides of the body have indicated that there is either no significant difference in skinfold thickness (23) or that the differences, although statistically significant, are of no practical significance (24) even when the subject's musculature and bone have hypertrophied on one side such as in tennis players (25, 26, 27). Variations from standard procedures, however, should be recorded on the proforma sheet. For example, if time permits, left-dominant subjects may be measured on their dominant side for somatotype analysis as originally described by Carter and Heath (17).
- If possible two–three measurements should be taken at each site with the average value being used in any further calculations if two measurements are taken, and the median value used if three measurements are taken. It is especially important for the beginner to repeat measurements so that confidence and reproducibility can be established. Where possible an assistant should be used to record values and help standardise measurement techniques.
- Sites should be measured in succession to avoid experimenter bias. That is, a single complete data set is obtained before repeating the measurements for the second and then third time. This may also help to reduce the effects of skinfold compressibility. They should be measured in the same order as listed on the proforma so that the assistant is familiar with the routine and errors are minimised.
- Measurements should not be taken after training or competition, sitting in a sauna, swimming, or showering since exercise, warm water, and heat produce hyperaemia (increased blood flow) in the skin with a concomitant increase in skinfold thickness. These activities can also affect body mass and girth measures.

4.7.2 Basic measurements

1. Body mass®

Body mass is the quantity of matter of the body when weighed in a standard gravitational field.

Equipment

The instrument of choice is an electronic scale incorporating a load cell. It should be accurate to within ±50 g.

Method

Nude mass can be measured by first weighing the clothing which is to be worn during measurement and subtracting this from the mass. Generally the mass in minimal clothing is of sufficient accuracy. Check that the scale is reading zero then the subject stands onto the centre of the scales without support and with the weight distributed evenly on both feet. The head is up and the eyes look directly ahead.

Note: Body mass exhibits diurnal variation of about 1 kg in children and 2 kg in adults (28, 29). The most stable values are those obtained routinely in the morning 12 hr after food and after voiding. Since it is not always possible to standardise the measurement time, it may be important to record the time of day when measurements are made. See Figure 4.35.

Figure 4.35 Measurement of Body mass®

2. Stature®

Stature is the linear distance between the vertex and inferior aspect of the feet.

There are three general techniques for measuring stature: free standing, stretch, and recumbent. The last may be used for infants up to 2–3 yr or adults unable to stand and will not be considered here. The other two methods give slightly different values.

It must also be remembered that there will be diurnal variation. Generally, subjects are taller in the morning, lose most of their height change within the first hour of standing, and are shortest in the evening. A typical overall loss of about 1–1.5% in stature is common throughout the day (30, 31, 32). The effect of the diurnal variation can be minimised by using the stretch stature technique. Repeated measures should be taken as near as possible to the same time of day as the original measurement.

Equipment

In the laboratory a stadiometer should be mounted on a wall and used in conjunction with a right-angled head board which is at least 6 cm wide and which can be placed firmly on the subject's head while fixed to the stadiometer. The floor surface must be hard and level.

The stadiometer should have a minimum range of measurement of 60 cm to 220 cm. The accuracy of measurement required is 0.1 cm. It should be checked periodically against a standard height such as a Siber-Hegner GPM anthropometer. In the field, when a stadiometer is not available, a girth tape fixed to a wall and checked for height and vertical positioning, may be used in conjunction with a 90° head board such as a large carpenter's set square. As a 'last resort' method, a piece of paper taped to a wall may be used to identify the height, using a headboard. Assessment of the height can then be completed using a steel tape. This method is not acceptable in a laboratory.

Method

The stretch stature method requires the subject to stand with the feet together and the heels, buttocks and upper part of the back touching the scale. The head when placed in the Frankfort plane need not be touching the scale. The Frankfort plane is achieved when the Orbitale® (lower edge of the eye socket) is in the same horizontal plane as the Tragion (the notch superior to the tragus of the ear). When aligned the vertex is the highest point on the skull as illustrated. See Figure 4.36.

Figure 4.36 Measurement of stretch Stature®

The measurer places the hands along the jaw of the subject with the fingers reaching to the mastoid processes. The subject is instructed to take and hold a deep breath and while keeping the head in the Frankfort plane the measurer applies gentle upward lift through the mastoid processes. The recorder places the head-board firmly down on the vertex, compressing the hair as much as possible. The recorder further assists by watching that the feet do not come off the floor and that the position of the head is maintained in the Frankfort plane. Measurement is taken at the end of a deep inspiratory manoeuvre.

3. Sitting height

Sitting height is the height from the table or box (where the subject sits) to the vertex when the head is held in the Frankfort plane.

Equipment

A stadiometer and anthropometry box

Method

The stretch stature technique is the preferred method for measuring sitting height. The subject is sitting on the anthropometry box in an erect position while the measurer places the hands along the jaw of the subject with the fingers reaching to the mastoid processes. The subject is instructed to take and hold a deep breath, and while keeping the head in the Frankfort plane the measurer applies gentle upward lift through the mastoid processes. See Figure 4.37.

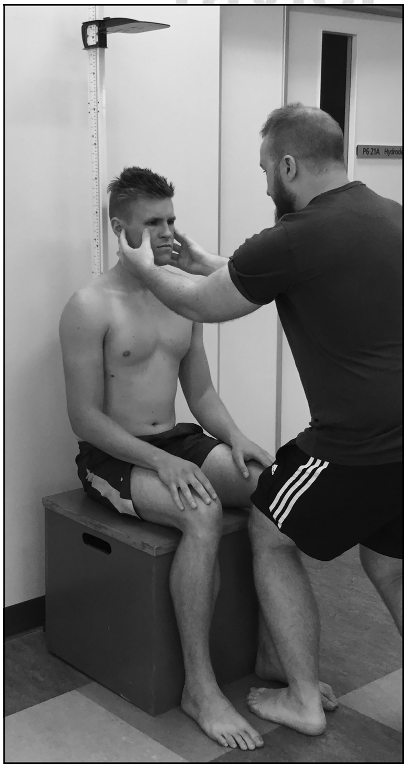

Figure 4.37 Subject position for Sitting height

4. Arm span

This is the linear distance between the Dactylia of the left and right hands with the arms outstretched horizontally.

Equipment

An anthropometric tape is used to measure the arm span.

Method

To prevent potential errors due to a large chest, the subject stands with his or her back to the wall, feet together and heels, buttocks and upper back touching the wall. It is often useful to use a corner of a room for one end of the measurement, thus only one mark needs to be made on the wall/board. The subject is instructed to take and hold a deep breath and measurement is made at end-inspiration. See Figure 4.38.

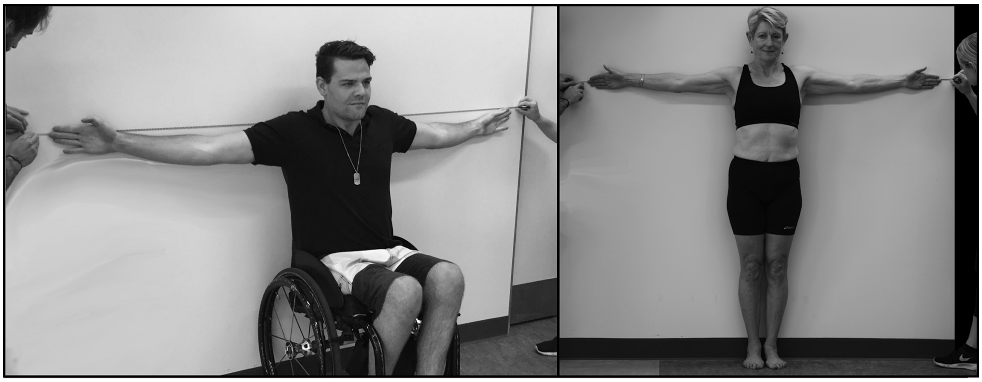

Figure 4.38 Position and measurement of Arm span

4.8 SKINFOLDS

In the standard ISAK Full profile there are 8 skinfold measurements. A further skinfold site – the Mid-axilla skinfold site – is listed at the end of this section which may be useful when using specific body density prediction equations (33, 34).

4.8.1 General techniques for measuring skinfolds

Skinfolds are usually associated with the poorest levels of accuracy and precision. It is the goal of the anthropometrist to maximise accuracy and reliability. Therefore, inter-individual tester technical error of measurement (TEM) should aim to be 7.5% or less while intra-individual TEM for repeat measures of skinfolds should aim to be 5% or less (8). Systematic and significant inter-individual differences in skinfold measures have been shown between criterion-level anthropometrists (35). This also reinforces the desirability of having the same anthropometrist measure subjects in longitudinal studies.

- Prior to measuring, ensure that the skinfold calipers are accurately measuring the distance between the centre of its contact faces by using the short blades of an engineer's vernier caliper. If possible check that the tension of the jaws remains constant throughout the range of measurement (12). Before using the caliper make sure that the indicator is on zero. For example, after unlocking the small screw on a Harpenden caliper, rotation of the outer ring of the caliper is used to adjust the position of the caliper dial directly under the indicator.

- The skinfold site should be carefully located using the correct anatomical landmarks. It is particularly important that the inexperienced measurer mark the skin with a fine tipped felt or dermographic pen for all skinfold landmarks. Skinfold thicknesses have been shown to vary when the caliper was placed small distances from the correct site (35, 36).
- The skinfold is picked up at the marked site. It should be grasped so that a double fold of skin plus the underlying subcutaneous adipose tissue is held between the thumb and index finger. The near edge of the thumb and finger are in line with the marked site. The back of the hand should be facing the measurer. Care must be taken not to incorporate underlying muscle tissue in the grasp. In order to eliminate muscle, the finger and thumb roll the fold slightly thereby also ensuring that there is a sufficiently large grasp of the fold. If difficulty is encountered the subject should tense the muscle until the tester is confident that only skin and subcutaneous tissue are in the grasp. Since a double fold of skin (dermis) is also being measured, some variability may be attributed to variations in skin thicknesses at different sites over the body and among different people (37). Despite skin thickness decreasing with age (due to changes in collagen structure (38), this should not normally be considered an important variable since it is outside of the resolution for detection with skinfold calipers.
- The nearest edge of the contact face of the caliper is applied 1 cm lateral to the thumb and finger. If the caliper is placed too deep or too shallow incorrect values may be recorded. As a guide, the caliper should be placed at a depth of approximately mid-fingernail. Practice is also necessary to ensure the same size of skinfold is grasped at the same location for repeat measures.
- The caliper is held at 90° to the surface of the skinfold site at all times. If the caliper jaws are allowed to slip or are incorrectly aligned the distance recorded may be inaccurate. Make sure the hand grasping the skin remains holding the fold while the caliper is in contact with the skin.
- Measurement is recorded 2 s after the full pressure of the caliper is applied (39). It is important that the measurer makes sure that fingers resting on the caliper trigger do not prevent the full caliper pressure from being exerted. In the case of large skinfolds the needle may still be moving at this point. The measurement is nevertheless recorded at this time. This standardisation is necessary since adipose tissue is compressible (37). A constant recording time enables test/retest comparisons to be made while controlling for skinfold compressibility.
- Skinfold sites should be measured in succession to avoid experimenter bias. That is, a complete data set is obtained before repeating the measurements for the second and then third time. This may also help to reduce the effects of skinfold compressibility. They should be measured in the same order as listed on the proforma so that the assistant is familiar with the routine and errors are minimised. (Note: If consecutive skinfold measurements become smaller, the adipose tissue is likely being compressed where the intra- and extracellular fluid content is gradually being reduced. This most often occurs in the fatter subjects. In this instance the tester should move to the next site and return to the original site after several minutes.)
- Skinfold measurements should not be taken after training or competition, sitting in a sauna, swimming or showering since exercise, warm water, and heat produce hyperaemia (increased blood flow) in the skin with a concomitant increase in skinfold thickness. Additionally, dehydration has been suggested (40) to cause the skinfold thickness to increase due to changes in skin turgidity (tenseness) although this has not always been found (41).

4.8.2 Skinfold measurements

The equipment used for all skinfold measurements is the skinfold caliper.

5. Triceps®

The Triceps® skinfold is raised with the thumb and index finger on the marked Triceps skinfold site®. The fold is parallel to the long axis of the upper arm.

Method

The marked skinfold site should palpated to gauge the musculature and level of adipose tissue prior to measurement. For measurement, the arm should be relaxed and elbow extended by the side of the body in a mid-prone position. The anthropometrist stands behind the subject. See Figure 4.39.

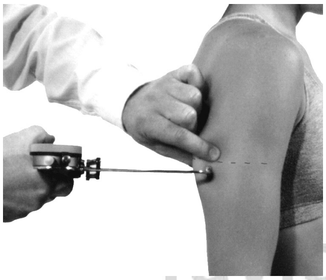

Figure 4.39 Measurement of Triceps® skinfold

6. Subscapular®

The Subscapular® skinfold is raised with the thumb and index finger on the marked Subscapular skinfold site®. The fold runs obliquely downwards as determined by the natural fold lines of the skin.

Method

The marked skinfold site should palpated to gauge the musculature and level of adipose tissue prior to measurement. The subject should assume a relaxed position with the arms hanging by the side. The anthropometrist stands behind the subject. See Figure 4.40.

Figure 4.40 Measurement of the Subscapular® skinfold

7. Biceps®

The skinfold is raised with the thumb and index finger on the marked Biceps skinfold site®. The fold runs parallel to the long axis of the upper arm.

Method

The subject stands with the arm relaxed and elbow extended. The fold is located on the most anterior aspect of the surface of the right arm. The marked point for the Biceps® skinfold is in the midline of the muscle belly over the anterior surface over the biceps at the level of the Mid-acromiale-radiale® line. See Figure 4.41.

Figure 4.41 Measurement of the Biceps® skinfold

8. Iliac crest®

This skinfold is raised immediately superior to the Iliocristale® at the marked Iliac crest skinfold site®.

Method

The subject abducts the right arm to the horizontal or places the arm across the chest. The natural fold of the skin runs slightly downwards toward the medial aspect of the body. See Figure 4.42.

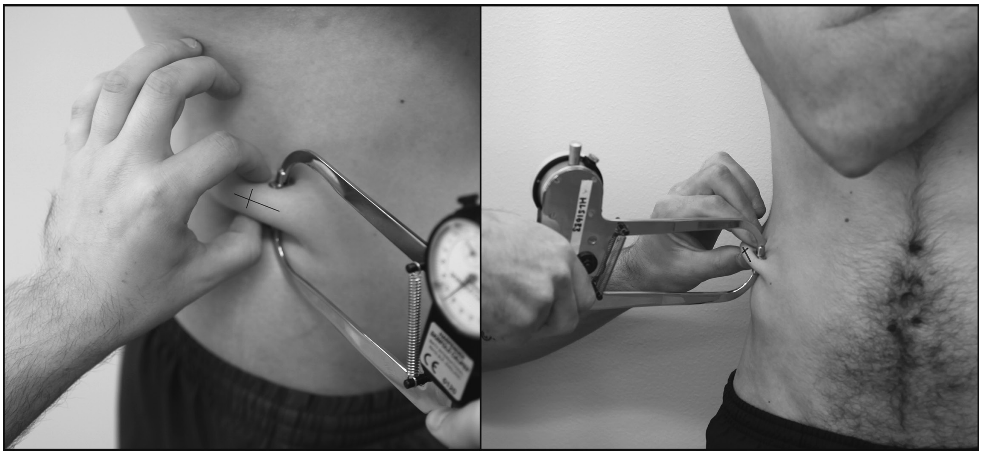

Figure 4.42 Measurement of the Iliac crest® skinfold

9. Supraspinale®

The skinfold is measured at the marked Supraspinale skinfold site®.

Method

The subject assumes a relaxed position with the arms hanging by the sides. The marked Supraspinale skinfold site® is typically about 5–10 cm above the Iliospinale® depending on the size of the adult subject, and may be much less in a young child. The fold runs medially downward and anteriorly at about a 45° angle. See Figure 4.43.

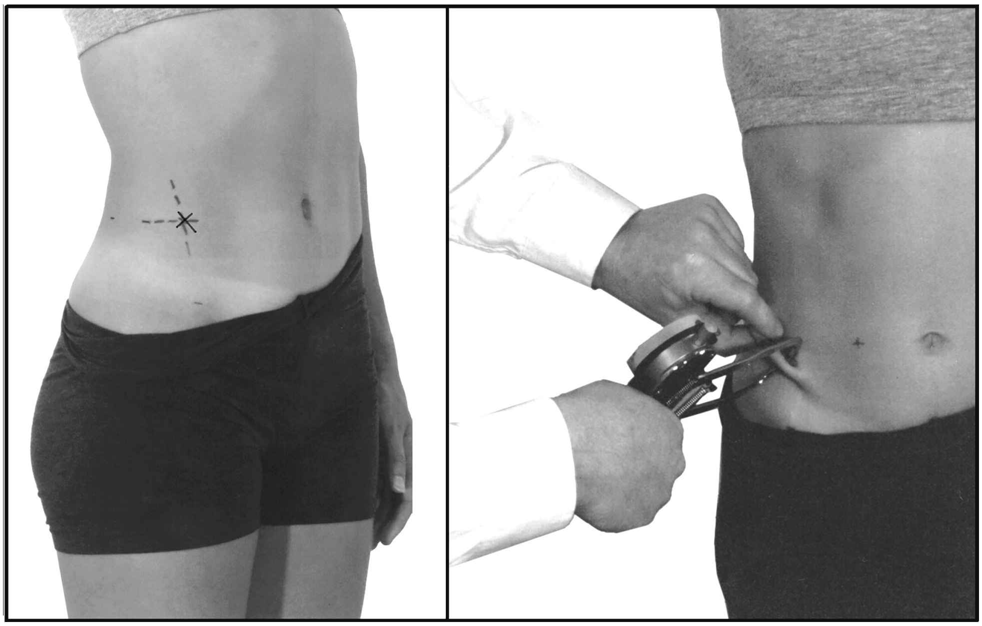

Figure 4.43 Location of the Supraspinale skinfold site® (left) and measurement of the Supraspinale® skinfold (right)

10. Abdominal®

The skinfold is a vertical fold raised 5 cm from the right hand side of the omphalion (midpoint of the navel) at the marked Abdominal skinfold site®.

Method

The subject assumes a relaxed standing position with the arms hanging by the sides. It is particularly important at this site that the measurer is sure the initial grasp is firm and broad since often the underlying musculature is poorly developed. This may result in an underestimation of the thickness of the subcutaneous layer of tissue. (Note: Do not place the caliper inside the navel.) See Figure 4.44.

Figure 4.44 Measurement of the Abdominal® skinfold

11. Front thigh®

The site is marked parallel to the long axis of the femur at the marked Front thigh skinfold site®. This is the mid-point of the distance between the Inguinal point® and the Patellare® while the leg is extended and the heel is on the floor.

Method

The measurer stands facing the right side of the subject on the lateral side of the thigh. The subject's leg is resting straight by placing the right foot on a box or by being seated. The skinfold measurement is taken while the leg is extended. If the fold is difficult to raise, the subject may be asked lift the underside of the thigh to relieve the tension of the skin. When subjects have particularly tight skinfolds, a recorder (standing on the medial aspect of the subject's thigh) can assist by raising the fold using two hands so that there is about 6 cm between the fingers of the right hand raising the fold at the correct anatomical landmark and the left hand which raises a distal fold. The caliper is then located between the recorder's hands, 1 cm from the recorder's thumb and forefinger. See Figure 4.45.

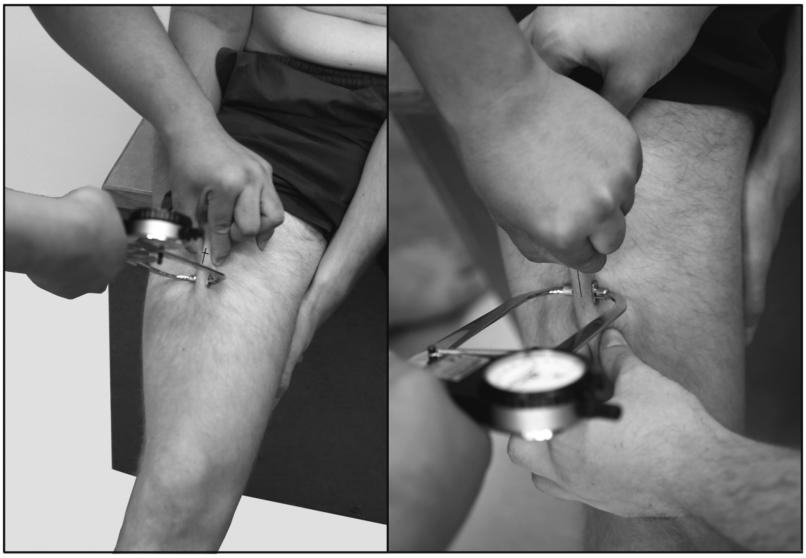

Figure 4.45 Measurement of the Front thigh® skinfold with subject assistance (left) and with additional assistance (right)

12. Medial calf®

The Medial calf® skinfold is taken at the marked Medical calf skinfold site®.

Method

The subject is either seated or has the right foot placed on a box with the right knee at about 90°. The calf muscle should be relaxed while a fold parallel to the long axis of the leg is raised on the medial aspect of the calf at a level where it has maximal circumference (marked when body mass is evenly distributed on both legs while in a standing position). See Figure 4.46.

Mid-axilla

This skinfold is optional as it does not form part of the contemporary Full profile. However, it is important for several body density prediction equations and was originally part of the Full profile when first developed (6). It is a vertical fold on the Ilio-axilla line® at the level of the marked Xiphoidale of the sternum.

Figure 4.46 Measurement of the Medial calf® skinfold

Method

The Xiphoidale is found at the lower extremity of the sternum. The landmark is the inferior tip of the xiphion. It is located by palpation in the medial direction of the left or right costal arch toward the sternum. These arches (which form the infrasternal angle) articulate at the xiphosternal joint. It is usual practice to have the subject lift the right arm at about 90° to the body with the subject's hand resting on their head. Elevating the arm further than this may cause the skin to become difficult to grasp. See Figure 4.47.

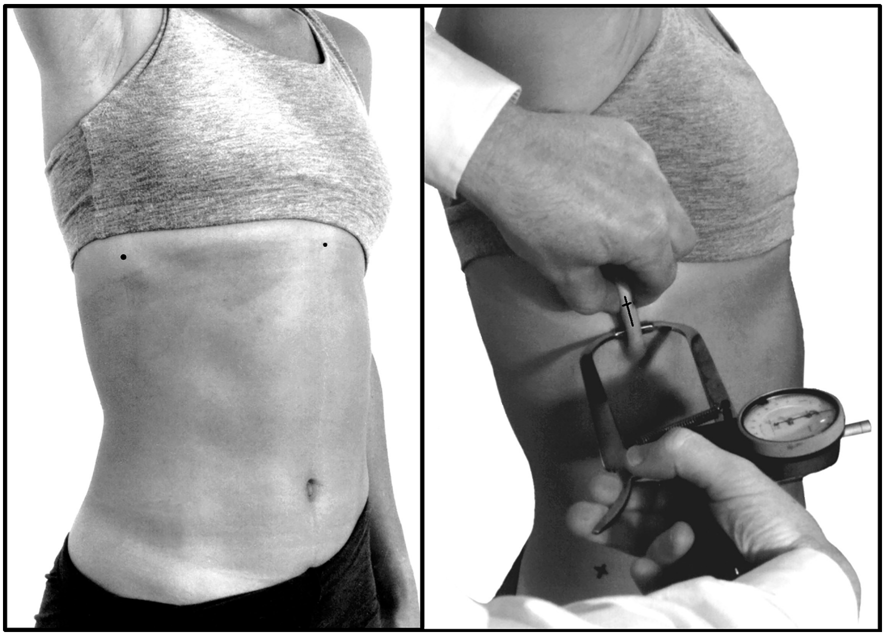

Figure 4.47 Landmarks (left) and measurement of the Mid-axilla skinfold

4.9 GIRTHS

4.9.1 General techniques for measuring girths

The cross hand technique is used for measuring all girths and the reading is taken from the tape where, for easier viewing, the zero is located more lateral than medial on the subject. In measuring girths the tape is held at right angles to the limb or body segment being measured and the tension of the tape must be constant. Constant tension is achieved by ensuring that there is no indentation of the skin but the tape holds its place at the designated landmark. While constant tension tapes may be available, non-tension tapes such as the Lufkin tape is preferred since it allows the measurer to control the tension.

To position the tape, hold the case in the right hand and the stub in the left. Facing the body part to be measured, pass the stub end around the back of the limb and take hold of the stub with the right hand which then holds both the stub and the casing. At this point the left hand is free to manipulate the tape to the correct level. Apply sufficient tension to the tape with the right hand to hold it at that position while the left hand reaches underneath the casing to take hold of the stub again. The tape is now around the part to be measured. The middle fingers of both hands are free to exactly locate the tape at the landmark for measurement and to orientate the tape so that the zero is easily read. The juxtaposition of the tape ensures that there is contiguity of the two parts of the tape from which the girth is determined. When reading the tape the measurer's eyes must be at the same level as the tape to avoid any error of parallax.

13. Head

The girth of the head is obtained in the Frankfort plane, perpendicular to the long axis of the head. It is measured at the level immediately above the Glabella (mid-point between the brow ridges) while the subject is seated or standing.

Method

The tape needs to be pulled tight to compress the hair. Use of the middle fingers at the side of the head is often necessary to prevent the tape from slipping over the head. Do not include the ears and ensure that there are no hairpins, clips, or similar items in the hair during the measurement. See Figure 4.48.

Figure 4.48 Measurement of the Head girth

14. Neck

The girth around the neck is measured immediately superior to the thyroid cartilage (Adam's apple) and perpendicular to the long axis of the neck. The subject should maintain the head in the Frankfort plane and may be seated or standing.

Method

It is important not to pull the tape tight in this region since the tissues are compressible. The tape is held perpendicular to the long axis of the neck which may not necessarily be in the horizontal plane. Do not include hair in the measurement. See Figure 4.49.

Figure 4.49 Measurement of the Neck girth

15. Arm relaxed®

The Arm relaxed® girth is the girth of the upper arm measured at the level of the marked Mid-acromiale-radiale®.

Method

The subject assumes a relaxed position with the arms hanging by the side of the body. The tape should be positioned perpendicular to the long axis of the humerus while the muscles of the arm are relaxed. See Figure 4.50.

Figure 4.50 Measurement of the Arm relaxed® girth

16. Arm flexed and tensed®

The Arm flexed and tensed® girth is the maximum girth of the right upper arm which is raised anteriorly to the horizontal with the forearm flexed at 90° to the upper arm. The measurement is made perpendicular to the long axis of the arm.

Method

The subject assumes a relaxed position with the left arm hanging by the side of the body. The measurer stands to the side of the subject and with the tape loosely in position asks the subject to partially flex the biceps to identify the point where the girth will be maximal. Loosen the tension on the casing end, then ask the subject to "clench your fist, bring your hand toward your shoulder so your elbow's at about 90° – and fully tense the biceps and hold it" while the measurement is made. See Figure 4.51.

Figure 4.51 Measurement of the Arm flexed and tensed® girth

17. Forearm

The Forearm girth is taken at the maximum girth of the forearm with the subject holding the palm up while relaxing the muscles of the arm.

Method

The subject assumes a relaxed position with the left arm hanging by the side of the body. The right elbow is extended and right forearm supinated. The measurer stands in front of the subject. Using the cross hand technique it is necessary to slide the tape measure up and down the forearm and make serial measurements in order to correctly locate the level of the maximal girth. It usually occurs just distal to the elbow. See Figure 4.52.

Figure 4.52 Measurement of the Forearm girth

18. Wrist

The Wrist girth is the minimum girth measurement perpendicular to the long axis of the forearm and distal to the styloid processes.

Method

The subject assumes a relaxed position with the left arm hanging by the side of the body. The right elbow is slightly extended, the right forearm supinated and hand relaxed. The measurer stands in front of the subject. Manipulation of the tape measure is required to be sure the minimal girth is obtained and the tissues should not be compressed by excessive tension of the tape. See Figure 4.53.

Figure 4.53 Measurement of the Wrist girth

19. Chest

The Chest girth is taken at the level of the marked Mesosternale landmark and perpendicular to the long axis of the thorax.

Method

The measurer stands to the right of the subject. The subject is standing relaxed while slightly abducting the arms allowing the tape to be passed around the chest. The subject should breathe normally and the measurement is taken at the end of a normal expiration (end tidal) with the arms relaxed at the sides. Care is required to ensure that the tape does not deviate from the correct plane, particularly around the subject's back. See Figure 4.54.

Figure 4.54 Measurement of the Chest girth for a male and female

20. Waist®

The Waist® girth is taken at the level of the narrowest point between the lower costal (rib) border and the iliac crest. The girth is measured perpendicular to the long axis of the trunk.

Method

The subject assumes a relaxed standing position with the arms folded across the thorax. The measurer stands in front of the subject to correctly locate the narrowing of the waist. The measurement is taken at the end of a normal expiration. If there is no obvious narrowing then the measurement is taken at the mid-point between these two landmarks. See Figure 4.55.

Figure 4.55 Measurement of the Waist® girth

21. Gluteal (hip)®

The Gluteal (hip)® girth is taken at the level of the greatest posterior protuberance of the buttocks and perpendicular to the long axis of the trunk.

Method

The measurer stands at the side of the subject to ensure the tape is held in a horizontal plane when measuring this girth. The subject stands with feet together and arms folded across the thorax. The subject should not tense the gluteal muscles. See Figure 4.56.

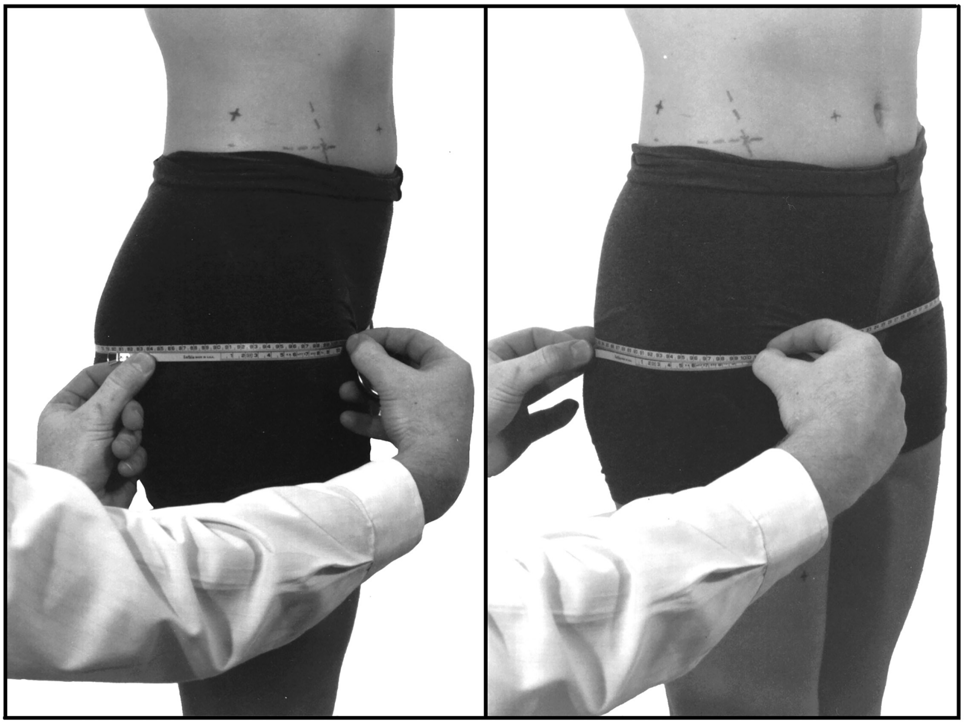

Figure 4.56 Measurement of the Gluteal (hip)® girth showing a side and front view

22. Thigh

The girth of the thigh is taken 1 cm below the level of the gluteal fold, perpendicular to the long axis of the thigh.

Method

The subject stands in a relaxed position with the feet slightly apart and mass equally distributed on both feet and arms folded across the thorax. It is usually helpful to have the subject stand on a box or stool for this measure. The measurer passes the tape around the lower portion of the thigh and then slides the tape up to the correct plane. Minimal pressure is applied to the tape. See Figure 4.57.

Figure 4.57 Measurement of the Thigh girth showing posterior view (left) and lateral view (right)

23. Mid-thigh

This is the right thigh girth taken perpendicular to the long axis of the thigh at the level of the marked Mid-trochanterion-tibiale laterale site.

Method

The subject stands in a relaxed position with the feet slightly apart and mass equally distributed on both feet and arms folded across the thorax. It is usually helpful to have subjects stand on a box or stool for this measure. The measurer passes the tape around the lower portion of the thigh and then slides the tape up to the correct plane. Minimal pressure is applied to the tape. See Figure 4.58.

Figure 4.58 Measurement of the Mid-thigh girth

24. Calf®

The maximum girth of the calf at the level of the marked Medial calf skinfold site®. It is measured perpendicular to the long axis of the leg.

Method

The subject stands in a relaxed position with the weight evenly distributed. It is useful to have the subject stand in an elevated position, for example, on a box or stool. The elevated position will make it easier for the measurer to align the eyes with the tape. The measurement is taken from the lateral aspect of the leg. See Figure 4.59.

Figure 4.59 Measurement of the Calf® girth

25. Ankle

The minimum girth of the ankle is taken at the narrowest point superior to the Sphyrion tibiale. It is measured perpendicular to the long axis of the leg.

Method

The subject stands in a relaxed position with the weight evenly distributed. It is useful to have the subject stand in an elevated position, for example, on a box or stool. The elevated position will make it easier for the measurer to align the eyes with the tape. The tape needs to be manipulated up and down this region to ensure the minimal girth is obtained. The measurement is taken from the lateral aspect of the leg. See Figure 4.60.

Figure 4.60 Measurement of the Ankle girth

4.10 LENGTHS

4.10.1 General techniques for measuring lengths

There are two methods for measuring body segment lengths. One involves measuring the vertical distance from the floor to a series of marked landmarks with an anthropometer. In this case the barefoot subject assumes the erect standing position with the feet together as previously described. This is the method of measuring projected segment lengths. Following these measurements it is possible (by subtraction) to determine the lengths of individual segments, for example Acromiale minus Radiale height, to give upper arm length (Acromiale-Radiale). The second method allows direct measurements of these segment lengths. In this case either a large sliding caliper or a segmometer is the instrument used. Previous research (42) has shown errors are more common when the projected segment lengths method is used. Therefore, it is recommended that segment lengths are measured directly. Rigid, large sliding calipers are preferable to a tape since the tape has a tendency to overestimate lengths because it is difficult to keep it straight (42). The following guidelines are based on the use of a large sliding caliper although with minimal alterations a segmometer may be substituted. Before making any measurements inspect each pointer on the caliper to make sure there has not been movement away from the landmark. It is preferable that the caliper end where measurements are to be read is located closest to the measurer's eye level.

26. Acromiale-Radiale

This is the upper arm length where the distance is measured between the Acromiale® and Radiale® landmarks.

Method

The subject stands erect with the palms slightly off the thighs. One arm of the caliper or segmometer is held on the Acromiale® while the other arm is placed on the Radiale®. Where subjects have large deltoid muscles an anthropometer must be used to avoid curvature of the segmometer. The measurement scale is held parallel to the long axis of the arm. See Figure 4.61.

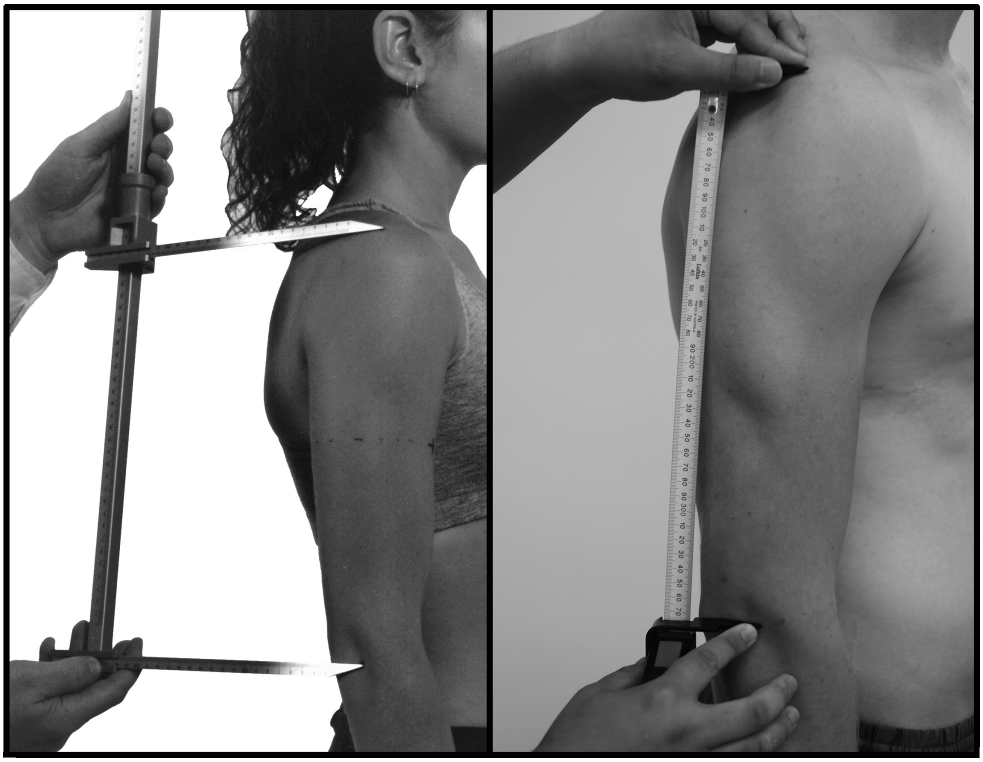

Figure 4.61 Measurement of the Acromiale-Radiale segment length

27. Radiale-Stylion

This is the length of the forearm. It is the distance between the marked Radiale® and Stylion sites.

Method

The subject stands erect with the palms slightly off the thighs. One caliper or segmometer arm is held against the Radiale® and the other arm is placed on the Stylion landmark. The caliper is positioned so that it runs parallel to the long axis of the radius. See Figure 4.62.

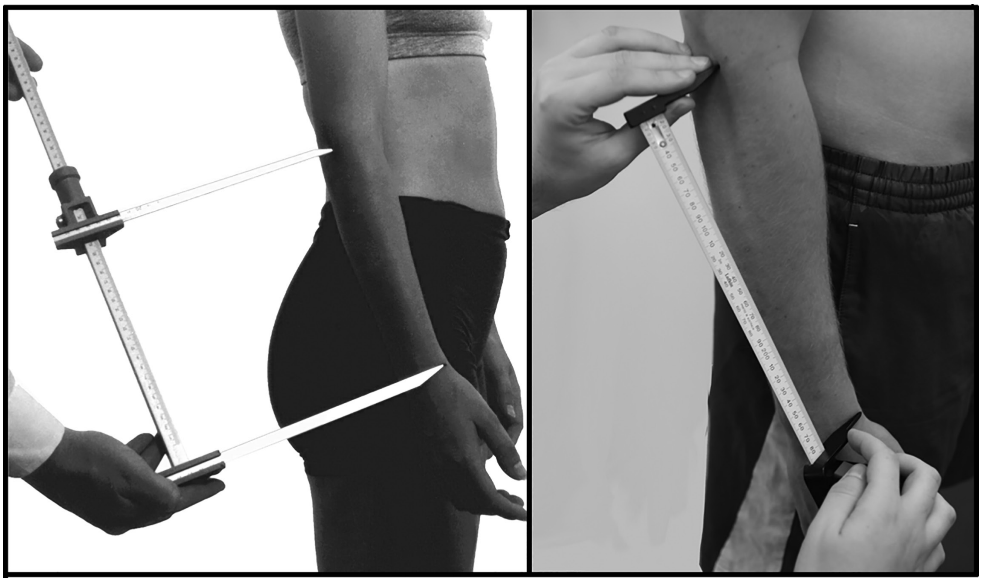

Figure 4.62 Measurement of the Radiale-Stylion segment length

28. Mid-stylion-dactylion

This is the length of the hand. The measurement is taken as the distance from the marked Mid-stylion site to the Dactylion with fingers outstretched (but not hyperextended).

Method

The subject places the hand in a supinated position (palms facing up) and the fingers extended. One end of the caliper is placed on the marked Mid-stylion line while the other end is positioned on the most distal point of the third digit. See Figure 4.63.

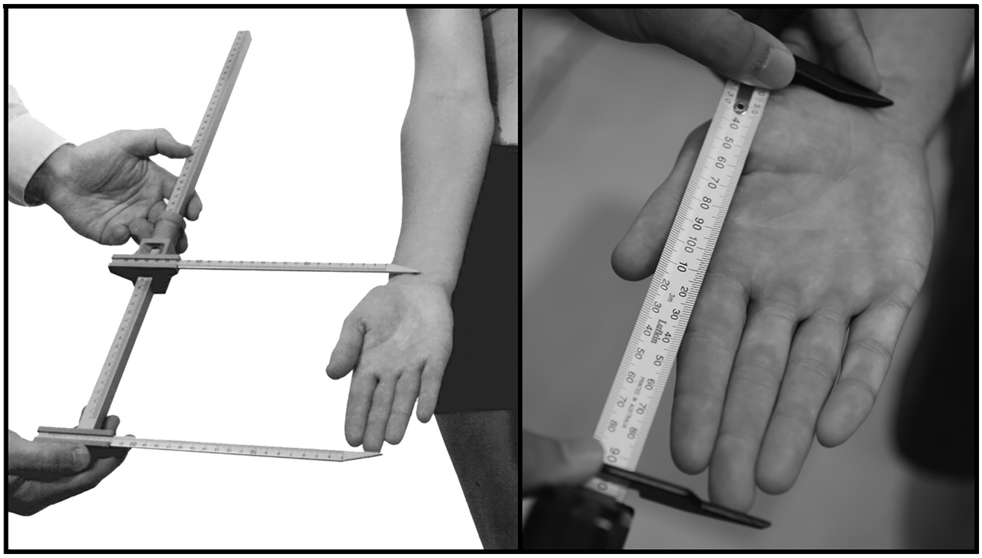

Figure 4.63 Measurement of the Mid-stylion-dactylion segment length

29. Iliospinale height

The vertical height from the standing surface to the marked Iliospinale® site.

Method

The subject stands with feet together facing the box so that their toes are placed in the cut-out portion of the box. The base of the anthropometer is placed flush on top of the box and the scale oriented vertically upwards with the moving arm positioned at the marked Iliospinale® site. (Note: The height of interest is the height from the floor to the landmark Iliospinale®. If a box is used this is obtained by adding the box height to the Iliospinale®-box height). See Figure 4.64.

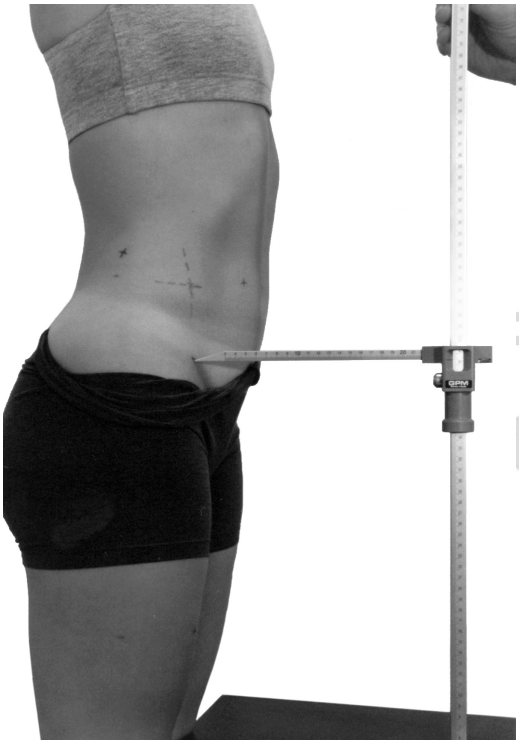

Figure 4.64 Measurement of the Iliospinale height using a box

30. Trochanterion height

The vertical height from the standing surface to the marked Trochanterion site.

Method

The subject stands with feet together and the lateral aspect of their right leg against the box. The base of the caliper is placed flush on top of the box and the caliper oriented vertically upwards with the moving arm positioned at the marked Trochanterion site. (Note: The height of interest is the height from the floor to the Trochanterion landmark. If a box is used this is obtained by adding the box height to the Trochanterion-box height.) See Figure 4.65.

Figure 4.65 Measurement of the Trochanterion height using a box

31. Trochanterion-tibiale laterale

This is the length of the thigh. It is the distance between the Trochanterion and Tibiale laterale landmarks.

Method

The distance is measured while the subject stands on the box in a relaxed position, weight evenly distributed and with the arms folded across the thorax. One end of the caliper is placed on the marked Trochanterion and the other end is placed to the marked Tibiale laterale site. See Figure 4.66.

32. Tibiale laterale height

This is the length of the lower leg, that is, the distance from the standing surface to the Tibiale laterale landmark.

Method

The distance is measured while the subject stands in a relaxed position, weight evenly distributed and with the arms hanging by the sides. It is usual practice to have the subject stand on the

Figure 4.66 Measurement of the Trochanterion-tibiale laterale segment length

box while the base of the caliper is on the top of the box and the moving arm is placed on the marked Tibiale laterale site. The caliper should be held in the vertical plane. The height from the Tibiale laterale to the top of the box is then measured. See Figure 4.67.

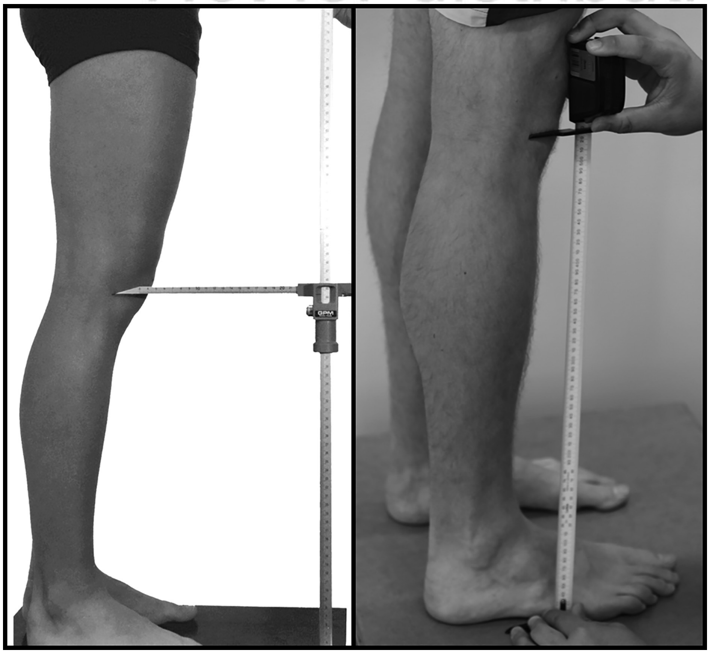

Figure 4.67 Measurement of the Tibiale laterale height

33. Tibiale mediale-sphyrion tibiale

This is the length of the tibia. It is the measured length between the Tibiale mediale and Sphyrion tibiale sites.

Method

The subject should be seated on the box for this measurement with the right ankle crossed over and resting on the left knee. One end of the caliper is placed on the marked Tibiale mediale site and the other end positioned on the marked Sphyrion site. See Figure 4.68.

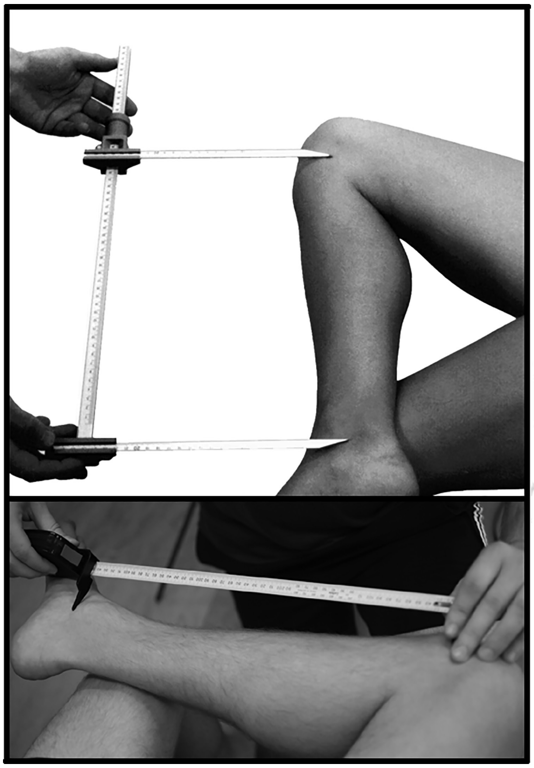

Figure 4.68 Measurement of the Tibiale mediale-sphyrion tibiale segment length

4.11 BREADTHS

4.11.1 General techniques for measuring breadths

Both the small sliding (bone) calipers and the large sliding calipers are held in the same way. The caliper body lies on the backs of the hands while the thumbs rest against the inside edge of the caliper arms, and the extended index fingers lie along the outside edges of the arms. In this position the fingers are able to exert considerable pressure to reduce the thickness of any underlying soft tissue and the middle fingers are free to palpate the bony landmarks on which the caliper faces are to be placed. The measurements are made when the caliper is in place, with the pressure maintained along the index fingers.

34. Biacromial

This is the distance between the most lateral points on the acromion processes.

Method

The subject stands in a relaxed position with the arms hanging at the sides. This site is measured with the arms of the large sliding caliper placed on the most lateral points of the acromion processes. On the right side, this usually does not correspond to the previously marked Acromiale® landmark, which is typically superior, medial, and anterior to these lateral points. The measurer stands behind the subject and should bring the anthropometer blades in to the acromion processes at an angle of about 30° pointing upwards. Firm pressure should be applied to compress the overlying tissues. Measurement is taken at end-tidal expiration. See Figure 4.69.

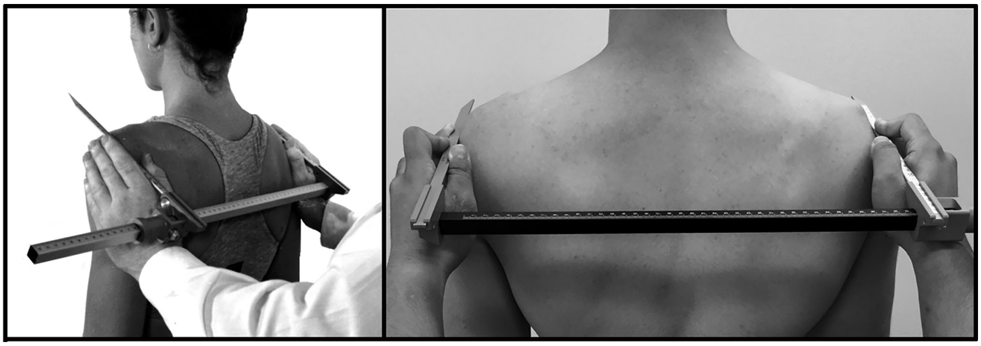

Figure 4.69 Measurement of the Biacromial breadth

35. Anterior-posterior abdominal depth

This is the A-P abdominal depth measured in the sagittal plane between the point on the skin surface of the abdomen immediately inferior to the omphalion and the corresponding most anterior extension on the dorsal surface of the torso.

Method

The subject assumes a relaxed standing position with the arms folded across the thorax. Measurement is taken at the end of a normal expiration. Subjects should relax and not contract the abdominal muscles which would reduce this measurement. See Figure 4.70.

Figure 4.70 Measurement of the A-P abdominal depth

36. Biiliocristal

The linear distance between the most lateral points on the iliac tubercles (crests). This is not necessarily the same location as the Iliocristale® which is on the Mid-axilla line®).

Method

The subject assumes a relaxed standing position with the arms folded across the chest. The branches of the anthropometer are kept at about 45° pointing upwards and the measurer stands in front of the subject. Firm pressure is applied by the measurer to reduce the effect of overlying tissues. See Figure 4.71.

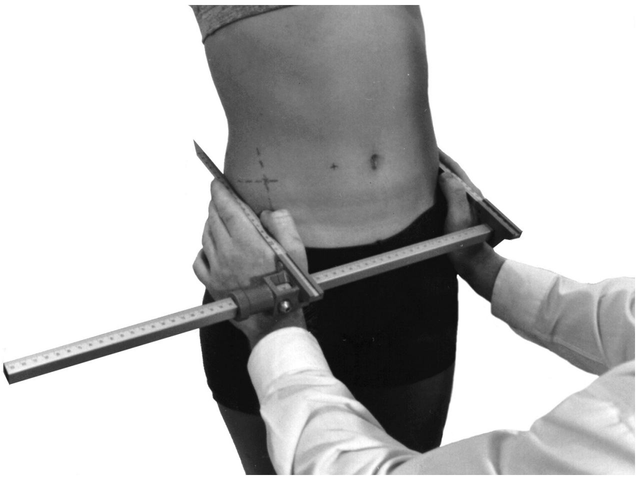

Figure 4.71 Measurement of the Biiliocristal breadth

37. Foot length

This is the distance from the Akropodion (anterior point on the longest toe) to the Pternion (most posterior point on the heel of the foot) landmarks.

Method

The subject stands with the weight equally distributed on both feet and arms hanging by the sides. The caliper should be kept parallel to the long axis of the foot and minimal pressure is applied. It is more convenient for the measurer if the subject stands on the box during this measurement. See Figure 4.72.

Figure 4.72 Measurement of the Foot length

38. Transverse chest

The Transverse chest breadth is measured between the most lateral aspect of the thorax when the superior aspect of the caliper scale is positioned at the level of the Mesosternale (at the front) and the blades are positioned at an angle of 30° downward from the horizontal.

Method

The measurer stands in front of the subject who may be either seated or standing. Care must be taken to avoid inclusion of the Pectoral or Latissimus Dorsi muscles. The 30° angle prevents the caliper from slipping between the ribs. The measurement is taken at the end of a tidal expiration. See Figure 4.73.

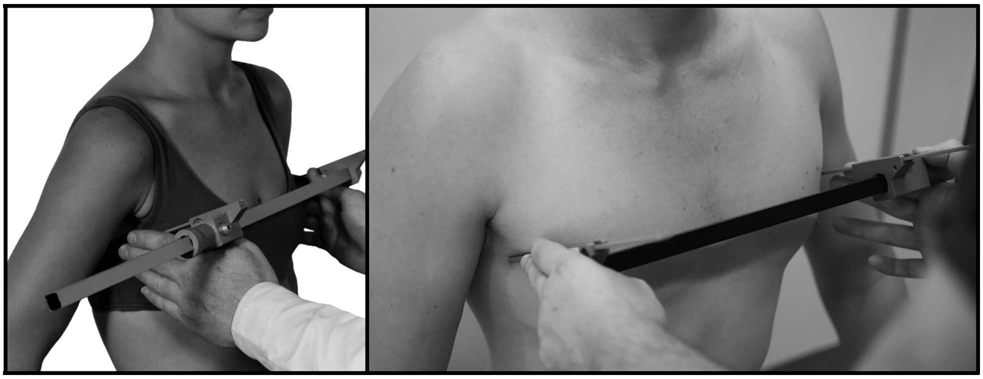

Figure 4.73 Measurement of the Transverse chest

39. Anterior-posterior chest depth

This is the A-P chest depth measured perpendicular to the long axis of the thorax at the level of the Mesosternale.

Method

The measurer uses the recurved branches of the wide-spreading caliper over the right shoulder of the subject who is seated in an erect position and is instructed to breathe normally. The rear branch of the caliper should be positioned on the spinous process of the vertebra at the horizontal level of the Mesosternale. The front branch of the caliper is placed on the Mesosternale landmark. Measurement is taken at end-tidal expiration and only very light pressure is applied. See Figure 4.74.

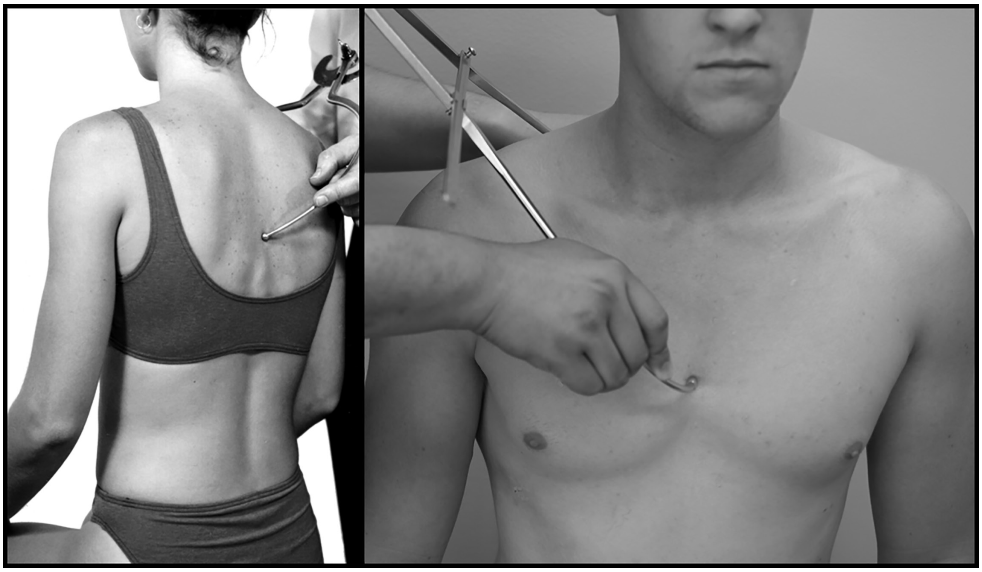

Figure 4.74 Measurement of the A-P chest depth from an anterior view and posterior view

40. Biepicondylar humerus®

The distance measured between the medial and lateral epicondyles of the humerus.

Method

The subject assumes a relaxed standing or seated position. The right arm is raised anteriorly to the horizontal and the forearm is flexed at right angles to the upper arm. With the small sliding caliper gripped correctly, use the middle fingers to palpate the epicondyles of the humerus, starting proximal to the sites. The bony points first felt are the epicondyles. The caliper face is placed directly on the epicondyles so that the arms of the caliper point upward at about a 45° angle to the horizontal plane. Maintain firm pressure with the index fingers as the value is read. Because the medial epicondyle is lower than the lateral epicondyle the measured distance may be somewhat oblique. See Figure 4.75.

Proof

Figure 4.75 Locating the humeral epicondyles by palpation (left) and measurement of the Biepicondylar humerus® (right)

41. Bi-styloid

The breadth of the wrist between the lateral radial and medial ulnar styloid processes is measured.

Method

The subject assumes a seated position with the right hand pronated and resting on the right knee. With the small sliding caliper gripped correctly, use the middle fingers to palpate the styloid processes. The caliper face is placed directly on the styloid processes so that the arms of the caliper point downwards at about a 45° angle to the horizontal plane. Maintain firm pressure with the index fingers as the value is read. See Figure 4.76.

Figure 4.76 The Bi-styloid breadth measurement

42. Biepicondylar femur®

The distance measured between the medial and lateral epicondyles of the femur.

Method

The subject assumes a relaxed seated position with the right leg flexed at the knee to form a right angle with the thigh. With the caliper in place use the middle fingers to palpate the epicondyles of the femur beginning proximal to the sites. The bony points first felt are the epicondyles. Place the caliper faces on the epicondyles so that the arms of the caliper point downward at about a 45° angle to the horizontal. Maintain firm pressure with the index fingers until the value is read. See Figure 4.77.

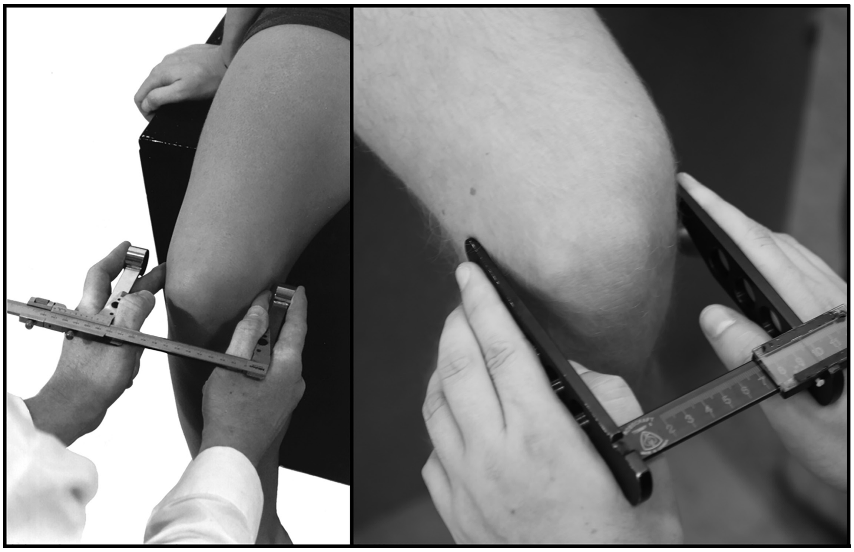

Figure 4.77 Locating the femoral epicondyles by palpation (left) and measurement of the Biepicondylar femur® (right)

Other common breadths

The following breadths are optional since they do not form part of the Full profile. However, they are useful measures for calculations and predictions of frontal surface area in sports such as running, cycling, and skating, and for monitoring changes in muscularity among athletes and in ageing studies.

Bideltoid

This is the linear distance between the most lateral aspects of the relaxed deltoid muscles.

Method

The subject stands relaxed with arms hanging by the sides and palms resting against the thighs. Bideltoid breadth is measured using the large sliding caliper. Minimal pressure must be applied to the site by the measurer so that no indentation of the skin occurs. The blades of the anthropometer should be angled pointing slightly upwards. See Figure 4.78.

Figure 4.78 Measurement of Bideltoid breadth

Bitrochanteric

The linear distance between the most lateral aspects of the Trochanteria.

Method

The subject assumes a relaxed standing position with the feet together and arms resting across the chest. The anthropometrist should stand in front of the subject and the blades of the anthropometer should be positioned on the most lateral aspects of the Trochanteria. The blades should be angled slightly upwards from the horizontal. (Note: This is not at the same level as the previously marked Trochanterion landmark.) See Figure 4.79.

Figure 4.79 Measurement of Bitrochanteric breadth

4.12 PRACTICAL EXERCISES

Practical 4.1 predicting body density and % body fat from anthropometric measurements

Purpose

The aims of this practical are to:

1 calculate body density and % body fat values using anthropometric prediction equations
2 demonstrate the variation in predicted % body fat values using different anthropometric prediction equations.

Procedures

Based on the measurement sites taken, the subject's gender, and (sometimes) other demographic information such as age and level of physical activity, an analysis can be performed to predict body density (BD) and percent body fat (%BF) using a number of compatible equations selected from the literature.

Table 4.3 shows several prediction equations that can be used to estimate BD and then %BF. It details several BD prediction equations for males and females that have been sourced from the scientific literature. It is not a complete list but identifies some of the more commonly used prediction equations. The equations are sex-specific and involve a number of different anthropometric measurements. These equations may result in a range of BD and %BF predictions for any particular individual. This laboratory will demonstrate the variation in prediction scores.

All of the listed equations use independent anthropometric variables whose sites are equivalent with the guidelines presented in this chapter. In some instances the original descriptions use slightly different terminology although the landmarks are the same. The required anthropometry measurements differ depending on the specific equations but most require the restricted profile measures in order to calculate BD and %BF. The conversion of BD to %BF is achieved using the following formula:

$$\%BF = 495 / BD - 450$$

Use volunteers and record the required anthropometry measurements so that you can enter the raw data into the prediction equations. Use a spreadsheet to calculate BD and corresponding %BF values using at least three different male or female equations. Summarise the final values to show a mean value and the range of scores that are calculated. You can also check your answers using the on-line *Exercise Science Toolkit* software (www.exercisesciencetoolkit.com).

Why are there differences in predicted values? Discuss the possible reasons that have contributed to the differences in the predicted %BF among the equations.

Practical 4.2 calculating intra-tester technical error of measurement (TEM) from raw data

Purpose

The aims of this practical are to:

1 calculate the percent technical error of measurement (%TEM) following duplicate measures of a (a) skinfold, (b) girth, and (c) breadth measurement
2 use the %TEM values to determine the 95% confidence interval around single anthropometry measures
3 use the %TEM value to determine if a true change has occurred between two anthropometry measures following an intervention.

Table 4.3 Prediction equations to estimate body density and % body fat

	Reference	*Anthropometry variables required*	*Equation*	*Notes*	*BD*	*%BF*
MALES						
®	**Durnin and Womersley (1974) (16)**	triceps, biceps, subscapular, and iliac crest skinfolds	$BD = 1.1765 - 0.0744(\log_{10} X)$	where: × (mm) = ∑ 4 skinfolds (triceps, biceps, subscapular, iliac crest in mm)		
	Forsyth and Sinning (1973) (33)	subscapular, abdominal, triceps, and mid-axilla skinfolds	$BD = 1.10647 - 0.00162(X1) - 0.00144(X2) - 0.00077(X3) + 0.00071(X4)$	where: X1 = subscapular skinfold (mm), X2 = abdominal skinfold (mm), X3 = triceps skinfold (mm), X4 = mid-axilla skinfold (mm)		
®	**Katch and McArdle (1973) (43)**	triceps, subscapular, and abdominal skinfolds	$BD = 1.09665 - 0.00103(X1) - 0.00056(X2) - 0.00054(X3)$	where: X1 = triceps skinfold, X2 = subscapular skinfold (mm), X3 = abdominal skinfold (mm)		
®	**Sloan (1967) (44)**	subscapular and front thigh skinfolds	$BD = 1.1043 - 0.001327(X1) - 0.001310(X2)$	where: X1 = front thigh skinfold (mm), X2 = subscapular skinfold (mm)		
	Thorland et al. (1984) (34)	triceps, subscapular, mid-axilla, iliac crest, abdominal, front thigh, and medial calf skinfolds	$BD = 1.1091 - 0.00052(X) + 0.00000032(X)^2$	where: X = ∑ 7 skinfolds (triceps, subscapular, mid-axilla, iliac crest, abdominal, front thigh, medial calf in mm)		
®	**Wilmore and Behnke (1969) (45)**	abdominal and front thigh skinfolds	$BD = 1.08543 - 0.000886(X1) - 0.00040(X2)$	where: X1 = abdominal skinfold (mm), X2 = front thigh skinfold (mm)		
®	**Withers et al. (1987) (46)**	triceps, subscapular, biceps, supraspinale, abdominal, front thigh, and medial calf skinfolds	$BD = 1.0988 - 0.0004(X)$	where: X = ∑ 7 skinfolds (triceps, subscapular, biceps, supraspinale, abdominal, front thigh, medial calf in mm)		

(Continued)

Table 4.3 (Continued)

	Reference	Anthropometry variables required	Equation	Notes	BD	%BF
FEMALES						
®	**Durnin and Womersley (1974) (16)**	triceps, biceps, subscapular, and iliac crest skinfolds	$BD = 1.1567 - 0.0717\ (\log_{10} X)$	where: X (mm) = $\sum$ 4 skinfolds (triceps, biceps, subscapular, iliac crest in mm)		
®	**Jackson, Pollock, and Ward (1980) (47)**	triceps, abdominal, front thigh, and iliac crest skinfolds, age, gluteal girth	$BD = 1.24374 - 0.03162(\log10\ X1) - 0.00066(X4)$ $BD = 1.21389 - 0.04057(\log10\ X2) - 0.00016(X3)$	where: X1 = $\sum$ 4 skinfolds (triceps, abdominal, front thigh, iliac crest in mm), X2 = $\sum$ 3 skinfolds (triceps, front thigh, iliac crest in mm), X3 = age (yr), X4 = gluteal circumference (cm)		
	Katch and McArdle (1973) (43)	subscapular and iliac crest skinfolds, biepicondylar humerus breadth, thigh girth	$BD = 1.09246 - 0.00049(X1) - 0.00075(X2) + 0.00710(X3) - 0.00121(X4)$	where: X1 = subscapular skinfold (mm), X2 = iliac crest skinfold (mm), X3 = biepicondylar humerus breadth (cm), X4 = thigh girth (cm)		
®	**Katch and Michael (1968) (48)**	triceps and subscapular skinfolds, gluteal girth, flexed arm girth	$BD = 1.12569 - 0.001835(X1) - 0.002779(X2) + 0.005419(X3) - 0.0007167(X4)$	where: X1 = triceps skinfold (mm), X2 = gluteal girth (inches), X3 = upper arm girth flexed (inches), X4 = subscapular skinfold (mm)		
®	**Lewis et al. (1978) (49)**	triceps and subscapular skinfolds, stature, arm girth relaxed	$BD = 0.97845 - 0.0002(X1) + 0.00088(X2) - 0.00122(X3) - 0.00234(X4)$	where: X1 = triceps skinfold (mm), X2 = stature (cm), X3 = subscapular skinfold (mm), X4 = arm girth relaxed (cm)		
	Pollock et al. (1975) (50)	iliac crest and front thigh skinfolds, wrist girth, biepicondylar breadth	$BD = 1.0852 - 0.0008(X1) - 0.0011(X2) BD = 1.0836 - 0.0007(X1) - 0.0007(X2) + 0.0048(X3) - 0.0088(X4)$	where: X1 = iliac crest skinfold (mm), X2 = front thigh skinfold (mm), X3 = wrist girth (cm), X4 = biepicondylar femur breadth (cm)		

®	**Sloan, Burt, and Blyth (1962) (51)**	triceps and iliac crest skinfolds	$BD = 1.0764 - 0.00081(X1) - 0.00088(X2)$	where: X1 = iliac crest skinfold (mm), X2 = triceps skinfold (mm)
®	**Thorland et al. (1984) (34)**	triceps, subscapular, and iliac crest skinfolds	$BD = 1.0987 - 0.00122(X) + 0.00000263(X)^2$	where: X = ∑ 3 skinfolds (triceps, subscapular, iliac crest in mm)
®	**Wilmore and Behnke (1970) (52)**	triceps, subscapular, and front thigh skinfolds	$BD = 1.06234 - 0.00068(X1) - 0.00039(X2) - 0.00025(X3)$	where: X1 = subscapular skinfold (mm), X2 = triceps skinfold (mm), X3 = front thigh skinfold (mm)
	Withers et al. (1987) (53)	triceps, subscapular, supraspinale, abdominal, front thigh, and medial calf skinfolds, gluteal girth, forearm girth, biepicondylar humerus breadth	$BD = 1.16957 - 0.06447(\log 10\ X1) - 0.000806(X2) + 0.00170(X3) + 0.00606(X4)$	where: X1 = ∑ 6 skinfolds (triceps, subscapular, supraspinale, abdominal, front thigh, medial calf in mm), X2 = gluteal girth (cm), X3 = forearm girth (cm), X4 = biepicondylar humerus breadth (cm)
®	**Withers et al. (1987) (54)**	triceps, subscapular, supraspinale, and medial calf skinfolds	$BD = 1.17484 - 0.07229(\log_{10} X)$	where: X = ∑ 4 skinfolds (triceps, subscapular, supraspinale, medial calf in mm)

Note: %BF = 495 / BD – 450
® indicates restricted profile is sufficient

Procedure

The technical error of measurement is a quantification of the level of error associated with anthropometry skills. It is used to check an error range for different types of anthropometry variables (skinfolds, girths, lengths, and breadths). There are two types of TEM calculations, a within-person TEM called intra-tester TEM and a between-person TEM called an inter-tester TEM. Generally the intra-tester TEM is smaller than the inter-tester TEM. This is because a particular tester typically follows a similar procedure when assessing anthropometry measurements and these might differ slightly among different testers, although we aim to make these negligible.

The calculated intra-tester TEM can also be used from time to time to see if the error range is changing as skills develop in anthropometry measurements. Additionally, a specific tester's TEM can be used to determine the 95% confidence interval (CI) around a single measure they take on a person. In this case, for example, the tester can generate a confidence interval around an anthropometry measure and can use the CI to determine if a true change has occurred between the test sessions. This change might occur because of some type of intervention such as a training program or a change in diet. We want to be confident a true change has occurred in response to the intervention rather than just because of an inconsistent or poor technique.

The generally accepted intra-tester TEM for the various types of anthropometry measurements are: 5% for skinfolds and 1% for other anthropometry measures.

The generally accepted inter-tester TEM for the various types of anthropometry measurements are: 7.5% for skinfolds and 1.5% for other anthropometry measures.

In this laboratory students will calculate their TEM using a skinfold, a girth, and a breadth measurement. Each of these will be measured in duplicate on at least five people. The pairs of data will then be entered into a spreadsheet to calculate the intra-tester TEM using the equations listed below. You can also check your answers automatically using the on-line *Exercise Science Toolkit* software as part of the Body Composition module.

Part 1: constructing your spreadsheet for %TEM calculation

1 Set up an Excel spreadsheet using the template and algorithms provided in this laboratory. You will need to program the cells in your spreadsheet as part of this laboratory. There should be two columns: Trial 1 and Trial 2 as illustrated in Table 4.4. Enter the raw data from Trial 1 in the first field, and the matching data from Trial 2 in the second field. There must be an equal number of pairs.

2 Determine the number of pairs
The number of lines of text (or values) in trial 1 = N1
The number of lines of text (or values) in trial 2 = N2
There must be pairs of measures, that is N1 must be equal to N2. In the example spreadsheet there are 5 lines representing 5 pairs of measurements or 5 subjects used. Each subject has had his or her Triceps skinfold measured on 2 separate occasions. It is important to separate the two measurements with sufficient time so that measurements are not biased in any way such as remembering the previous measurement.

3 Calculate the sum of each column
The sum all the values in Trial 1 = Sum1
The sum all the values in Trial 2 = Sum2
(these two Sum values are used to calculate SST below)

4 **Sum1 / N1 = Mean1**
Sum2 / N2 = Mean2

Table 4.4 Example spreadsheet for determining the %technical error of measurement for a Triceps skinfold variable. Raw data entered for subjects 1–5 are in mm.

Subject #	*Trial 1*	*Trial 2*	*P values*	*P^2 values*
1	8.2	7.9	16.1	259.21
2	5.5	5.7	11.2	125.44
3	11.7	12.4	24.1	580.81
4	10	10.6	20.6	424.36
5	6.8	6.6	13.4	179.56
Sum	42.2	43.2		
Means	8.44	8.64		
SumTot	85.4			
GrandMean	8.54			
SumSquaredTot	785.2			
SST	55.884			
SumPSquared				1569.38
SSB	55.374			
MSW	0.102			
MSB	13.8435			
TEM	0.319			
%TEM	3.7			

5 Enter your Trial 1 and Trial 2 values to create two lists with all values in Trial 1 and all corresponding values in Trial 2. Since they are pairs of measurements taken on each volunteer each pair should be aligned next to one another across the columns.

6 Sum all the individual values in the list to give an overall sum, that is:
all trial 1 values + all trial 2 values = SumTot

7 Next determine the overall grand mean value:
SumTot / (N1+N2) = GrandMean

8 Sum each line squared of the combined List (i.e., where all Trial 1 and Trial 2 values are listed in one column):
(line X of List)^2 + (line X+1 of List)^2 + (line X+2 of List)^2 . . . etc.
(in the spreadsheet example this would be the sum of 10 values) = SumSquaredTot

9 Now use this sum of squared values (SumSquaredTot) to calculate the sum of squares total (SST):
SumSquaredTot – (SumTot^2 / [N1*2]) = SST

10 Now calculate the sum of P squared values (SumPSquared [to calculate SSB]) using the following method:
Repeat with each value in the Trial 1 column
Add line 1 of Trial1 + line 1 of Trial2 = P1
Add line 2 of Trial1 + line 2 of Trial2 = P2

11 Square all the P values and add the squared values together:
P1^2 + P2^2 + P3^2 . . . etc. = SumPSquared

12 Calculate the following to determine the sum of squares between (SSB):
SumPSquared / 2–SumTot^2 / (2*N1) = SSB
13 Calculate the mean squares within (MSW):
(SST–SSB) / N1 = MSW
14 Calculate the mean squares between (MSB)
SSB / (N1–1) = MSB
15 The square root of MSW = TEM (in the units used in the original raw data, for example, mm for skinfolds and cm for girths):
square root (MSW) = TEM
TEM = Technical error of measurement (use 3 decimal places for TEM)
16 The percent TEM is more meaningful and is what we want to calculate to check against standards:
% TEM = (TEM / GrandMean*100)
(use 1 decimal place for %TEM)

Question

Report the TEM and %TEM for the chosen skinfold measure, girth, and breadth variable. Did your %TEM fall within the guidelines?

Part 2: use your %TEM to calculate the confidence interval around a single measurement

The procedure below allows you to determine the 95% confidence interval around a single measure taken on a subject after you have already established your %TEM for that specific anthropometry variable. In the example the triceps skinfold is used since the triceps %TEM has been calculated above and we now know the %TEM is 3.7%.

After measuring a single raw measurement and knowing your %TEM value for that anthropometry variable, you can calculate the 95% confidence interval for that measurement.

The single raw measurement (Value) and the %TEM are used in the calculations as follows:

(Value+2*%TEM / 100*Value) = Upper confidence interval
(Value–2*%TEM / 100*Value) = Lower confidence interval

Measure an anthropometry site after completing the %TEM calculations for that site.

Question

Calculate the 95% CI to determine the Lower confidence interval to Upper confidence interval. Write in words what this 95% confidence interval means.

Part 3: determining if a 'real change' has occurred between two measurements

The procedure below allows you to use your %TEM and the two raw measurements (that is a first time and second time measurement separated by some sort of intervention or significant time period) to see if a real change has occurred between the repeat measurements.

Record your first measure (Value 1) = the 'measurement on the first occasion'
Record your second measure (Value 2) = the 'measurement on the second occasion'

Now calculate the following:

Value 1–Value 2 = D (difference)
%TEM*Square root(2) = SE
(D+2*SE / 100*[Value 1+Value 2] / 2) = UCL
(D–2*SE / 100*[Value 1+Value 2] / 2) = LCL

Now, if LCL ≤0 and UCL ≥0 then you can conclude 'Since the confidence interval (LCL–UCL) includes zero then we cannot be sure a real change has occurred'.

However, if LCL <0 and UCL <0, or LCL >0 and UCL >0 then you can conclude 'Since the confidence interval (LCL-UCL) does not include zero then we are 95% sure a real change has occurred'.

Question

Once you calculate your %TEM for a specific anthropometry site then take two measurements one week apart on the same person. Has a real change occurred?

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