Body composition

What is the body made of ?

The body composition of a hypothetical, normal weight adult is shown in Figure 1.0. It can be seen that the major component of the human body is water. The protein and fat component are relatively small, with the remainder being primarily bone and minerals. When we measure body composition, nutritionist use terms to describe compartments of the body.

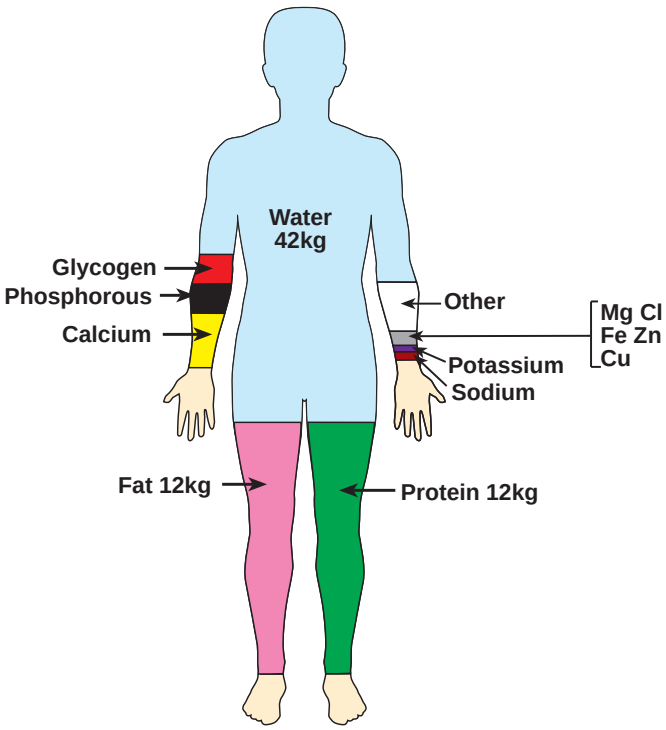


Figure 1.0 Body composition: example of normal weight male

- The non-fat component of body composition is termed fat free mass (FFM) and exists primarily as the chief structural and functional component of the human body. The FFM compartment consists in proportions of water (72%), protein (21%) and bone minerals (7%).

- Bone minerals can be measured by dual-energy x-ray absorbitanetry (DEXA) scan See figure 2.0 for a picture of a subject undergoing a dexa scan. Typically, an adult has around 2-4 kg of body weight only, from bone.

Figure 2.0 Subject undergoing a DEXA scan to measure bone mass

- The fat compartment of the body is termed fat mass (FM) and will vary considerably between individuals in terms of absolute amount. Fat mass consists of 20% water and 80% adipose tissue and can, in obese persons be the largest component of the body. Figure 2.0 shows the composition of an obese male. He has twice the amount of adipose tissue on his body, compared to the lean man.

Figure 3.0

	Lean man 70 kg	Obese man 100 kg
Water	60%	47%
Protein	17%	13%
Fat	17%	35%
Remainder	6%	5%

- There is a small amount of body protein available for energy, in the labile amino acid pool and muscle proteins during catabolism, (when the body is starving).

- Carbohydrate is stored in the body typically as glycogen in the liver and in muscle and can vary between individuals ranging from approximately 500g in normal individuals to over a kilogram in trained athletes. Values also vary depending on body size and previous carbohydrate ingestion.

Body composition and obesity

When people gain or lose weight they will add or reduce the amount of fat mass and to a much lesser degree, fat-free mass. We can measure all the compartments in the body using the following techniques (Figure 4.0)

BONE	by DEXA (dual-energy x-ray absorptiometry) scan
FAT	by bod pod (densitometry)
PROTEIN	by bod pod (densitometry)
WATER	by isotopic dilution

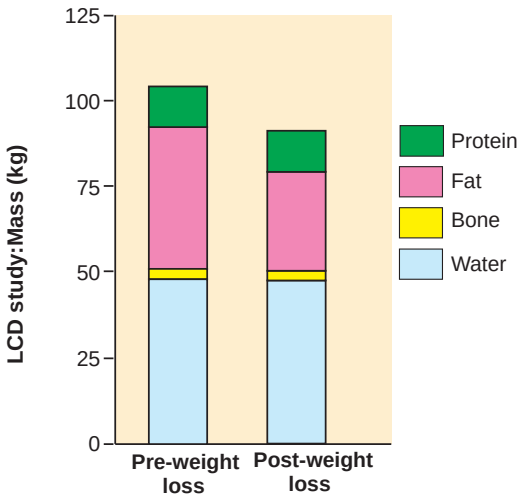


Figure 4.0. Changes in body composition with weight loss

Figure 4.0 shows some data on weight loss in obese men. The men underwent a dietary weight loss regime at the Rowett Research Institute's Human Nutrition Unit. They lost, on average 12 kg in 6 weeks. Around 80% of the weight loss was due to fat loss. Bone mass remained unchanged, with a small loss in protein and water mass. The reduction in body fat led to an improved quality of life, reduced blood pressure and overall subjects felt better and fitter.

Is there an ideal body weight ?

There is no 'ideal body weight', instead health professionals look at a range of healthy weight which reflects the lowest risk of ill health. Other factors such as age, smoking status, fitness and family history will determine the overall health of an individual. Body mass index (BMI) is a simple ratio of weight-for-height that is commonly used to classify overweight and obesity in adults. It is calculated as the weight in kilograms divided by the square of the height in metres (kg/m^2).

For example, an adult who weighs 70kg and whose height is 1.75m, will have a BMI of 22.9 (normal weight for height)

$$BMI = \frac{wt\ (kg)}{Height\ (m^2)} = \frac{70}{1.75^2} = 22.9$$

BMI is age-independent and the same for both sexes. However this calculation does not correspond to the same degree of fatness in different populations. For example a body builder will have a lot of muscle and therefor weigh more than a non-active individual. His BMI may be higher, but his body fat will be low. Therefore, the BMI calculation is only a useful index of your body fatness and should be used in conjunction with other measures of fat distribution e.g. waist circumference.

This calculation is not suitable for children, because they are still growing and not reached their full, adult height. Growth charts should be consulted for height for age in children.

BMI less than 18.4 is classified as underweight for height

Being underweight also introduces some health risks, such as infertility in women, increased risk of infections and osteoperosis (thin bones). Ensure your diet is healthy and avoid further weight loss.

BMI 18.5 – 24.9 is classified as normal weight for height

This is the range that adults should aim to be for optimal health. Individuals should aim for body weight maintenance. Consider other lifestyle factors e.g. smoking, non-healthy diet, physical inactivity as these may be a risk factor for less optimal health.

BMI 25.0 – 29.9 is classified as overweight

Body fat will be elevated increasing the risk of coronary heart disease, diabetes and high blood pressure. Aim to reduce body weight slowly, with a weight loss of 5-10kg over 12 weeks. Seek medical advice before initiating a dieting regime.

BMI 30.0 – 39.9 is classified as obese

Weight loss is required to reduce heath risks. Set a goal of 5-10kg weight loss. Consider a lower-calorie diet and drug therapy if diet, exercise and lifestyle programme is unsuccessful after 12 weeks.

BMI more than 40 is classified as severely obese

Immediate weight loss is required, consult your GP to be referred to specialist management for of surgical or drug intervention. Aim for a 20-30% weight reduction.

Body Composition Techniques

Circumference: waist and hip

The circumference technique measures body shape, using a tape measure. It is important that the same investigator takes repeated measurements to reduce inter-individual differences due to positioning of the tape. Subjects are required to wear underwear during the measurement, so that the thickness of clothing does not influence the result. The measurement is typically conducted as a morning measurement, before eating and after emptying bladder. Subjects are measured in the standing position. Subjects should be asked to breathe normally and at the time of the measurements, and asked to breathe out gently. This prevents the subject from contracting their muscles or from holding their breath. Measurements are made in duplicate (twice or thrice). See photo of waist circumference measurement.
Waist circumference greater than or equal to 94 cm action level 1 (BMI>25); greater or equal to 102 cm action level 2 (BMI > 30)

Health risks

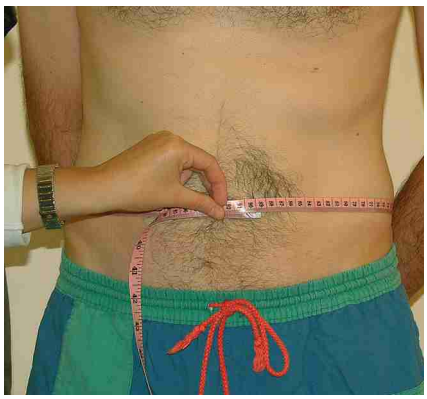
Waist/hip ratio - divide the waist circumference by the hip circumference. Above 0.95 for men (or 0.8 in women) indictive of a health risk.

Equipment / Preparation:

A plastic tape measure i.e. non elastic or metal.
Marker pen (felt tip)

A. Waist

Measurements should be taken midway between the inferior margin of the last rib and the crest of the ilium, in a horizontal plane. Each landmark is palpated and marked and the midpoint determined by tape measure. The observer needs to sit in front of the subject and fit the tape round the site, not compressing the soft tissue. The duplicate measurement is measured to the nearest 0.1 cm at the end of a normal (gentle) expiration. Ask the subject not to tuck their stomach in (see adjacent photo).



B. Hip

Subject needs to be wearing non-restrictive underwear standing with arm by the side and feet together. The observer needs to sit in front of the subject and fit the tape round the widest part of the trochanters (buttocks). This is measured in duplicate to the nearest 0.1 cm (see adjacent photo).

C. Mid upper arm (MUAC)

The subject should be standing with the arm hanging loosely by the side palms towards thighs. The circumference is measured in the midpoint of the arm (between the tip of alecranon, elbow bent at 90 degrees). Duplicate circumferences are measured to the nearest 0.1 cm. See diagram of arm (see adjacent photo).

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D. Thigh

Measured in duplicate for both legs 2 cm below the gluteal fold, with the weight on the non measured leg. ie. the leg being measured is relaxed. Measured in duplicate for both legs (see adjacent photo).

E. Calf

Subject needs to be standing with the feet about 20 cm apart and weight equally distributed between both feet. Position the tape measure horizontally so that it is in complete contact with the skin, but not indenting. Record the measurement by moving up and down the calf to find the widest part. Measured in duplicate for both legs (see adjacent photo).

Bod Pod (body density)

Principles and assumptions

The Bod Pod Body Composition System (Life measurements Instruments, Concord, USA) is based on air displacement plethysmography. It is based on a two-compartment model of body composition (fat mass and fat-free mass), and uses the inverse relationship between pressure and volume (Boyle's law) to derive body volume (l) for a subject.
Once body volume is determined, the principles of densitometry are used to determine body composition from body density. If volume and body weight are both known then density can be calculated from the following equation:

Body Density = mass/volume where mass= body weight (kg)
volume = litres (l)

Thus, the change in pressure and volume between the empty chamber and the subject present can be used to calculate the subjects volume, since one side of the equation is known.

Boyles law: $P1 \times V1 = P2 \times V2$ where P = pressure
V = volume

The relationship between pressure and volume is calculated using Poissions Law and Boyles law (above). The calculation of body volume is then corrected for body surface area by a constant (Dubois and Dubois 1916) and thoracic volume (residual gas) to account for the fact that air within the thoracic cavity and surrounding skin surface is maintained close to the physiological temperature.

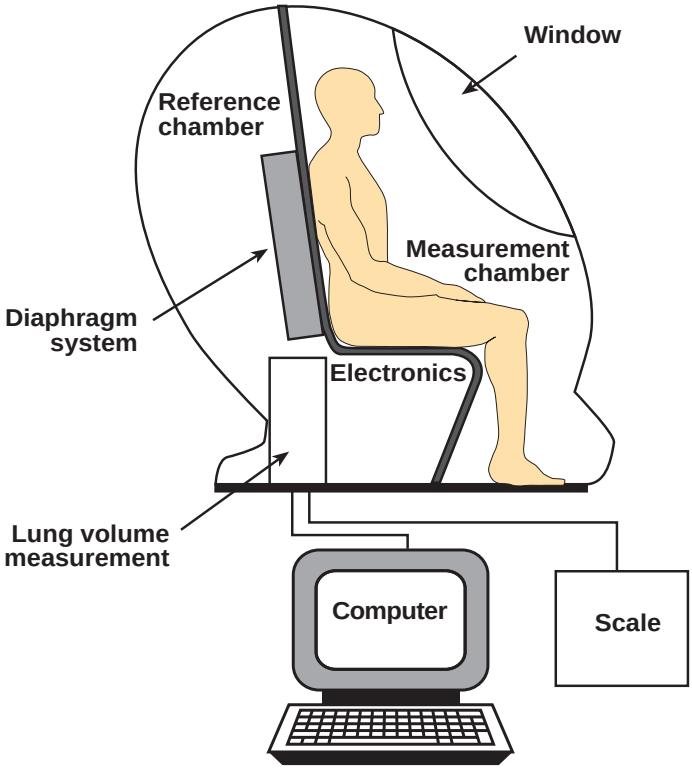


Figure 5.0 Diagrammatic representation of the Bod Pod

Description of method

Prior measurement the volume of the chamber is calibrated with a known standard (49.550 l) and the weighing scales are also calibrated against a known weight (20kg). Subjects are asked to wear minimal clothing such as a swimsuit as it is thought that hair and clothing show apparent negative volume effects altering body surface area calculations. The Bod Pod is housed in a room with a constant temperature (24-26 ^{O}C), with barometric pressure and relative humidity recorded on the day of measurement. Before entering the Bod Pod an accurate measurement of body weight is taken, using the scales attached to the Pod Bod system. The subject then enters the Bod Pod chamber and asked to sit in a standardised way, with back straight and not touching the back wall of the machine, feet slightly apart and hands placed in a relaxed manner on their lap. The subject can viewed by the investigator though the clear perspex window during the measurement. The subject's age, height and sex are also entered in the computer and 4 estimates of body volume are then obtained using predicted lung volume. Percentage body fat is then estimated using the Siri formula (1961). See photo of bod pod system below.

Skinfold thickness (SFT)

A skinfold thickness (SFT) is defined as a measure of the double thickness of the epidermis, underlying fascia and subcutaneous adipose tissue. See photographs below. There are two main assumptions in determining total body fat from skinfolds:

(i) that there is a constant relationship between total body fat and subcutaneous fat at the sites measured. The equation of Siri (1961) uses a two-compartment model, such that the human body consists of fat mass (FM) and fat-free mass (FFM) and assumes that the density of the two compartments is constant between individuals at 0.90 g/cm3 for FM and 1.10 g/cm3 for FFM.

(ii) that the density of FFM is constant.

Skinfold measurements also assume that subcutaneous fat is a reliable indicator of total body fat and that skinfold compressibility remains constant. Durnin and Womersley (1974) validated the sum of four SFT (biceps, triceps, subscapular and suprailiac) against densitometry and devised sex and age dependent population-based linear regression equations to estimate total body density.

Collection of skinfold thickness measurements

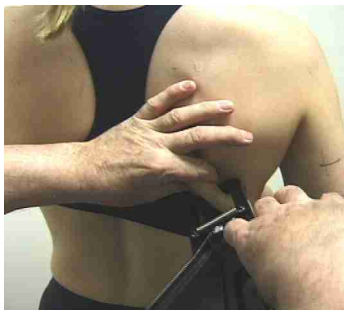
All SFT measurements should be taken by the same trained member of staff from identical positions on each subject, following the World Health Organisation (WHO 1987) anthropometic guidelines. Holtain skinfold calipers (Holtain Ltd., Dyfed, Wales) can be used, with the subject in a standing position. A tape measure and finger and thumb should be used when the calipers are not large enough. See photo of measurements.

The four sites were as follows (Durnin and Womersley 1974):

1. Triceps: A mark is made at the mid-upper arm, midline of the posterior aspect of the arm over the triceps muscle, measured with the elbow bent at 90º, used for identifying the biceps and triceps SFT. During the measurement, the arm should be hanging freely by the side, palms inwards towards the thighs.

2. Biceps: Measured midline of the anterior aspect of the arm, over the biceps muscle, mid-point on the arm as above.

3. Subscapular: Found just below and lateral to the bottom tip of the scapula, measured in a 45º angle. Subjects stand with their arm relaxed by their side. The scapula was palpated with the fingertips to find the bottom of the bone and the SFT is then measured in the natural crease. Subject's shoulders are relaxed.



4. Suprailliac (waist): Found 1 cm above the anterior superior iliac spine (top of the hip bone) in the mid-axillary line (waistline). Measured horizontally with the subject breathing gently.

To take the measurement, the skin is gripped about 1cm above the selected site and the calipers applied below this site, the grip is removed and the measurement noted to the nearest 0.2mm. The calipers are then removed. This is repeated for 3 successive measurements, with the mean value calculated.

Body density and percentage body fat is calculated using the equations of Durnin and Womersley (1974), for each side of the body, using the following equations:

$$\text{Density } (g/cm^3) = c - m \ (\log \Sigma S)$$

Where:

D = Density
c and m = standard age and sex-specific coefficients
ΣS = Sum of all four skinfold measurements (mm)

Once density is calculated, the Siri (1961) equation is used to estimate percentage body fat:

$$\text{Fat } (\%) = [(4.95 / D) - 4.5] \times 100$$

Where:

D = Density
4.95 and 4.5 are the constants calculated by Siri (1961) using the assumptions on the density of FM and FFM