THE ESTIMATION OF TOTAL BODY FAT BY INELASTIC NEUTRON SCATTERING-A GEOMETRICAL FEASIBILITY STUDY

F.Lizos*, M.Kotzasarlidoou, A. Makridou, K. Giannopoulou

About Fats

It has always been hard to distinguish fats and oils. The reason is that there is not a clear definition for either of them. The two words are frequently used by nutritionists to refer to foods that are fatty in nature and greasy in texture and they are both insoluble in water. We can differentiate fats from oils only by their melting points; fats are solids at room temperatures but oils are liquids (Chemical Abstracts Service 1999).

By looking at the chemical properties of fats and oils, the differentiation between them becomes even harder because they are both regarded as esters of glycerol with fatty acids. Because of these problems, we can introduce the word "lipid" in order to describe a group of chemical substances that are insoluble in water and soluble in specific chemical solvents such as chloroform, alcohol and various others. In this particular chapter the word "lipid" will refer to triacylglycerols, which make up a specific category of fats (Sharon 1998).

Fats are mainly comprised of triacylglycerols. They are important as a source of energy for the human body and the main reason for excessive weight among all humans (Chemical Abstracts Service 1999).

The main body lipids are: storage, structural and metabolic. In this presentation we will be concerned with the definition of the quantity we are going to simulate and measure, which is fat and comprises of triacylglycerols and is located I the adipose tissue.

The predominant constituent of triacylglycerols is the isotope ^{12}C and during the presentation we will introduce a set–up to accurately measure it and as a result estimate the amount of triacyglycerols, contained within a certain volume of storage fat.

Since carbon can be found in other types of fat (DNA and other organic cell constituents) it is not possible to estimate the amount of storage fat with accuracy, without allowing for a correction factor.

* Presenting author: kotzasm@yahoo.gr

Methods of Fat Measurement

A rough quantitative representation of the basic elements in a human body is shown below. It deals with a hypothetical, normal adult weighting 70 kg. it is possible to measure two basic quantities, the FFM, standing for Fat Free Mass and the FM, standing for Fat Mass. Because there are three kinds of fat in the body (see previous chapter), the word fat, for the purpose of this chapter will refer to the storage fat. Measuring fat is essential in order to define the energy store of the human body. We can deduce the latter be calculating the amount of various chemicals delivered to the human body from various nutrients, but this procedure is by far too complicated and inaccurate.

1. Water
2. Fat
3. Glycogen
4. Potassium
5. Calcium
6. Protein (12kg)
7. Sodium
8. Phosphorus
9. Magnesium, Zinc, Copper, Iron, Chloride

A quantitative approximation of the substances contained in the human body

By examining the different methods of fat measurement, one can say that there is no direct method for the in vivo evaluation of body fat. Fat can be determined, either by subtraction of lean body mass weight or by measuring the effect that fat has on macroscopic physical properties of the body (hydrodensitometry, photon absorptiometry, Quetelet's index e.t.c.).

The lack of direct fat measuring method creates two major problems in the evaluation of body composition. The first is related to the methodological accuracy; meaning that small systematic errors in estimating FFM can be translated to gross errors in evaluating fat by subtraction from body weight. The degree of the error propagation depends inversely on the fat content of the body. The second methodological problem involves the assumptions inherent in indirect methods. For example, determining FFM either by total body potassium or water alone, assumes a constant content of these substances in lean tissue.

Combined techniques reduce these assumptions and have been found to work well in the normal population for determining FFM. They remain assumption-depended and there are well-established circumstances that most models fail to account for.

After those types of problems that we face in determining body fat, we need to adopt a

radiation-based technique that will solely target upon the predominant element of fat which is carbon.

The Simulation

The present simulation deals with the most important aspect of the estimation of storage fat in the human body and in order to accomplish such a task, we consider a representation of the human body, containing a uniform distribution of triacylglycerols, in a shape of cylindrical phantom

A deuterium-tritium neutron generator fires a fast neutron beam of 14.7 Mev kinetic energy towards the phantom where ^{12}C atoms of the triacylglycerols are excited, via a fast neutron inelastic scattering interaction. As a result, gamma rays are emitted and by using a bismuth germanate inorganic scintillation detector, we detect the out coming gamma radiation of 4.44 Mev photon – energy.

The whole process is analyzed and simulated by a geometrical model and with the aid of a computer program which takes into consideration the different attenuation for neutrons and photons, we calculate the amount of gamma radiation reaching the detector. The net result is the determination of sensitivity for a particular set-up and by relating the out coming data to the amount of carbon; the quantity of fat is estimated. In addition, the non-uniformity is calculated, from the computer programs expressing the consistency of our system.

During the simulation, there are numerous parameters that we alter, in our set-up, such as the position and the number of the sources and detectors and the size and shape of the phantom, in order to observe the behavior of our system and deduce the changes in the sensitivity and non-uniformity under different circumstances.

So in order to determine the storage fat we built a simulation model that will enable us to represent the detection of the carbon atoms in triacylglycerols. The basic set-up comprises of a moving bed, which is placed between two detectors and one source underneath the bed. A similar system has already been used for the in-vivo work and is proven to be optimum. For simplicity the phantom we use in out simulation has a cylindrical shape and it is filled with triacylglycerol compound in order to simulate the human body the best we can.

The source is a 14.7 Mev neutron generator and neutrons are emitted isotropically reacting with the carbon atoms in the triacylglycerols, resulting in 4.44 Mev gamma rays, which are detected from the BGO detector. Neutrons are attenuated quite differently from gamma radiation but we assume a simplified model of attenuation because otherwise we need to use the Monte – Carlo software to accomplish accurate calculations.

Calibrating our set-up for phantoms of different sizes containing known amounts of carbon is accomplished by irradiating each phantom and measuring the amount of gamma radiation (N_γ factor) for every single one. Using the $N_\gamma$factor we can assure the safety of our experiment by checking our dosimetry figures and how well they lie within the dosimetry boundaries of NRPB.

We can then get measurements from a subject by scanning for about 15 minutes, starting from the shoulders and ending at the knees.

It is better to perform other measurements as well in order to allow for a better accuracy in our results. Namely, we can take into consideration radiation resulting from carbon container in protein and glycogen and as a result do the calculation for a total body fat estimate the errors involved in the experiment.