ELSEVIER

e-SPEN,
the European e-Journal
of Clinical Nutrition
and Metabolism

http://intl.elsevierhealth.com/journals/espen

EDUCATIONAL PAPER

Basic concepts in nutrition: Body composition and its measurement

Klaas R. Westerterp

Department of Human Biology, Maastricht University, PO Box 616, 6200 MD Maastricht, The Netherlands

Received 5 February 2008; accepted 8 February 2008

KEYWORDS
Body composition;
Measurement;
Fat mass;
Fat-free mass;
Body volume;
Total body water

Learning objectives

- Assumptions and application of techniques for the measurement of body composition
- To have knowledge on their precision and limitations
- To be informed about the two-, three- and four-compartment models for body composition

Background

In vivo, body composition can only be measured indirectly. There is nowadays a great variety of methods available with different assumptions and limitations. All these assumptions stem from the chemical analysis of a limited number of cadavers with a normal body condition until death. The general model for body composition is the two compartment model, i.e. fat mass (FM) and fat-free mass (FFM). Accepted methods for the measurement of body composition are densitometry, total body water and anthropometry.

Densitometry

Densitometry assumes a constant chemical composition of FM and FFM resulting in a density of 0.90 and 1.10, respectively. The method requires the measurement of body weight and body volume. The most widely used technique for measuring body volume is according to Archimedes' principle, i.e. the volume of an object submerged in water equals the volume of water the object displaces. The difference between weight in air and weight under water, corrected for the density of the water at the temperature at the time of measurement, is the body volume. Body volume has to be corrected for lung volume, ideally by measuring simultaneously residual lung volume during submersion (Fig. 1). Densitometry has gained widespread use and was until recently the 'gold standard' for body composition measurement with other techniques.

E-mail address: espenjournals@espen.org (Editorial Office).

1751-4991/$ - see front matter
doi:10.1016/j.eclnm.2008.02.005

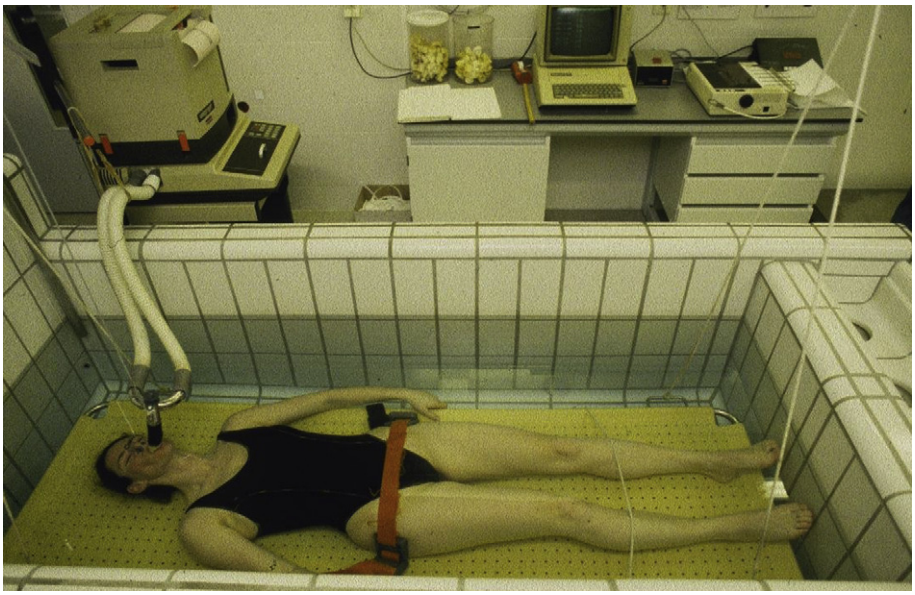

Figure 1 A subject submersed in water during under water weighing. The subject is lying on a stretcher suspended from a scale while breathing in a spirometer for the simultaneous measurement of lung volume with Helium dilution.

The theoretical error of densitometry for predicting FM and FFM is 3—4%, associated with the uncertainty in the density and chemical composition of FFM. The main variables are water content and bone density. In practice, additional error sources are variability in gastrointestinal gas volume and residual lung volume, the latter when lung volume is not measured during but before or after submersion. An error of 0.1 l in one of the two is roughly equivalent to a 1% error in FM and FFM. Usually errors are not additive and the overall accuracy of densitometry for body composition is 1—2%.

Body volume measurement by submersion in water is not always applicable in adult subjects, i.e. patients and the elderly. A recent development is to measure body volume in air instead of water. The advantage is not only the applicability, but also the required time for an observation. Under water weighing in a trained subject takes half an hour while measuring body volume in an air tank is done in 5—10 min.

Total body water

Total body water (TBW) is a measure of body composition assuming a fixed hydration of FFM, usually 73%. Measuring body mass (BM) and TBW allows the calculation of FFM as TBW/0.73 and the calculation of FM as BM minus FFM. TBW is measured with dilution of isotopes of water i.e. isotopes of hydrogen and oxygen: ^{3}H, ^{2}H, and ^{18}O. The underlying assumption is that these have the same distribution volume as water. A subject gets an accurately measured oral or intravenous dose of labelled water, followed by an equilibration period of at least 2 h and subsequent sampling of the body fluid. Dose, equilibration time, and sampling medium depend on the isotope, the dosing route and the facilities for sample analysis. Tritium or ^{3}H is a radioisotope, which is measured with liquid scintillation counting. Deuterium or ^{2}H and ^{18}O are both stable isotopes, ^{2}H can be measured in higher concentrations with infrared absorption and both isotopes are measured in low concentrations with isotope ratio mass spectrometry (IRMS). Body fluids for sampling are saliva, blood, and urine. The length of the equilibration period is minimally 2 h with intravenous dosing and taking blood as a sampling medium. Using the less invasive oral route of dosing and sampling urine needs a minimal equilibration time of 4—6 h. The calculation of TBW is based on the relationship:

$$C_d \times V_d = (C_1 - C_0) \times \text{TBW}$$

where C_d — concentration of the tracer; V_d — volume of the dose; C_0 — basal concentrations of the tracer; C_1 — concentrations of the tracer after dose consumption (Fig. 2).

In practice, using a non-invasive method with stable isotopes at low concentrations, subjects get a dose of labelled water in the post-absorptive state after collecting a background sample, i.e. saliva or urine. Background levels for ^{2}H and ^{18}O are around 150 and 2000 ppm, respectively. The minimal excess enrichment to be reached is around 100 ppm. After equilibration, lasting 4—6 h, a final saliva or urine sample is collected. For urine, this should be a sample from at least a second voiding after dosing the labelled water. The use of ^{18}O as a tracer is preferred over ^{3}H and ^{2}H as the dilution space of ^{18}O is very close to TBW. The dilution space for the hydrogen isotopes is on average 4% larger and the dilution space for ^{18}O is on average 1% larger than TBW, due to the exchange of the label with non-aqueous substances in the body. On the other hand, the cost of ^{18}O is 100 times higher than the other labels.

Anthropometry

The quickest and cheapest method to measure body composition is from skin fold thickness. The assumptions forming the basis for the method are: