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BODY COMPOSITION: HISTORY, METHODS AND APPLICATIONS

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History

Before I begin to talk about the history of the body composition, and researches which are, from my point of view, an important line of investigation within the field of anthropology, I think it is necessary to define the concept of body composition.

For me, it would be "The evaluation of the different components of the body, but considered as a whole. The analysis is done with consideration to the chemical, physiological and morphological changes that act on the body."

(If I have not mentioned the numerous methods of measuring body composition yet, it is because I will talk about them later.)

Historically, since the closing years of the 19th century, studies have been performed with the aim of learning the biochemical changes occurring in the body with age. These studies were carried out on foetuses and newborn babies. During the first third of the present century, metabolic balance techniques were used to quantify the composition of the mass put on during a gain in weight. From that time, studies by the Czech anthropologist MATIEGKA (1921) are particularly noteworthy. This author was the first to make an estimation of the different main components of the body weight on the basis of anthropometric data. - And this, in a period when anthropology was mainly osteologic and descriptive, was simply revolutionary.

During the 1950-s the studies by SKERLJ and BROZEK were also important for they reinvestigated body composition. BROZEK (1952) pointed out how the analysis of body composition greatly increases the field of application of physical anthropology, giving it a biomedical meaning, helping as to know the intraindividual and interindividual alterations in weight related to age, environment, activity, sex, etc.

In the 1960-s, the methods of determining body composition were set, as were a great number of applications of these measurements: a) Sports Centers, b) nutrition and bromatology, c) medical sciences: paediatrics, gerontology and forensic medicine.

Which techniques were thought up to measure and study the mass between the skin and the bones?

Body weight was almost the only measurement taken into consideration by paediatricians, internal physicians and others to characterize a live individual, though, as BROZEK pointed out, weight can be mistaken even when related to a length (height) of a certain individual (nevertheless, weight for height and the ratio height/weight are still common indices in clinics).

For instance, in an adult person, the body weight for height can increase for different reasons, such as:

1. Changes in the "body scaffolding", i.e. an increase or decrease in the bony mass.

2. Increased muscular tissue (after a period of exercise).

3. Increased fat tissue (caused by a metabolic disease, a sedentary life or bad nutritional habits).

A decrease in body weight in an adult person can be a result of many different losses, with very different implications:

1. Loss of tissular water (as occurs, naturally, during the ontogenetic processes from birth to old age) or due to pathologic causes.

2. A diminution in the amount of muscular tissue (e.g. during periods of inactivity or when a physical effort ceases).

3. A diet restriction, which affects the fat tissue or, in certain cases, other tissues (undernutrition).

Of course, all these factors have very different biological meanings.

The inclusion of other anthropometric measurements, such as the trunk circumference did not help much to clarify the picture. There was something else to know, something that defines the shape of every individual: the fat tissue.

WIDDOWSON (1968) analysed the subcutaneous fat precipitate from dead foetuses aged 28 to 40 weeks and observed that the amount of fat increased with time (age).

BEHNKE (1942) studied great depth divers and worked out the basis of the equations later applied for the analysis of the human weight divided into its two fractions: fat weight and lean weight, through total body weight, body volume and total body water.

Related to this field, I must also mention the work of LJUNGGREN (1957) on nutritional anthropology, where the variation in body composition was analysed during the growing process and through the metabolic balance.

All the above-mentioned findings lead us to think that there is great agreement in considering the body weight divided into two main fractions.

Fat body weight

Fat, as a fraction of the body weight, but also as a component of the fat tissue, and a part of the nervous fibres, viscera, etc., has fundamental missions not only as an isolator, but also as an energy storage that gives to the organism a certain independence from the environment.

Its density is practically constant: 0.9×10^3 kg/m^3. The fat mass greatly varies not only interpopulationally and interindividually, but also in a given person throughout his life and/or depending on situations of organic stress. Fat tissue also shows a clear sexual dimorphism related to the hormonal changes in adolescence.

Lean body weight

This is the body weight minus the fat weight. Hence, the lean body weight includes: osseus tissue, muscles, mineral fractions, water, etc. It is evident when considering fat-free tissues (which particularize only the mass exempt of fat) that the lean tissues contain a small amount of fat (2%: essential lipids as lecithin and phospholipids).

In practice, the two concepts are often equal. The lean tissue density is approximately 1.10×10^3 kg/m^3, containing 68 milliequivalents of potassium for every kilogram of lean tissue in males (10% less in females), and 720 g of water. Its composition is 20% proteins, 7% minerals and 1% carbohydrates, the rest being water.

Evidently, the lean mass also shows a great variation, as observed in the fat mass. The factors that must be considered for both (lean and fat) tissues are as follows:

age, sex, race/ethnics, physical activity, exercise, nutrition, disease, social context.

Age

By the seventh month of intrauterine life, the foetusis rapidly increasing in weight. This occurs basically by an augmentation in adiposity, rather than in lean tissue. To a certain extent, the tissues dehydrate, their water content decreasing from 94% to 82% in the eight month of pregnancy.

The percentage body fat at birth is approximately 13%. This increases later, during the neonatal period.

Between 9 months and the first year of age, a negative rate of growth of the fat tissues is usually observed, the lean body mass then increasing (the child starts to become more slender). The loss of water continues during the first year of life, and at the end of this year the water content is about 74%. After another year (children aged 2 years), the water content has decreased to 60%.

During the growing process, there is an alternation between periods with increasing fat storage and periods with increasing lean tissue. For instance, between 3 and 4 years of age, children tend to be more ectomorphous; at 5-6 years, mesoendomorphous, etc., though it is certainly variable and dependent on the growing rhythm and speed for every individual. Thus, the top growing speed for lean tissues occurs at some undefined age, during the period known as adolescence, when important changes in fat tissue and total body weight also happen, in both males and females. There is a loss of water, more evident in females than in males.

In adult people, variations in body composition may be distinct from the events of growing. Thus, the augmentation of fat stores is mainly due to environmental factors, exceptions being pregnancy and breast-feeding periods in women.

The fat tissue remains almost constant through the whole adult life. In the last involutive period, two interesting phenomena develop:

1. Re-distribution of the fat tissue at about the age of 40-60 years. The fat tissue is still centralized, but this tendency increases the internal fat of the abdominal wall.

2. The lean tissue starts its deterioration after the fourth decade of life, leading to

a progressive decrease in height and some other partial lengths and a net deterioration of the muscular tissues, which is especially clear in old age.

Sex

This sort of genetically determined variation is not significant during the intra-uterine period and at birth (though there is a slightly higher lean content in males than in females). Howewer, such dimorphism increases during the growing process, the difference being 1% at the end of the first year of life, and 6% at pre-puberty (10 years). These differences accelerate considerably at adolescence, generating a predominance in the total body fat (internal and subcutaneous) in girls.

Although fat tends to centralization in both sexes, in women fat accumulation is more peripheral and goes together with a lower lean mass development in both bone and muscle. In males, lean mass development is prevalent, and though males have a lower fat tissue proportion than females, it shows a central distribution, generating different fat-storage patterns for men (apple-shaped) and women (pear-shaped), the etiologic consequences of which on morbidity can be regarded as risk factors for cardiovascular diseases.

These adult characteristics remain invariable during maturity and until the last stages of old age, when a clear diminution in fat, bone and muscular tissues is observed in both sexes.

Race/ethnics

It is difficult to talk about any racial differences in our species because of the great heterosis, and we cannot find "pure races". We are all somewhat half-breeds, "mestizos", because of migrations and other changes. Nevertheless, individuals with negroid ancestors (and so, clearly negroid individuals) show a higher lean/fat development. In europoids, higher accumulations of fat/lean mass can be observed, defining thereby a different structural prevalence in these groups, with larger shoulders and hip widths in negroids than in caucasoids. I do not dare to talk about a physical pattern, because many anthropometric data are related to a different socio-economic context in the two groups, which is always associated with the type of nutrition, type of work and quality of life.

This makes us think of the importance of analysing not only the racial context of body composition, but also the ethnicity (e.g. gipsy populations in Spain).

Physical activity/exercise

It is interesting to study this point, mainly if it is considered to be a marker, first of lower fat stores which are metabolized during the physical stress, and then, because of the higher lean development being basically muscular, muscle hypertrophy.

Not all the types of activity produce the same individual pattern, or rather, not every individual has a good predisposition to practise a certain activity. For example, a swimmer's body composition is different from that of a long-distance runner, and both are different from the body composition of a sedentary office worker.

The physical activity of an individual must be considered when estimating diets and body composition.

Nutrition

"Tell me what you eat and I will tell you who you are" says an old Spanish proverb. There is evidently a great deal of truth in this assertion.

The mode of nourishing presupposes a supply of the "bricks" (of one kind or another) to build our body, though with some safeguards.

Overnutrition (eating more than needed for the organic maintenance and the physical activity) leads to overweight, which, if not rectified, becomes obesity, with important increases in relative and absolute proportions of fat tissue.

Undernutrition causes an energetic demand that is mitigated by using the stored fat (emagramiento). If undernutrition persists, then the lean fraction is affected and there is a severe organic loss.

Disease

It is known that certain diseases also cause changes in body composition. For example, in children and still growing individuals it occurs, in certain environments, because of dehydration processes caused by diarrhoea, loss of fat and lean tissues caused by vomiting, due to infections, parasites, etc.

In adults, diabetes or gout produce alterations in the body fractions or in their distribution, as in the case of cardiovascular diseases (in this case, it is thought that it is the fat distribution that involves the higher or lower risk).

Social context

We are all familiar with the First World pattern versus the Third and Fourth World ones, i.e. injustice reflected in different body frames.

Individuals who live in a propitious environment have a greater lean development together with a larger fat store (even excessive) as compared with those of individuals from the same environment but belonging to a lower social class.

It has been like this until very recent times, when the lower classes from developed environments display a larger fat development and a higher tendency to obesity. This pattern has also been observed in studies made on recent "Western impact" areas, such as Polynesia, or in rural communities that have emigrated to industrialized areas.

Determination of body composition

Different work methods have been developed to determine body composition. These can be resumed in two different methodologies, with different fields of application:

1. Direct method

This method is applied in corpse dissection and chemical analysis of the corpse.

Starting from dissection, body fractions are evaluated as percentages of the total body weight. For instance, from the dissection of two caucasoid individuals aged 35 and 45 years, respectively, the fractions of the total body weight obtained were:

skeleton	14.8%, 17.6%
skin	7.8%, 6.3%
fat tissue	13.6%, 11.4%
striated muscle	31.6%, 39.8%
rest of the body	32.2%, 24.9%

To integrate these indirect data with the live individual, it is usually necessary to characterize the body composition in chemical terms (e.g. proteins, 11 kg; fat, 9 kg; carbohydrates, 1 kg; water, 40 kg; minerals, 4 kg; for an individual weighing 65 kg, that is: 17.6% proteins, 13.8% fat, 1.5% carbohydrates, 61.6% water and 6.1% minerals).

2. Indirect methods

These are used to estimate body composition in live individuals. There are sundry methods, all of them involving narrower or wider margins of error.

The first methods applied were:

A) Anthroposcopic-photoscopic methods

The technique consists in direct surveying or pictures and then, reference pictures to quantify the physical frame.

The obvious disadvantage of the method is the observer's subjectivity, which makes the comparison of data analysed by different observers less reliable.

B) Photogrametry

Starting from this method, SHELDON (1950) developed a typologic system: the somatotype, which, though not a proper method to determine body composition, has contact points with it.

With use of the somatotype, fat tissue (endomorphism), muscles (mesomorphism) and linearity (ectomorphism) are evaluated. The method starts from the concept that an individual has a constant morphogenotype during his ontogeny, provided that the conditions of energetic expenditure and nutrition are kept invariable (in practice, this is really difficult, and almost impossible).

In 1955, BROZEK derived an equation to the predict body density and the total body fat through endomorphism.

C)Radiogrametry

This is based on the study of X-ray plates, in which it is possible to evaluate subcutaneous fat, bone and muscle in terms of linear dimensions (thickness) and in transversal areas, allowing an estimation of the volumes of tissues.

STUART and REED started these studies in 1940 (1951), REYNOLDS in 1948 and GARN in 1954 (1956).

Such estimations can be advantageous since:

- Examination of the fat tissue is possible in areas of the body inaccessible to other kinds of determinations (subcutaneous skinfolds).

- The technique is not complicated and the procedure is feasible despite the ontogenetic differences in the compressibility of the fat tissue.

- X-ray plates of extremities allow on evaluation not only of the fat, but also of the muscle and bone volume and size.

Nevertheless, there are some disadvantages to this method: First, the method is actually considered to be "invasive", and so it is accepted only in very concrete cases. Second, this technique is very expensive: X-ray plates and the necessary installations are not cheap. And third, the distances must be perfectly calibrated in order not to distort the real readings.

There are data from the 1950's and 1960's that are useful for the study of fat tissue regionalization.

Starting from this method, formulae have been calculated to estimate body composition:

GARN model: Based on a linear equation, with data obtained from X-ray plates:

$$W = a + bs$$

where W is the weight, b is a constant and s is the amount of fat tissue.

If s=0, then a = lean body weight

and $W = L + A$ (adiposity).

Though the model does not fit reality, it is true that the two body fractions (fat and lean mass) are involved.

D)Anthropometry

This consists in the use of anthropometric techniques together with other indirect methods to determine body composition:

- Linear measurements to determine fat tissue development: subcutaneous skinfolds.

- Musculature and robusticity: diameters and circumferences.

Subcutaneus skinfolds

About half of the stored fat is subcutaneous. This allows an easy measurement due to its accessibility. Given that the skin thickness is constant, the amount of fat stored can be evaluated from the thickness measured with a special skinfold caliper.

When this method is used, it is important to differentiate well between muscle and fat, and this requires some practice by the anthropometrist.

The number of points (skinfolds) to be measured depends on the specific work to be done, but the I.B.P. (International Biological Program) usually demands inclusion of at least the tricipital and subscapular skinfolds (for extremities and thorax fat stores) and also recommends inclusion of the suprailiac skinfold.

The most frequently used calipers are the HOLTAIN and LAUGE instruments. They both have a pressure of 10 g/mm^2 and it adds another difficulty to the measurement that the fat tissue "moves" during the first measurement, so the following measurement of the same skinfold must be done after an interval. Further, in obese people, it is difficult to include the last stratum of subcutaneous fat, which is very often omitted.

Musculature

Muscles can be characterized in terms of widths or diameters, with calculation of the transversal surfaces of the segments starting from the circumferences and subcutaneous skinfolds.

BROZEK established that, if the extremity is a cylinder, then from the known circumference, the diameter can be calculated, though the fat portion (the subcutaneous skinfold measure) must be corrected for:

$$c = \pi \cdot d \qquad d = c/\pi$$

$$d = c/\pi - s$$

JELLIFFE (1969) derived the following equations:

CA = circumference of the arm

TS = tricipital skinfold

MCA = muscular circumference of the arm

MDA = muscular diameter of the arm

MSA = muscular surface of the arm

FSA = fat surface of the arm

TSA = total surface of the arm

$MCA = CA - (\pi \cdot TS)$ $MDA = CA/\pi - TS$

$MSA = (\pi/4) \cdot (MDA)^2$

$FSA = (TS \cdot CA/2) - (\pi(TS)^2/4)$

$TSA = MSA + FSA = (CB)^2/4\pi$

In certain studies, other less familiar formulae have been used, such as the energy/protein index, etc. These formulae have an important disadvantage: the muscle and bone values cannot be eliminated.

Body frame: weight/height

The deviation of an individual's body weight referred to the standard value for a given height is useful for a rough estimate of his body composition.

These relationships belong in classical anthropometry:

- BOUCHARD index = weight/height
- Quetelet index or body mass index (B.M.I.) = weight/height^2
- ROHRER index = weight (kg)/height^3 (m^3)

In terms of nutrition, these indices can give a proper diagnostic criterion. The handicap is not to be able to differentiate between weight due to fat, muscle or oedema.

In 1982, KATCH and FREEDON developed a mathematic model to define the body architecture: the body frame. In males and females, this correlates the height, biacromial and bitrochanteric diameters, classified in categories, with the body weight, percentage of fat and lean body weight.

Differences in weight for the categories were due to the lean mass in men, and to the fat mass in women.

Some inaccuracies have been observed in the Actuary Society Tables. In 1983, the elbow diameter was included.

Nowadays, it is thought that the wrist and ankle better meet the aim of eliminating the weight free of fat (HIMES and BOUCHARD, 1985).

Tissue mass estimation

Densimetry techniques

These techniques appeared early (1949) and a great number of prediction formulae have been developed from them. The method is based in Archimedes' theorem, which estimates body densities from the volume displaced inside a fluid (D = M/V), so it is necessary to weigh the individual in water and then correct for the weight of the residual air in the lungs, estimating that:

$$\text{Density} = \frac{W_{ta} \times 0.996}{W_{ta} - W_{tb} - (V_{alr} \times 0.996)}$$

W_{ta} = weight out of water
W_{tb} = weight under water
V_{alr} = volume of residual air
0.996 = water density at 37 °C.

Once density is calculated, the amount of fat as a fraction of the total weight can be obtained by means of a general equation. This allowed the development of formulae to find the percentage of fat or the total fat weight:

Examples:

- KEYS and BROZEK (1953):
  $\%Fat = (4.95/d - 3.813) \times 100$
- SIRI (1956) produced the most widely used formula:
  $\%Fat = (4.95/d - 4.50) \times 100$
- Minnesota (this equation estimates density from the skinfold values):

$$\text{Density} = 1.0084 - 0.00071X_1 - 0.00048X_2 - 0.00055X_3$$

X_1 = mid armpit skinfold
X_2 = thorax skinfold
X_3 = tricipital skinfold

Later, PARIZKOVA (1971) devised a reliable estimation from the measurement of ten subcutaneous skinfolds, which took into consideration differences due to age and sex. Such a great number of measurements made the sampling very difficult. The skinfolds measured were: face, neck, thorax-1, triceps, subscapular, thorax-2, abdomen, suprailiac, thigh and calf.

Children (9-12 years)

Girls: %Fat = 2.399X - 2.457

Boys: %Fat = 2.660X - 3.134

Adults (17-45 years)

Women: %Fat = 39.572X - 61.25

Men: %Fat = 22.32X - 29.00

where $X = \log \Sigma$ skinfolds.

One of the most commonly used methods of prediction is that of DURNING and RAHAMAN (1967), which needs four subcutaneous skinfolds (bicipital, tricipital, subscapular and suprailiac) to calculate density, and, as before, $X = \log \Sigma$ skinfolds.

This possibility was enlarged in 1974 by DURNING and WOMERSLEY to facilitate working with equations in a wide range of ages (16 to 72 years) and including a great variety of types: workers, sportsmen, dancers, students, etc.

A total of 180 equations for body density were obtained with different number of skinfolds combinations.

For example, for the four skinfolds mentioned above, the formulae and constant values calculated for both sexes were:

$$\text{density} = c - m \times \log \Sigma \text{ skinfolds}$$

Males

Age (In years)	17-29	20-29	30-39	40-49	50+	17-72
c	1.1620	1.1631	1.1422	1.1620	1.1715	1.1765
m	0.0630	0.0632	0.0544	0.0700	0.0779	0.0744

Females

Age (In years)	16-19	20-29	30-39	40-49	50+	16-68
c	1.1549	1.1599	1.1423	1.1333	1.1339	1.1567
m	0.0678	0.0717	0.0632	0.0612	0.0645	0.0717

Then, SIRI's formula is used to obtain the percentage of fat.

POLLOCK et al. (1984) found another system of equations for each sex, in which the estimation is based not only on skinfolds, but also on other measurements such as knee diameter and even breast size in women.

JOHNSTON (1982) developed a formula to predict fat weight in adolescent people, based on a multiple linear relation between B.M.I., tricipital skinfold and age:

Girls : %Fat = 0.355 x age + 1.109 x B.M.I. + 0.170 x tricipital skinfold - 15.869

Boys : %Fat = 0.492 x age + 0.584 x B.M.I. + 0.668 x tricipital skinfold - 1.024

This model is useful only for populations similar to the one on which the model is based.

In 1987, WELTMAN made estimations for fat people, whose skinfold measurements are not as precise as desirable. This author derived a series of equations as follows:

Women: kg of fat = 0.46361 x CG + 0.31303 x CMA + 0.13614 x height + 0.22885 x CM - 83.43495

Men: kg of fat = 0.46590 x CMA + 0.20468 x CM - 39.642

where CMA is the mid-abdomen circumference, CM is the thigh circumference and CG is the gluteus circumference.

Circumferences have evidently been chosen due to the imprecisions in measurements of skinfolds thicker than 40-50 mm, though circumferences are more associated with lean tissue than with fat tissue. The prediction error is lower than 4% in females and 3% in males.

Hydrometry

Every method used to establish the total body water is divided into two separate fractions (extra - and intracellular water). This determination is the basis estimation of the water-free mass.

Various substances are used in this technique:

- antipyrine
- urea
- heavy water (DHO)
- tritiated water (THO)
- sulphamide

The extracellular composition is determined by using thiocyanate and correcting with a factor of 0.7 to obtain the real extracellular space.

Intracell. water = total water - extracell. water

According to BROZEK (1961):

M = F + N

where M = total body weight, F = fat weight and N = everything that is not fat.

N = T - K

where T is the total body water and K is a constant that, in adult humans, ranges from 0.71 to 0.73.

In a study on body water, SHENG and HUGGING (1979) established that the fat-free weight contains about 73.2% of water. This is of great importance because it allows separation of the body mass into two compartments.

For example, if a man weighs 70 kg, with K= 0.732, the percentage of fat is 15%.

Isotope radiometry

In 1953, FORBES et al. discovered that the lean body mass contains more potassium that the rest of the body. About 0.0019% of the total potassium in the organism is radioactive potassium (K40), and so it is possible with a radioactivity counter to evaluate the total potassium content of the body and then, the lean body weight, as follows:

$$\text{Lean body weight} = \frac{\text{total potassium (g)}}{2.66271}$$

given that in adults there is a content of 68.1 meq/kg and that 1 meq weighs 0.0391 g.

In 1963, FORBES also estimated that:

$$\text{Fat weight} = \frac{\text{total body weight - total potassium}}{68.1}$$

LUKASKI et al. (1981) compared the results of calculating the lean body weight and the percentage of fat by several methods and found that these results were coincident:

	Densitometry	K40	Body water
Lean body weight	62.3	62.2	63.9
% Fat	15.2	15.5	13.9

The radioactive potassium method is not traumatic and does not need large equipment as hydrometry does, but it is not a very reliable method to use on very thin individuals. In middle-aged women, there is also an overestimation of the fat tissue when this technique is used (NOPPA et al., 1979). FOMON et al. (1982) pointed out that an overestimation of about 13% was observed when they applied the radioactive potassium method to children aged 9-10 years.

Computerized axial tomography

This method can be applied from photometry used to study densitometry and bone composition. There are actually three basic techniques to determine bone mass which are not "invasive":

1. Photometric absortion of a simple photon.
2. Photometric absortion of a double photon.
3. Computerized tomography.

The first method can be used to determine the peripheral skeleton bone tissue at certain points of the osseus cutting. This technique is fast, cheap and uses low radiation, and it is possible to study trabecular bone areas with it.

The second method is a logical evolution of the first one. It allows characterization of the whole skeleton and not only of one area. This method needs more time, but the doses of radiation are lower than in the first one and it is also highly precise.

Tomography allows the direct measurement of the trabecular bone density, mainly at the vertebral column level. The advances in computerization and software are continuously improving explorations, comparisons and diagnosis.

Thus, in individuals suffering from severe obesity, tomography is a good estimation method. Starting from bone standards, which must be corrected to fit each population, with the latest generation of densitometers it is possible to know the body composition of these individuals compared to the references and according to their sex, race, height, weight, etc.

This method has permitted the correction of some estimation formulae on body composition.

The study of adipocytes

Adipocyte size and number can also be included in body composition studies. There are some specialized techniques, such as direct measurements of frozen cells obtained by surgical incisions. Adipocyte size is estimated from a very small portion of subcutaneous fat ($1/10^6$), the result being extrapolated to the rest of the fat stores, though some differences in size have been found depending on the part of the body where the adipocytes are from and the age of the individual. Thus, for example, bigger sizes were found in the abdominal wall and gluteus. These differences are larger in children than in adults.

With regard to the ontogenetic process, it has been observed that the number of adipocytes mainly increases during the first year of life, though at the age of 4 years there is another slight increase in number. In adults there are no appreciable changes.

Nevertheless, the increase in size can vary in relation to metabolic alterations or obesity, mainly in the abdominal adipocytes.

High correlations with the fat fraction of the body composition have also been observed.

Applications

I should like to talk to you now about one application of body composition. These investigations find great application in the field of health and the determination of the state of human nutrition.

The study analyses the changes in body composition and the increase and distribution of fat tissue in women suffering from severe undernutrition due to starvation, with a great loss of muscular tissue. Our main goal in this first study was to know the somatic moment at which these women re-started their menses, bringing new data to the theory of the threshold in the percentage of fat needed to start and maintain the menstrual function.

In 1990, a group of prisoners belonging to a terrorist group operating in Spain (GRAPO) began a hunger strike to pressure the authorities into making a series of concessions. The strike began on November 26, 1989, and ended on February 8, 1991. Not all members of the group upheld it with the same degree of firmness; only a minority did so.

Two days after the strike ended, the medical department of the Women's Penitentiary Centre in Madrid commissioned us to carry out somatic and physiological studies of two female prisoners, M. and V. They had been transferred to this prison one year before, both in a state of considerable deterioration. The principal disorder they were diagnosed as suffering from was a type of encephalopathy known as

Wernike's disease.

These women had adopted a rigid stance about eating: they agreed to be fed intravenously with a glucose solution (500 cm^3 3 times a day) and a glucosaline solution (500 cm^3 2 times a day). After 15 months on the hunger strike, the loss of muscle tissue was dramatic and they were scarcely able to hold themselves erect.

Measurements were made every two weeks. Data were gathered according to I.B.P. norms, but their severely incapacitated state demanded that outside assistance was required. We considered height, weight, circumferences (arm, waist and hip), skinfolds (tricipital, bicipital, subscapular and suprailiac) and general capacity. These women, who were gynaecologically controlled, obviously suffered from amenorrhoea.

Tables 1 and 2 show somatic measurements on M. and V. Their height was 154.3 and 160 cm, respectively. When my study began, this values the weights were below the 10th and 5th percentiles for their sex and age.

Table 1. Somatic measurements on men.

TRI.	BI.	SUP.	SUB.	ARM.	WAI.	HIP.	V.C.	WEI
05.6	5.0	5.4	5.2	19.9	60.0	72.6	2.5	35.0
07.8	6.2	6.2	5.2	21.0	63.0	81.0	2.8	39.0
08.2	7.0	7.4	6.8	21.2	63.9	81.0	2.4	43.0
09.8	5.0	9.8	7.8	22.4	65.8	82.3	2.5	42.0
10.0	6.0	9.0	7.8	22.5	66.4	82.1	2.2	43.0
11.8	7.2	9.2	7.8	22.4	67.4	82.2	2.1	44.5
09.8	6.8	12.4	6.6	24.4	67.2	82.4	2.6	46.0
10.8	8.6	13.6	8.4	25.0	67.2	82.9	2.8	46.5
14.8	9.0	13.6	9.2	25.0	67.4	84.5	2.7	46.5
15.6	9.0	12.6	9.4	25.5	70.0	87.0	3.1	48.4

Table 2. Somatic measurements on women.

TRI.	BI.	SUP.	SUB.	ARM.	WAI.	HIP.	V.C.	WEI
06.8	6.2	6.4	5.2	19.2	65.2	75.3	1.8	39.5
11.0	7.2	7.6	6.8	20.1	69.3	80.1	2.5	43.0
12.6	7.8	8.2	7.8	22.1	70.1	84.6	2.6	49.0
15.0	8.8	8.6	10.0	23.8	71.7	88.0	2.8	56.4
15.3	9.2	8.9	10.1	24.0	72.3	88.2	2.7	56.4
16.6	9.4	9.0	10.2	22.4	73.3	88.4	2.7	56.0
16.8	9.4	9.8	10.3	22.4	74.0	89.1	2.6	55.0
16.2	9.4	8.4	10.8	25.8	74.3	89.9	3.4	56.0
19.8	10.2	10.6	8.8	26.0	74.5	89.0	3.5	56.0
19.8	9.8	10.8	9.8	26.6	75.6	88.2	2.5	57.0

As conserns nutrition, the medical team gradually modified the women's diet and their level of physical activity (Table 3).

The day after these measurements were taken, the women had just begun to receive a very light diet. The estimated percentage of fatty tissue was about 15%, and the density was relatively high. Complete bed rest was prescribed during this period. The women performed no physical activity at all. A complex "Pentaplus", with vitamins and minerals, was provided to the women every day.

Table 3. Daily nutrition.

BABY FOOD	PROT.	LIP.	C.H	Kcal	
Chicken/rice		6.6	2.2	19	124
Chicken/calf		6.6	3.2	12	102
Hake/vegetable	7.0	0.4	18.2	104	
Fruit (100g)		0.3	0.1	17.7	73
PENTAPLUS (1) 200 ml	19.4	4.2	20.8	200	
FURICH (3)				780	
TOTALS	39.9	10.3	87.7	1,383	

Over a period of 5 months, the somatic parameters changed favourably: M. gained 13.4 kg and V. gained 17.5 kg. This gain in weight involved a replacement of the fat reserves in the skinfolds. The percentage of fat in both women was higher than 26%. Due to the women's rapid weight gain, the medical team put them on a more controlled diet during the second half of March, when the recovery was well established.

If we take the ratios of body mass and waist and hip measurements as indicators of the distribution of recently acquired fat (Table 4), we can see a constant increase in both women. The fact that the waist/hip ratio increases could indicate a tendency to fat accumulation around the waist. This always contitutes a greater risk factor for some cardiovascular diseases, according to VAGUE et al. (1988). On the other hand, the robusticity index rose.

Table 4. ROHRER index, waist/hip ratio, and Quetelet index.

	MEN	
R.I.	W/H	Q.I.
09.46	0.82	152.38
10.30	0.77	165.88
11.74	0.78	189.03
13.51	0.79	217.58
13.51	0.80	217.58
13.51	0.81	216.04
13.17	0.81	212.18
13.17	0.81	218.18
13.41	0.82	216.04
13.65	0.83	219.83

	WOMEN	
R.I.	W/H	Q.I.
9.69	0.86	148.73
10.80	0.86	165.73
11.91	0.82	182.73
11.63	0.81	178.48
11.91	0.81	182.73
12.32	0.82	189.10
12.78	0.83	195.48
12.88	0.82	197.60
12.88	0.83	197.60
13.40	0.85	205.68

What happened with the gynaecological history? These were studied women in order to relate the menstrual cycle to the body composition (Table 5). Before the hunger strike began, the women had not experienced any periods of amenorrhoea or serious irregularities. Menarche was 12.5 for M. and 13.0 for V. After the strike was under way, the women had lost 20% of their normal weight in December (the strike began in November).

Table 5. Somatic parameters after menstruation began again.

	V.	M.
WEIGHT	49kg	45.5kg
SKINFOLDS	36.4 mm	44.2 mm
DENSITY	.040	1.038
% FAT	24.6 %	26.6%
F.B.W/L.B.W	3.06	2.78
QUATELET INDEX	182.73 g/cm^2	216.08 g/cm^2
ROHRER INDEX	11.91 kg/m^3	13.41 kg/m^3
	DATE: MARCH '91 AMENORRHOEA: 15 M.	DATE: MAY '91 AMENORRHOEA: 17 M.

After the hunger strike was over and the women began to eat normally, they began to menstruate, V. in March and M. in May.

We should point out that the women's periods of ammenorrhoea did not have the same duration. As regards the changes in their body composition, it can be seen in Table 5 that the percentage of body fat was 25%, and one of the most important things: the density was more or less the same for both.

When we compare the changes in the body fat proportions in these women with the monograms of McARTHUR, we can see that, for height, the weight and percentage of fat are very similar to those indicated for the renewal of menstruation. Our women needed more than 22.0% for the renewal of menstruation, perhaps because of the extreme wasting of the body caused by the prolonged hunger strike.

I must end now, I hope that you understand more than at the beginning of my contribution as concerns the important relation of body composition and fertility in women.

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