1.1 Kinanthropometry

1.1.1 History and Application

The term ***kinanthropometry*** derives from the Greek roots *kinein* (movement), *anthropos* (related to man) and *metrein* (measure), and can therefore be interpreted as the measurement of a human being in movement. While its origins are not entirely clear, it is attributed to **William D. Ross** in the 1970s. It has been defined as "the quantitative interface between anatomy and physiology, or between structure and function" (Ross, and Marfell-Jones, 1995, p. 277). This scientific discipline is based on the use of diverse body measurements to evaluate the size, form, proportions, composition, maturing and the gross functions of the human body. Its application allows us to address problems related to growth, exercise, nutrition and athletic performance (Table 1). (Funiber 2017)

Table 1: Applications of kinanthropometry

Identification of kinanthropometry	Specification	Application	Importance
Measurement Human body Movement	For the study of the human body in relation to: size; form; proportion; composition; maturing, and gross functions.	Aids the understanding of: growth; exercises; athletic performance, and nutrition.	Has implications for: medicine; education; sports, and government policies.

Source: prepared based on Ross, y Marfell-Jones (1995).

1.1.2 Basic Areas: Proportionality, Body Composition and Somatotype

The three basic areas that *kinanthropometry* is based on are:

- Proportionality.
- Body Composition.
- Somatotype.

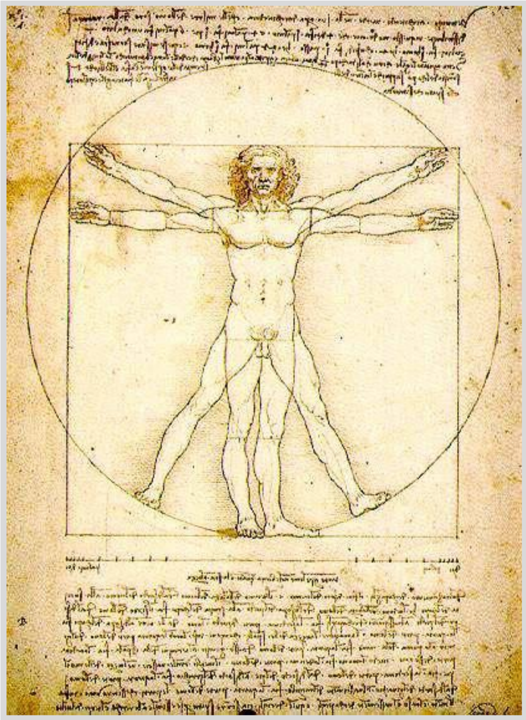
In this section we will develop the first point. The other two will be developed later on.

Proportionality

In anthropometric evaluations we often want to make comparisons, for example: comparing the size of two body segments (e.g. the length of the thigh with the length of the leg), comparing some part of the body with some more global measurement (e.g. weight or height), comparing groups of men and women or comparing athletes from different disciplines. This kind of analysis forms part of what is known as *proportionality* (Olds, Norton, Van Ly, y Lowe, 2000; Ross, y Marfell-Jones, 1995).

This topic goes back a long way in human history. It has been particularly related to art, to the assessment of symmetry and to the establishment of beauty standards. Perhaps most famous in the context of art is the *Vitruvian Man* by Leonardo Da Vinci (Figure 1). All the same, these concepts can be traced back as far as ancient Egypt.

Figure 1: *The Vitruvian Man* by Leonardo Da Vinci



Source: Da Vinci, 1490, http://goo.gl/5bYwsh

The concept of proportionality can be considered as complementary to the concept of body type (this refers to the whole structure taken together, evaluated using different methods. The most popular is the somatotype), (Garrido, 2015) but they refer to different aspects of the human body.

The study of proportionality could be considered important, as strong relationships have been found between different physiological and/or functional variables. Weight is one of the most important of these. Furthermore, some body proportions can determine or affect athletic performance.

Since the 70s, the human being most commonly used for reference has been the **Phantom**, developed by Ross & Wilson (1974). This refers to an arbitrary unisex human reference, whose anthropometric characteristics (weight, height, lengths, girths, breadths, skinfolds and fractional masses) have been defined based on analyses of studies of large populations (Olds et al., 2000; Ross, y Marfell-Jones, 1995).

The proportionality results obtained with this method are expressed in *Z values* or *proportionality scores*. To calculate the Z value of each anthropometric variable, the following formula is used (Olds et al., 2000):

$$Z = (V_{adjust} - P) / s$$

Where:

V_{adjust}: gross value of the variable measured adjusted for height, that is, multiplied by Phantom height/subject height (170.18/h).

P: average Phantom value for the measured variable.

s: standard deviation of the Phantom value for the measured variable.

For example, if when evaluating a subject's tricipital skinfold we obtain the result $Z = -1.5$, this means that the subject has a tricipital skinfold which is 1.5 standard deviations below (negative) the Phantom average.

One relevant point when interpreting this data is to keep in mind that the values obtained do not represent an ideal norm (i.e. a normative or prescriptive system); instead they are a useful method for carrying out comparisons (Olds et al., 2000; Ross, y Marfell-Jones, 1995).

While this method is fairly simple to calculate and useful for comparing proportionality, it is not free of problems. In the effort to simplify the reference model, key variables are lost that explain the intrinsic variability of the human being, for example sex (the model is unisex), age and race.

In summary, this model of proportionality is not a normative or prescriptive system, but it does allow us to quantify the proportional differences for a large number of anthropometric variables between subjects or for a single subject over time.

Another method of anthropometric proportionality is the **combined method** (Lentini, y Verde, 2004). This method aims to obtain ideal values for a given population or group, such as high performance athletes. In other words, it attempts to provide specificity in agreement with the group that is being worked with in order to obtain a reference model to strive for.

Using specific statistical techniques (i.e. Bayesian inference) it combines the databases of large population studies used in the Phantom with the particular contribution of a sample considered to be ideal or specific, without making an adjustment for height. The result obtained is a **combined *Z* classification (*CZC*)** that reflects the information obtained from the sample and is very easy to interpret, since the closer the *CZC* value is to 0, the closer it is to the specific reference value.

Figure 2: Result of the combined method applied to a triathlete

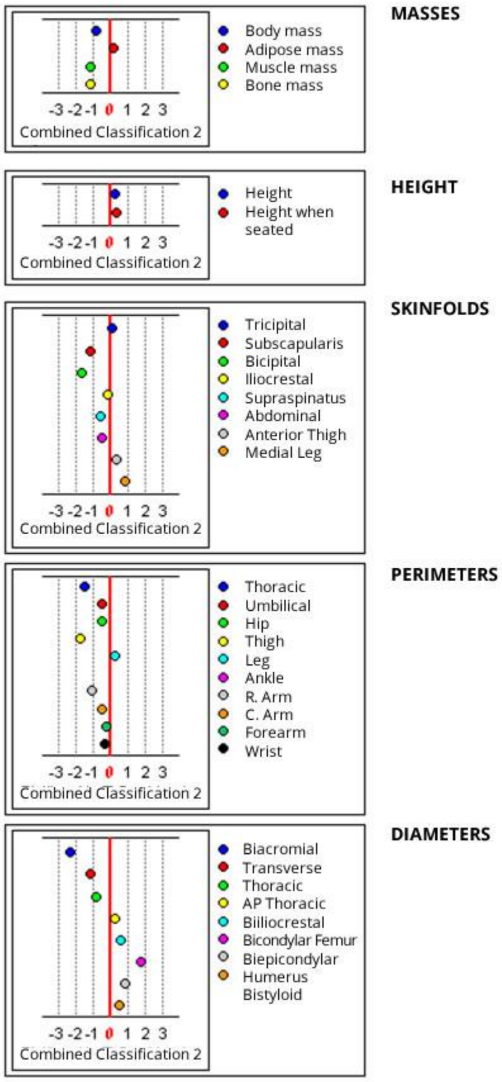
BODY PROPORTIONALITY

COMBINED METHOD (Lentini and Verde)

Proportionality refers to the relationship established between the different parts of the human body. The combined method was proposed by Dr. Néstor A. Lentini and Pablo Verde (2004) where the fundamental basis for the conceptual model of the Phantorn stratagem is used alongside representative data for the populations to be evaluated. Each subject is compared with a combination of statisticians for reference groups, generally from a specific sport. The closer the Combined Classification 2 (CC2) is to 0, the closer it is to the reference.

#	Body Variables	Ideal	Subject	CC2
1	Body mass (kg)	56,45	51,90	-0,90
2	Adipose mass (kg)	16,03	16,59	0,17
3	Muscle mass (kg)	24,31	20,43	-1,25
4	Bone mass (kg)	6,66	5,85	-1,22
5	Height (cm)	162,2	163,3	0,24
6	Height when seated (cm)	86,3	87,5	0,34
7	Tricipital Skinfold (mm)	11,4	11,5	0,02
8	Subscapularis Skinfold (mm)	9,5	6,3	-1,19
9	Bicipital Skinfold (mm)	5,2	2,5	-1,71
10	Iliocrestal Skinfold (mm)	14,4	13,5	-0,19
11	Supraspinatus Skinfold (mm)	8,9	7,0	-0,60
12	Abdominal Skinfold (mm)	16,3	13,3	-0,57
13	Anterior thigh Skinfold (mm)	18,2	20,0	0,29
14	Medial Leg Skinfold (mm)	11,6	14,8	0,86
15	Thoracic Girth (cm)	87,0	80,0	-1,54
16	Umbilical Girth (cm)	71,2	69,0	-0,51
17	Gluteus Girth (cm)	91,3	88,5	-0,55
18	Medial thigh Girth (cm)	55,8	48,3	-1,78
19	Leg Girth (cm)	33,7	34,2	0,24
20	Ankle Girth (cm)	20,6	---	---
21	Relaxed arm Girth (cm)	25,2	23,0	-1,10
22	Contracted arm Girth (cm)	27,1	26,0	-0,51
23	Forearm Girth (cm)	22,8	22,5	-0,24
24	Wrist Girth (cm)	14,6	14,3	-0,37
25	Biacromial Breadth (cm)	37,0	33,8	-2,44
26	Tranverse thoracic Breadth (cm)	26,1	24,3	-1,23
27	AP thoracic Breadth (cm)	18,4	17,3	-0,84
28	Biiliocrestal Breadth (cm)	26,3	26,6	0,26
29	Femur Bicondylar Breadth (cm)	8,70	8,95	0,61
30	Biepicondylar Humeral Breadth (cm)	6,05	6,45	1,76
31	Bistyloid Breadth (cm)	4,91	5,20	0,81
32	Bimalleolar Breadth (cm)	6,38	6,55	0,49

MEAN POSITIVE STANDARD DEVIATION: 0.80



Source: prepared by the author.

1.1.3 Variables and anthropometric profile

Anthropometric variables

Anthropometry as a science goes back a long time, so throughout its evolution it has followed different paths. One of the consequences of this evolutionary process has been the lack of standardization in the identification of measurement locations and the techniques used for measurement. This makes comparisons of the results extremely difficult.

Currently, the **International Society for the Advancement of Kinanthropometry (ISAK)** has proposed a set of anthropometric variables, along with their respective measurement techniques, for obtaining a **complete profile** (seen further on) of an individual (Marfell-Jones, Olds, Stewart, y Carter, 2006). These variables can be used for a variety of objectives, such as longitudinal monitoring of athletes and the evaluation of growth and development, as well as aging, evaluation of the impact of nutritional interventions and of physical activity on body composition and type, etc.

After taking the measurements, the data is analyzed. A wide range of models can be used based on the desired objective. The most common include the **somatotype**, **the fractionation of body mass**, **estimates of proportionality, the prediction of body density to estimate the percentage of body fat using a 2-component model** (seen further on), **the evaluation of global or localized obesity**, and of other indexes, for example the **waist-hip quotient**, **sum of skinfolds, girths corrected for skinfolds**, etc.

The anthropometric variables are normally grouped into 5 categories: **basic measurements, skinfolds, girths, lengths/heights and breadths** (Marfell-Jones et al., 2006).

Basic measurements

This group includes the following measurements:

- **Body weight (BW).** Body mass is the quantity of matter in the body. It is normally calculated by weight, that is, the force exerted by the matter under the action of the force of normal gravity. Typically, the BW varies throughout the day by between 1 kg for children and 2 kg for adults. The most stable values are those obtained in the morning, after the nighttime fast and emptying the bladder (Marfell-Jones et al., 2006).
- **Height.** This is the perpendicular distance between the transverse plane of the *vertex* and the bottom of the feet.
- **Seated height.** This is the perpendicular distance between the transverse plane of the *vertex* and the bottom of the buttocks when the subject is seated.

Skinfolds

Some anthropometric measurements can be difficult to carry out. Among them, measurement of the skinfolds normally produces the most errors. Therefore, careful attention should be paid to the measurement protocol.

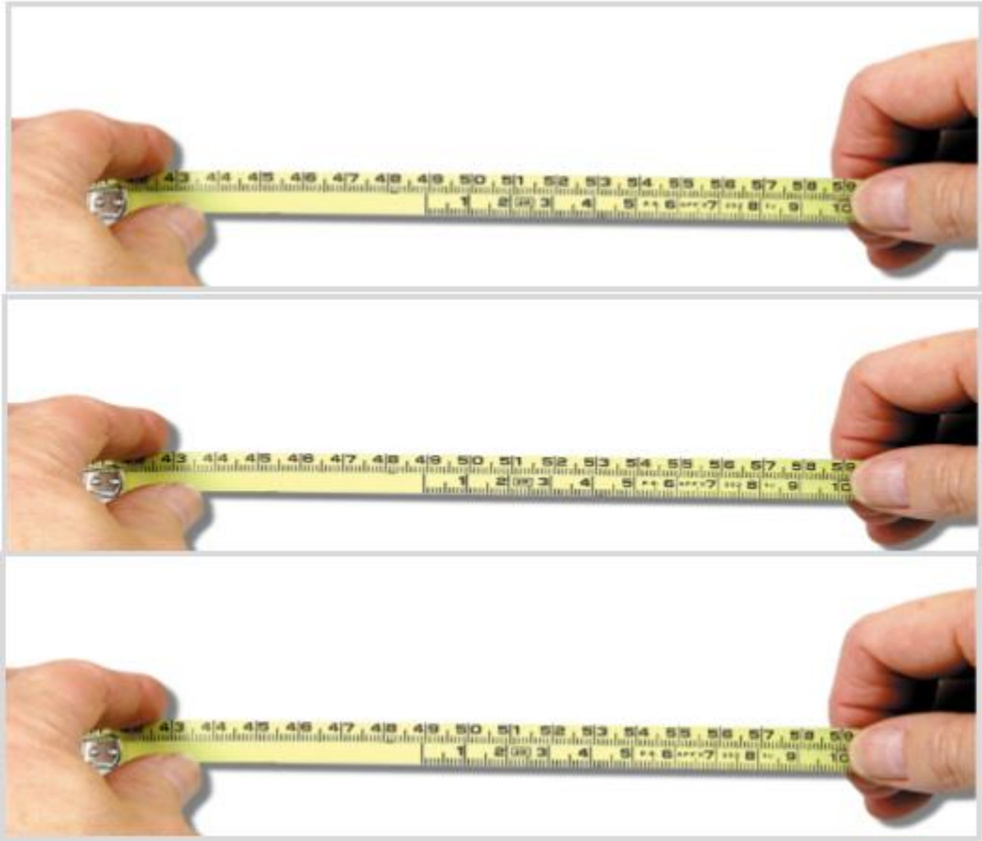
Some of the general recommendations that are often made to improve the precision and the reproducibility of these measurements are the following (Marfell-Jones et al., 2006; Norton et al., 2000):

- Before carrying out measurements, the evaluator should check that the calipers being used are measuring in a precise manner.
- Before carrying out measurements, the evaluator should have obtained sufficient skill to carry out the measurements in a precise manner.
- The location where the skinfold will be measured should be identified with precision using the correct anatomical landmarks.
- The skinfold is taken exactly at the reference point, pinching a double layer of skin and subcutaneous adipose tissue with the thumb and index finger. The near edges of the caliper are applied 1 cm below the fingers that are supporting the skinfold.
- The skinfolds should be taken consecutively, not successively. That is, first take a measurement of all of the skinfolds, before repeating the measurements a second and third time.
- In all of the skinfolds the caliper should be held at 90° to the surface of the measuring site.
- The reading of the value of the skinfold is registered two seconds after applying pressure with the calipers.
- Measurements should not be taken after a training session, competition, a sauna session, after swimming or taking a shower; these factors increase the thickness of the skinfolds.

Girths

To measure all of the girths, what is known as the **hands-crossed technique** is used. The tape is held at a right angle with respect to the segment that is being measured and the tension of the tape should be constant. Spaces between the tape and the skin should be minimized, and one should avoid applying pressure to the skin as much as possible, although in some measurements this is not possible. The juxtaposition of the tape ensures that there is continuity between its two parts for the girth measurement (Figure 3). When reading the tape, the evaluator's eyes should be at the same level as the tape to avoid any error in reading.

Figure 3: Reading the tape measure using the crossed-hands technique



Source: Marfell-Jones et al., 2006, p. 10.

Segment lengths and heights

There are two methods for measuring the lengths of body segments. Historically, the **derived lengths method** was used, which requires using an anthropometer to measure the projected heights (i.e. the vertical distances) between the surface where the subject stands and anatomical reference marks. The lengths of all the segments are then determined by subtraction.

Today, as derived lengths have a higher error, **direct lengths** are the preferred method, whereby the measurements are taken directly as segment lengths from one anatomical mark to another anatomical mark, using a large caliper or a segmometer.

Breadths

These are generally measured with a large sliding caliper or a small sliding caliper (bone calipers). Both are used in the same way. The caliper rests on the backs of the hands, while the thumbs press on the inside of the handles and the index fingers are extended along the outer edges of the caliper. In this position the middle fingers can feel the protruding bones, where the edges of the caliper should be located, and the index fingers can exert pressure to reduce the thickness of the soft tissue that covers the area (figure 4) (Norton et al., 2000).

Figure 4: Technique for measuring biacromial breadth

Source: Marfell-Jones et al., 2006, p. 86.

Anthropometric profile

Today kinanthropometry has an international academic framework: the **International Society for the Advancement of Kinanthropometry (ISAK).** This scientific discipline, like any other area of science, relies on the strict adherence to certain measurement rules and protocol which permit high quality data, which is reliable and valid, to be obtained. ISAK has developed international standards for anthropometric assessment and an **International Accreditation Scheme (IAAS)**. The system of accreditation is based on a hierarchical 4-level system: (ISAK, 2017).

- **Level 1: technique (limited profile)** (Table 2).
- **Level 2: technique (complete profile)** (Table 2).
- **Level 3: instructor.**
- **Level 4: anthropometrist criteria.**

Two profiles are used for anthropometric assessment: the **restricted** and the **complete**. The restricted profile uses **17 variables**, and is a subgroup of the measurements of the complete profile, which uses **39 variables** (Table 2). Both can be logged on the same score sheet. The variables are divided into 5 categories: **basic measurements, skinfolds, girths, lengths/heights and breadths.**

Table 2: Variables included in the anthropometric profile

Type	No.	Variable	®	Type	No.	Variable	®
Basic measurements	1	Weight	X	*Lengths /*	25	Acromial-radial	
	2	Height	X	*Heights*	26	Radial-stylion	
	3	Seated height			27	Midstylion-dactylion	
					28	Iliospinal height	
Folds	4	Triceps	X		29	Trochanter height	
	5	Subscapularis	X		30	Trochanterion-tibial lateral	
	6	Biceps	X		31	Tibial lateral height	
	7	Iliac crest	X		32	Tibial medial-sphyrion tibial	
	8	Supraspinatus	X				
	9	Abdominal	X	*Breadths*	33	Biacromial	
	10	Front thigh	X		34	Biilocristal	
	11	Mid-calf	X		35	Length of foot	
					36	Transverse chest	
Girths	12	Head			37	Anteroposterior chest	
	13	Neck			38	Humerus	X
	14	Arm (relaxed)	X		39	Femur	X
	15	Arm (tensed)	X				
	16	Forearm (maximum)					
	17	Wrist (distal)					
	18	Chest (mesosternum)					
	19	Waist (minimum)	X				
	20	Buttock (hip)	X				
	21	Thigh (1 cm from buttock)					
	22	Thigh (middle)		The 39 locations make up the complete profile.			
	23	Calf (maximum)	X	The 17 locations make up the restricted profile;			
	24	Ankle (minimum)		these locations are identified with the symbol ®.			

Source: prepared based on Marfell-Jones et al., 2006.

1.1.4 Anthropometric Equipment and Measurement Techniques Utilized in Kinanthropometric Assessment

Listed below are the basic tools and equipment for carrying out anthropometric measurements.

Scale

Traditionally, mechanical scale accurate to 100 g have been preferred. All the same, the use of electric scales is becoming more and more popular, and the accuracy of these is equal to or better than that of mechanical scales. An important aspect of using balances is their regular calibration.

Stadiometer

Used to measure both height and seated height. The most commonly used are fixed to the wall, although mobile stadiometers are increasingly common. It has a mobile part that slides until it reaches the *vertex* of the head, or a set-square can be used for this. The minimum range of measurement is between 60 and 220 cm. The required precision is to 0.1 cm.

For field measurements, when there is no stadiometer available, a measuring tape can be used, fixed to the wall and with its height and vertical position checked, along with a set-square for the head.

Anthropometric tape

This is used for the measurement of body girths. It is recommended that it be metallic, flexible, non-retractable, with a width less than 7 mm and with a blank space of at least 4 cm before the zero, and that it should be at least 1.5 m in length. It should be calibrated in centimeters and graduated in millimeters.

Calipers for skinfolds

The skinfold calipers require a constant closure pressure of 10 g/mm^2 across the entire range of measurements (Norton et al., 2000). The reading scale often varies, depending on the model, but usually remains between 80 and 85 mm. The precision varies based on the type of caliper; for the highest precision models, like the **Harpenden caliper** (Figure 5), it is 0.1 mm, while for the plastic calipers, like the **Slim Guide** (Figure 5), it is normally 0.5 mm.

While ISAK does not recommend a specific type of caliper for skinfolds, the Harpenden caliper is widely used and is considered the caliper of reference. So far, the only plastic caliper that the ISAK kinanthropometrists have found to be comparable to the Harpenden is the Slim Guide, although the results are not identical (Marfell-Jones et al., 2006).

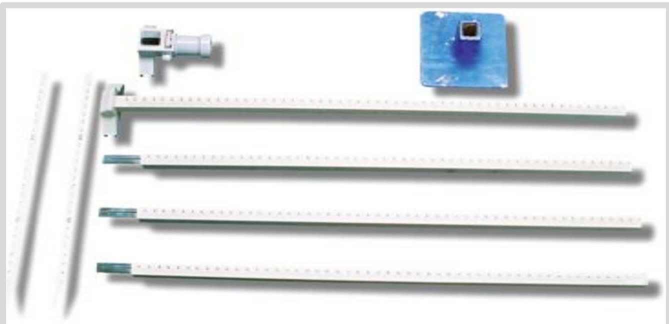
Figure 5: Harpenden (left) and Slim Guide (right) skinfold calipers.

Source: Marfell-Jones et al., 2006, p. 11.

Anthropometer

Used to measure both direct and indirect heights and lengths. However, depending on the model, it can also be used to measure large bone breadths (e.g. biacromial), non-bone breadths (e.g. bideltoid), as well as height and seated height (Marfell-Jones et al., 2006). In any case, while possible, it is recommended that segment lengths be measured directly using a segmometer or a large sliding caliper (Marfell-Jones et al., 2006).

Figure 6: Siber-Hegner Anthropometer



Source: Marfell-Jones et al., 2006, p. 11.

Segmometer

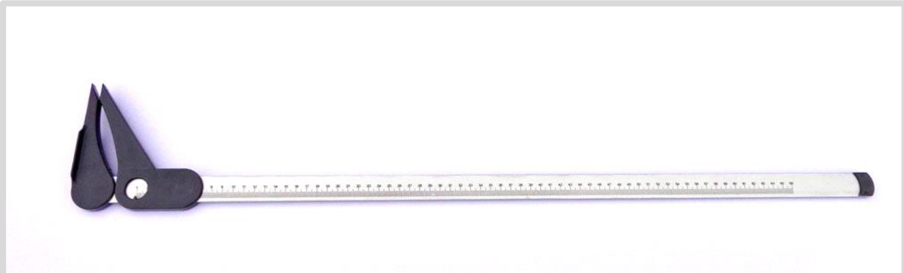
Used to measure segment lengths directly. This arose as a more economical alternative to the anthropometer, although it is not suitable for measuring large bone breadths (Marfell-Jones et al., 2006; Norton et al., 2000). For this purpose, the correct instrument is a large sliding caliper (seen further on). It is manufactured with a metallic tape that is 100 cm long and a minimum of 15 mm wide, attached to which are two straight arms, about 7 or 8 cm long (Figure 7).

Figure 7: Rosscraft Segmometer

Source: Marfell-Jones et al. (2006), p. 12.

Due to the difficulties of using **flexible segmometers** (short useful lifespan of the scale that stays folded, and a higher possibility of measuring errors due to the flexibility of the ruler), currently **rigid segmometers** exist (Figure 8).

Figure 8: Rigid Segmometer Argentine Calipers



Source: [Untitled image of a rigid segmometer Argentine Calipers]. (n. d.). Recovered from https://goo.gl/fwpYki

Large and small sliding calipers

Traditionally the upper segment of the anthropometer has been used as *large sliding calipers*, although today there are various models on the market. It has two straight arms that are joined to a rigid metal ruler, which allows measurement of large bone breadths, like the biilocristal and biacromial.

Small sliding calipers are similar, but they are used to measure the breadths of the femur and humerus. They generally have a precision of 1 mm.

Anthropometric box

This is a wooden box, strong enough for the subject to sit or stand on in order to facilitate measurement (Figure 9). It generally has a hole on one of the faces where the subject can put their feet and thus be closer to the edge of the box, which facilitates certain measurements (e. g., iliospinal height). The exact measurements are not given, but ISAK recommends dimensions of 40 cm (height) x 50 cm (width) x 30 cm (depth).

Figure 9: Anthropometric box

Source: Vitamex, s.f., https://goo.gl/NgUBGS

The measurement locations and the techniques used to measure the main anthropometric variables are briefly described below (Marfell-Jones et al., 2006; Norton et al., 2000).

Skinfolds

Triceps or tricipital: vertical skinfold parallel to the longitudinal axis of the arm, taken on the rear face, at the middle point of the acromial-radial distance. The arm should be relaxed, the articulation of the shoulder with a slight external rotation, and the elbow straight down the side of the body.

Subscapularis: 2 cm from the inferior angle of the scapula, an oblique skinfold is taken downwards and laterally, at approximately a 45° angle from the horizontal.

Biceps or bicipital: vertical skinfold parallel to the longitudinal axis of the arm, taken on the front face, at the middle point of the acromial-radial distance.

The arm should be relaxed, the articulation of the shoulder with a slight external rotation, and the elbow straight down the side of the body.

Iliac crest: skinfold directly above the iliac crest, at the midaxillary line. It runs gently downwards, from the back to the front of the body.

Supraspinatus: taken at the intersection point of 2 lines; that which runs from the anterior axillary edge to the upper anterior iliac spine, and the other that results from the forwards projection of the iliac crest mark. It runs in a medial, descending direction, at approximately a 45° angle from the horizontal.

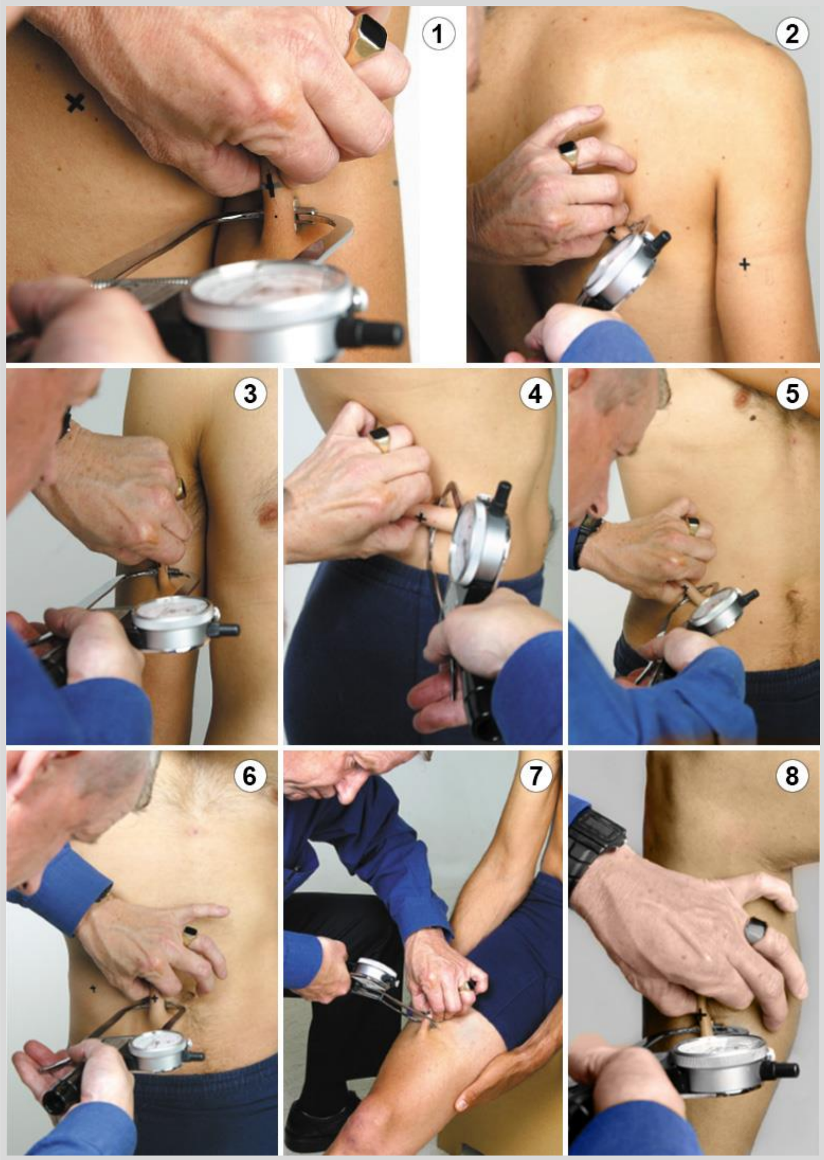
Abdominal: vertical skinfold, parallel to the longitudinal axis of the body, approximately 5 cm to the right of the belly button. It is important that neither the fingers nor the caliper are placed in the belly button.

Front thigh: the subject sits on the front edge of the box, with the trunk erect and the knee extended. The skinfold runs vertically, parallel to the longitudinal axis of the thigh, at the middle point of the distance between the inguinal skinfold and the upper edge of the knee, along the mid-line of the thigh.

Mid-calf: the subject is standing, with the right foot on the box, the right knee bent at approximately 90°. The skinfold is vertical and is taken in the medial (internal) part of the calf, at the part of greatest girth.

Figure 10 shows the measurement locations for the skinfolds described.

Figure 10: Measurement locations for skinfolds



Source: prepared based on Marfell-Jones et al., 2006.
Key: 1, tricipital skinfold; 2, subscapularis skinfold; 3, bicipital skinfold; 4, iliac crest skinfold; 5, supraspinatus skinfold; 6, abdominal skinfold; 7, front thigh skinfold; 8, mid-calf skinfold.

Girths

Head: directly above the Glabella (midpoint between the 2 arcs of the eyebrows) and perpendicular to the vertical axis of the head. The tape needs to be firmly adjusted to press down the hair.

Neck: measured directly above the thyroid cartilage ("Adam's apple") and perpendicular to the vertical axis of the neck, but it is not necessary to keep it on a horizontal plane.

Relaxed arm: taken with the arm relaxed, at the level of the mark in the acromial-radial mid-line, perpendicular to the longitudinal axis of the arm.

Tense arm: measured perpendicular to the longitudinal axis of the arm, at the level of the highest point of the contracted biceps, with the arm in a horizontal position and the elbow bent between 45 and 90°.

Maximum forearm: taken with the right arm gently bent, at shoulder-height and with the elbow extended. The aim is to measure the maximum girth of the forearm, perpendicular to the longitudinal axis of the segment, distal to the humeral epicondyles, and with the palm facing upwards (flat).

Wrist: corresponds to the minimum girth, perpendicular to the longitudinal axis of the forearm, distal to the styloid processes, with the hand resting flat and the wrist in a neutral position.

Chest (mesosternum): measured at the level of the mesosternum mark (the midpoint of the sternum). The subject should breathe normally. The measurement is taken at the end of a normal exhalation.

Minimum waist: at the narrowest point between the lower rib area (10^{th} rib), and the highest part of the iliac crest, perpendicular to the longitudinal axis of the trunk. If the narrowest area is not apparent, it is taken at the midpoint between these two references. The measurement is taken at the end of a normal exhalation.

Buttock (hip): taken at the level of maximum protrusion of the gluteal muscles, on the longitudinal axis of the trunk.

Maximum thigh: registered at 1 cm below the buttock skinfold, perpendicular to the longitudinal axis of the thigh.

Mid thigh: measured at the level of the midpoint between the trochanter and tibiale laterale marks, perpendicular to the longitudinal axis of the thigh.

Maximum calf: the subject stands on a bench or the anthropometric box and the measurement is taken on the lateral face of the calf, at the point where the maximum girth is observed.

Minimum ankle: corresponds to the minimum girth of the ankle, above the middle sphyrion, perpendicular to the longitudinal axis of the leg.

Lengths / heights

Acromial-radial: represents the length of the arm. The linear distance between the acromial and radial marks is measured (Figure 11). The subject is standing, with the arms hanging by the sides, and the right forearm is prone (palm of the hand rotated towards the thigh).

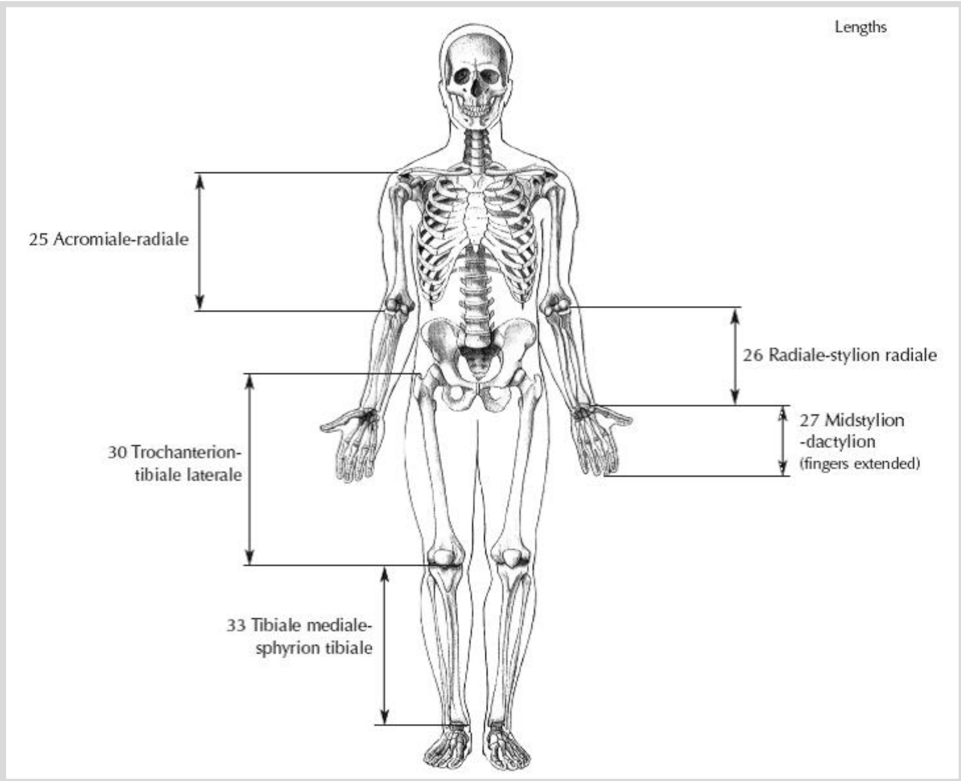
Radial-stylion (Radial-styloid): represents the length of the forearm. This is the linear distance between the radial and styloid (the most distal point on the lateral side of the styloid process of the radius) marks (Figure 11).

Midstylion-dactylion: represents the length of the hand. The linear distance between the Midstylion mark (the midpoint, on the front surface of the wrist, of a horizontal line located at the styloid level) and the dactylion mark (tip of the middle finger) (Figure 11).

Iliospinal height: this is the vertical distance from the iliospinal mark (the point below the anterior-superior iliac spine) to the floor. It can be taken in 2 ways: measuring the height from the upper part of the box (Figure 12), or from the floor, to the iliospinal.

Height of the trochanter (trochanterion): this is the vertical distance from the mark of the trochanter to the floor. As with the iliospinal height, it can be taken from the box (Figure 12) as well as from the floor.

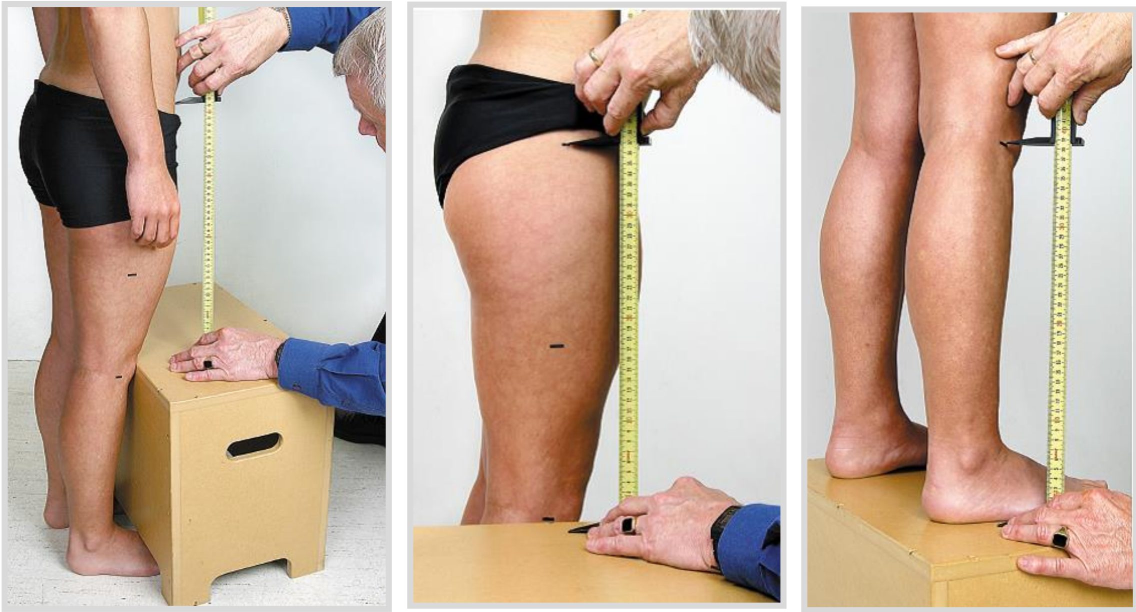
Figure 11: Lengths



Source: Marfell-Jones et al., 2006, p. 76.

It is important to underline that all of the measurements are taken on the **right side of the body** (independently of the subject's right handedness or left handedness)**,** and **perpendicular to the longitudinal axis of the trunk**.

Figure 12: Iliospinal height (left), trochanter height (center) and tibiale laterale (right)



Source: Marfell-Jones et al., 2006(pp. 80-83).

Trochanter-tibial lateral: this represents the length of the thigh. The linear distance between the trochanter mark (*trochanterion*) and the tibial mark is measured (Figure 11).

Tibial lateral height: this represents the length of the leg. This is the vertical distance between the tibial lateral mark and the floor (Figure 12).

Tibial medial-sphyrion tibial: this represents the length of the tibia. This is the distance between the tibial medial mark and the sphyrion tibial (Figure 11).

Breadths

Biacromial: this is the linear distance between the most lateral points of the acromion; it is measured with large sliding calipers (Figure 4).

Biilocristal: this is the linear distance between the most lateral points of the iliac crest (Figure 13).

Length of the foot: this is the distance between the furthest projecting toe (could be the first or the second) and the rearmost point of the heel. To facilitate the measurement, the subject normally stands on the bench.

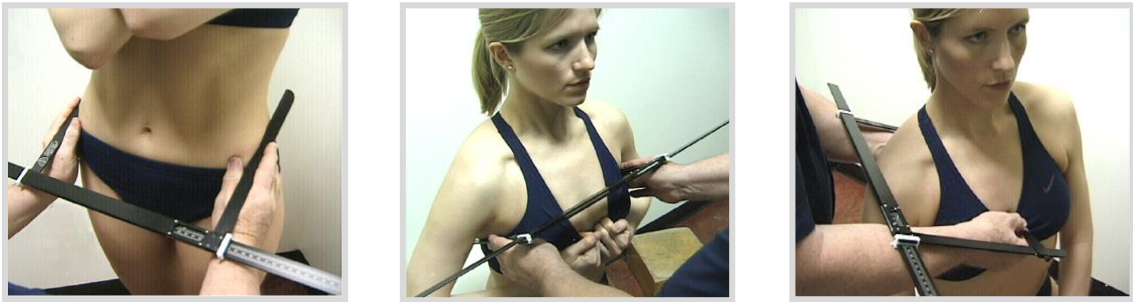
Transverse chest: this is the distance between the most lateral faces of the chest, at the level of the mesosternum. The caliper is located at the level of this mark, and its arms are oriented downwards, at approximately a 30° angle. The measurement is taken at the end of a normal exhalation.

Anteroposterior of the chest: this is the depth of the chest at the level of the mesosternum (Figure 13). The measurement is taken at the end of a normal exhalation.

Humerus: this is the linear distance between the most protruding edges of the lateral and medial humeral epicondyles. The right arm is raised forwards towards the horizontal, and the elbow is bent at a right angle.

Femur: this is the linear distance between the most protruding edges of the lateral and medial femoral epicondyles. The subject sits with the knee bent forming a right angle.

Figure 13: Biilocristal (left), transverse chest (center) and anteroposterior chest (right) breadths



Source: Marfell-Jones et al., 2006(pp. 88-90).