Sarcopenic Obesity

Time to act

A Guide to Measuring Sarcopenic Obesity with BIA Technology

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Monitoring Your Health

What is Sarcopenic Obesity?

Sarcopenia is the technical term for a low muscle mass (from the Greek for 'poverty of flesh') and usually refers to a loss of mass in the major skeletal muscles. This can be caused by a variety of medical conditions ranging from rare inherited disorders to a simple atrophy through insufficient use of the muscles. A loss of muscle function as well as simple loss of muscle mass is incorporated in some definitions of sarcopenia (1).

Sarcopenic Obesity (SO) describes the condition in which obesity co-exists with sarcopenia as shown by the red area in Figure 1.

In the absence of specific clinical conditions there are two main causes of muscle loss: inactive lifestyles and ageing. These same conditions tend to lead to obesity and, since both are common in the modern world, SO is rapidly emerging as a major health issue.

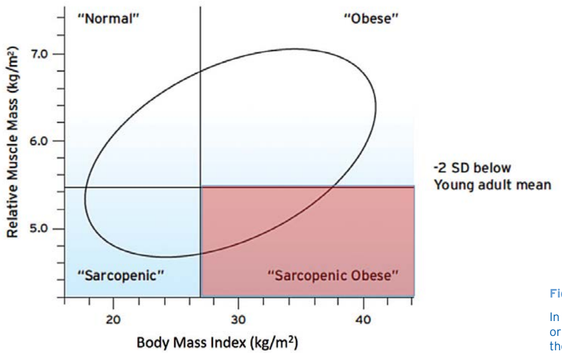


Figure 1

In this figure sarcopenia is defined as a relative muscle mass or muscle index (kg/m²) less than 2 standard deviations below the young adult mean and obesity is defined as BMI >27 kg/m².

Why does Sarcopenic Obesity Matter?

Muscle is beneficial to health in many ways. For example, fit muscles help create a virtuous cycle of active lifestyles, and healthy muscles aid independence in the elderly and protect them from life-threatening falls and fractures.

Sarcopenic Obesity is of particular concern to metabolic health where it creates a double jeopardy. Fat and muscle (and lean tissue more generally) have opposing effects on glucose sensitivity and hence the ratio of the two masses is an important determinant of metabolic health especially in relation to insulin resistance and the associated metabolic syndrome. Muscle utilizes glucose whereas the fatty acids derived from excess adipose tissue inhibit the utilization of glucose; hence the double jeopardy. Hitherto there has been a major focus on the ill effects of a large fat mass without a full consideration of the compensatory value of a large, healthy and exercised muscle mass

Reasons for Loss of Muscle Mass and Function

Muscle atrophy (wasting) occurs as a side-effect of many clinical conditions that affect food intake and cause cachexia and tissue catabolism. Cancers, AIDS, heart failure, lung and renal diseases, severe burns and alcoholism are examples of such muscle-wasting conditions.

Normal ageing also results in a loss of muscle mass and strength (sarcopenia) caused by a combination of a gradual failure in the ability of satellite cells to regenerate new muscle cells and a decrease in the actions of the growth factors that normally maintain a healthy muscle mass. Between 50 and 80y of age muscle mass declines substantially (Figure 2) and muscle strength approximately halves (Figure 3) (2). This can be slowed by training and a good diet, but it seems it cannot be wholly avoided.

Additionally there are many neurological disorders that affect muscle function and may ultimately lead to muscle weakness (stroke, Parkinson's disease, multiple sclerosis, myasthenia gravis, etc).

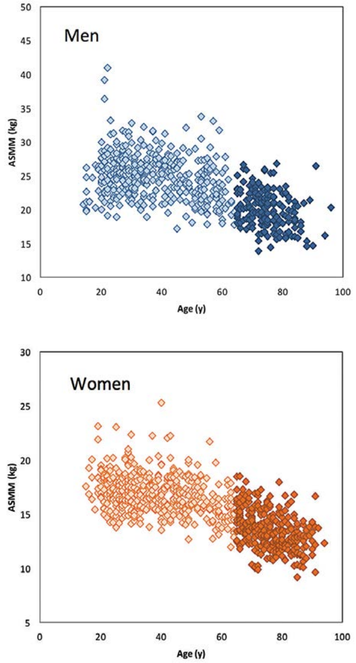
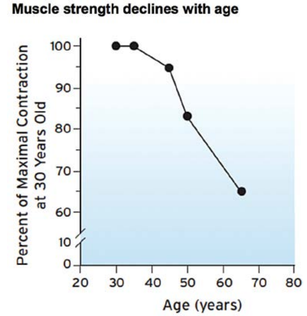


Figure 2

Data for appendicular skeletal muscle mass (ASMM) from Japanese subjects (courtesy of Tanita Ltd). Note that the Y-axes differ. Men have greater ASMM than women.



Thompson LV. (1994) Effects of age and training on skeletal muscle physiology and performance. Phys Ther; 74: 71-81

Figure 3

Sarcopenia is a feature of ageing and sedentary societies

The Importance of Maintaining a Healthy Muscle Mass

Muscle mass and function vary over a wide range within any population group even excluding the extreme ends of the spectrum represented by muscle disease at one end and elite athletes at the other.

In young children a healthy muscle mass and motor development supports participation in play and sports that can entrain a lifelong love of recreational physical activity that is so important in maintaining metabolic health in the modern obesogenic environment.

In adulthood a gain in the proportion of fat mass to muscle mass reduces a person's power-to-weight ratio and makes everyday tasks, such as climbing stairs, more difficult. This creates a downward cycle in which a reluctance to take exercise (for instance, choosing to use escalators and elevators instead of stairs) encourages a further gain in body fat and a deterioration in metabolic health.

In the elderly, a healthy muscle mass is essential to maintain mobility, everyday functions and quality of life (3). It is especially important in maintaining good balance and hence avoiding the falls and fractures that contribute greatly to ill-health and death among older people (4).

The Metabolic Double Jeopardy

Fat and muscle (and lean tissue more generally) have opposing effects on glucose sensitivity and hence the ratio of the two masses is an important determinant of metabolic health especially in relation to insulin resistance and the associated metabolic syndrome.

Too much fat ...

Excess adipose tissue predisposes people to insulin resistance, the metabolic syndrome and type-2 diabetes mellitus (T2DM) through a variety of contributory pathways.

... and too little muscle

Muscle represents the major 'end organ' that utilizes glucose and hence helps to maintain insulin sensitivity. A large, healthy and exercised muscle mass therefore helps maintain health.

Defining the Fat and Muscle Compartments

Human body composition is generally subdivided into the relative proportion of fat vs lean tissue.

The following basic definitions are useful:

Fat mass (FM)

The total amount of fat in a body including that in nerve tissues and the brain

Fat-free mass (FFM)

All the remaining tissues including fluids and the skeleton. Skeletal muscle forms the largest single component.

Lean body mass (LBM)

Usually used inter-changeably with FFM.

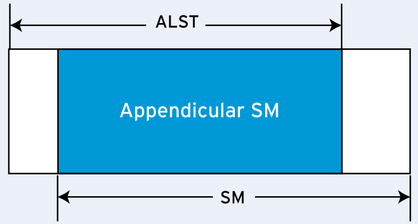
Skeletal muscle mass (SMM)

All skeletal muscle. Since it is impossible to quantify total SMM the term appendicular skeletal muscle-mass (ASMM) refers to the major muscles on the arms and legs, and provides a proxy for total SMM.

Bioelectrical impedance analysis (BIA)

BIA assesses body composition by passing a very small current through the body and assessing differences in impedance caused by the fact that fat and lean tissues have different electrical properties. Since all lean tissue in the limbs is either bone or muscle use of segmental BIA can provide a good proxy for skeletal muscle mass (SMM) by assessing the composition of limbs alone (see Box 1). As BIA is the focus of this report it is described in more detail later.

Box 1



ALST - appendicular lean soft tissue (ie excluding bone)
SM - skeletal muscle

Anthropometry (skinfold thickness combined with limb circumferences)

A formula exists whereby an estimate of the cross-sectional area of muscle in the upper arm can be computed by combining measures of the anterior and posterior skinfold thickness (to estimate subcutaneous fat) and the limb circumference. This is a highly approximate method developed for assessing malnutrition in developing countries and only estimates cross-sectional area at a single site. It is therefore of very limited value and rarely used.

Dual-Xray absorptiometry (DXA)

DXA body scanners used in clinical practice to measure bone density can also give an estimate of body composition. They use 'soft' X-rays that have a different level of attenuation as they pass through fat and lean tissue. The system can be calibrated using animal carcasses. DXA can give regional measures for the limbs and trunk, and – as with BIA – the limb lean tissue mass (appendicular) can be used as a good proxy for muscle mass(6) (see Box 1). However, the equipment is expensive, non-transportable and measurements are time consuming.

Peripheral quantitative computerized tomography (pQCT)

pQCT can be used to assess muscle density and the cross-sectional areas of muscle and fat in either the calf or forearm(7). The equipment is expensive and semi-transportable.

Other highly technical methods

There are a variety of other methods each of which has some significant advantages for assessing skeletal muscle, but each of these is highly technical and very expensive. These include: total-body potassium-40 counting (TBK); in vivo neutron activation analysis (NAA); computerized axial tomography (CAT scanning); magnetic resonance imaging (MRI) or spectroscopy (MRS); and total body electrical conductivity (TOBEC). These are used by a very small number of centres worldwide and only for detailed research studies. MRI and CAT scanners can be used to assess muscle mass of the heart also.

Normal Variations in Muscle-to-Fat Ratio (MFR)

Because both muscularity and fat mass can each vary over a wide range there is a very large range in the muscle-to-fat ratio (MFR) between people of the same age. The MFR tends to be greater in men than women and to decline with age in both sexes.

Children

MFR data from a large sample of children (5-18y) in the UK are illustrated in Figure 4. There is a 3-fold range from the lowest MFR to the highest and a striking difference between boys and girls. The median value for boys is 2.1 and for girls is 1.4. The impact that these differences might have on present and future metabolic health has not yet been investigated but represents an important research gap. The ease with which MFR can be measured using BIA technology should accelerate this field.

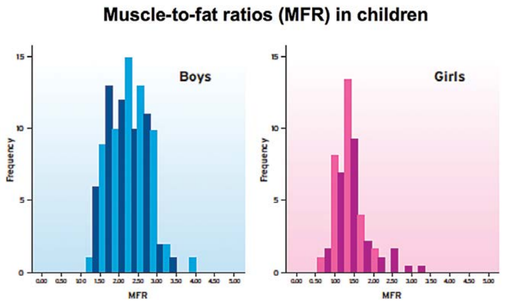


Figure 4

Data from 1985 Caucasian children in UK schools collected by McCarthy et al (5) using the Tanita BC418.

Adults

Muscle-to-fat ratios also vary across a very wide range in adults as shown in Figure 5 using data from over 11,000 US adults of different races. In young men and women there is a 4-6 fold range between the lowest and highest MFRs. Very low MFRs occur in obese individuals and very high MFRs occur in ultra-lean and muscular athletes. Note that the median MFR in young men (1.25) is double that in young women (0.65).

The effect of ageing is graphically apparent from Figure 5. Interestingly the median values do not decline greatly but the right-hand spread diminishes profoundly.

Analysis of this MFR data by race shows that African Americans generally have a higher MFR and Asians have a lower MFR than Caucasians.

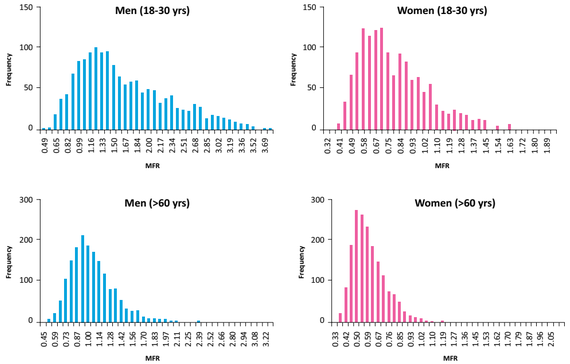


Figure 5

Muscle-to-fat (MFR) ratios calculated as the ratio of appendicular lean soft tissue (ALST, which closely approximates to muscle). Data from over 11,000 US adults (Caucasian, Asian and African Americans) supplied by Prof Steven Heymsfield.

Data collected from adults in Tokyo measured using the Tanita MC-180 BIA monitor shows a very similar pattern with lower ASMM/FM ratios (equivalent to MFR) in women and a very substantial decline with ageing in both men and women (Figure 6).

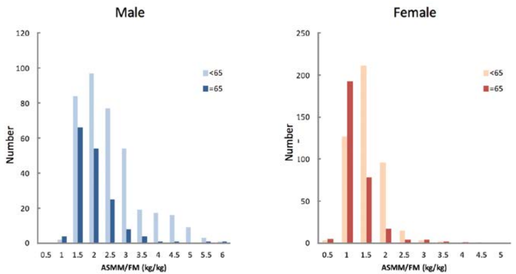


Figure 6

Distribution of ASMM/FM in healthy Japanese adults.

n=375 males <65y and n=163 males ≥65y and n=458 females <65y: n=304 females ≥65y. ASMM: Appendicular skeletal muscle mass, FM: Fat mass

Muscle mass and fat mass were measured by BIA using MC-180. Data from Tanita Institute (Tokyo).

Sarcopenic-Obesity in Adults

Note that there is no definition of sarcopenic obesity in children.

When adults gain weight it is usually gained in the proportion 75% fat to 25% lean tissue. Thus obese people are expected to have a higher lean body mass than normal or underweight people. This extra lean tissue is required to carry around the extra weight (extra skeletal muscle and denser bones) and to service it (a larger heart, liver and digestive tract). However, some obese people have an inappropriately low muscle and lean mass. The combination of a high fat mass with a low muscle mass is termed sarcopenic-obesity (see Figure 1). Cutoffs defining sarcopenic-obesity together with the associated prevalence rates in the communities studied are now appearing in the literature.

There is strong evidence that moderate and high rates of physical activity are associated with lower risk of SO though the direction of causality is not proven (eg 6).

There are strong theoretical reasons that sarcopenic-obesity will be predictive of poor metabolic health and the evidence base in support of this is starting to emerge though further research is still required. Until recently the technological difficulties in assessing muscle mass, especially in large-sample and field settings has hampered research. These have now been overcome by BIA technology and it will be possible to refine studies of the obesity phenotype in relation to health outcomes. Methods such as BIA that can discriminate between fat, lean and muscle tissue will be required to elucidate the precise relationships between obesity, ageing and the major health outcomes (7).

Progressive Sarcopenia in the Elderly; a contributor to SO

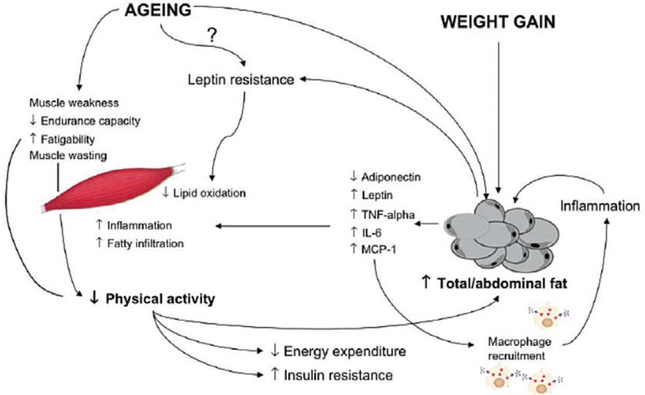
The decrease in anabolic drive (partly due to disuse atrophy) and in muscle sensitivity to anabolic signals that occurs with ageing causes a decline in muscle mass (see Figure 7). There is a strong innate biological tendency towards this progressive muscle loss. It is driven by reductions in oestrogen and testosterone, in the sex hormone binding proteins (DHEAS) and in IGF-1.

Muscle loss is associated with slowness, weakness and general frailty which in turn lead to early fatigue and low physical activity that then reinforce the cycle of muscle wasting.

However, catabolism can be slowed by high levels of physical activity (eg by high work loads in poor subsistence-farming populations, or simply by personal choices to remain very physically active in affluent populations). They can be slowed and, to some extent reversed, by strength training even in the later decades of life (8).

This sarcopenia is a major determinant of some of the morbidities associated with old age. Geriatric medicine now recognizes the key role of sarcopenia on the causal pathway to deteriorations in mobility and quality of life (9,10), and in serious and life-threatening outcomes such as hip fractures (11,12).

When this sarcopenia is combined with excess fat, as is often present in the elderly, the result is sarcopenic-obesity that tends to have a higher prevalence in the elderly. It remains controversial as to whether sarcopenic obesity is a predictor of mortality in the elderly with some studies showing that it is and others not (13,14). It does, however, have a clear association with increased levels of disability and a reduced ability to perform the functions of daily living in the elderly (15-17).



Inter-relationships between adipose tissue and muscle. A mechanism leading to sarcopenic obesity.

Figure 6

Given the critical importance of sarcopenia to health in later life there is a need to encourage measurements of muscle mass in a variety of settings: in epidemiological studies (where little attention has previously been focused on muscle), in health monitoring throughout adulthood, and in therapeutic programmes aimed at improving strength, mobility and quality of life in older people. BIA offers a simple and cost-effective method for such monitoring that could be widely used across many health settings from primary health care to hospital settings

What is Novel about Tanita BIA Monitors?

Tanita pioneered the use of foot-to-foot BIA in which subjects simply have to remove their shoes and stand on a monitor that sends a minute current from one foot to the other. The measurement can be completed in 20 seconds, and is backed by a strong research programme over 20 years. There was initial scepticism as to whether a system just passing a current though the legs could be as accurate as previous `tetrapolar' systems that attached stick-on electrodes to each ankle and each wrist. However, later research showed that (because they represent a very long thin conductor) arms actually introduce a disproportionate weighting to tetrapolar monitors and may hence reduce their accuracy if not adjusted for carefully.

A New Generation of Tanita BIA Analysers

The new Tanita Body Composition Analyser MC-980 uses 8-electrodes and require subjects to hold two hand-grips whilst standing on the monitor. This allows segmental analysis of the composition of arms, legs and trunk. Further analysis provides key indicators of the subject's muscle mass, body water and body fat status and can be shown on a Consultation Sheet (see Figure 7). With an in built Windows Operating System, automatic storage of measurements is possible, ensuring accurate trend analysis and database management.

Of particular interest is the 'Leg Muscle Score' plotted against reference data from healthy Americans (see Figure 8). This is based on the principle that leg muscle represents the largest fraction of muscle mass and hence comparisons of leg muscle give a good proxy indicator of overall muscle mass. Similar scores could be derived for appendicular SMM (arms and legs).

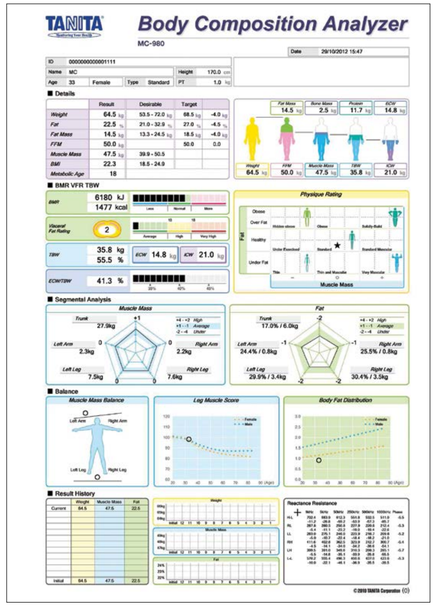


Figure 7
Consultation Sheet

Figure 8
Leg Mucle Score

Sarcopenic-Obesity and Cancer

A study has shown that sarcopenic-obesity was a strong independent predictor of survival in patients with solid tumours of the respiratory and gastrointestinal tracts (18) and has suggested that failure to assess decrements in muscle and lean mass might lead to chemotoxicity through overdosing with cancer-therapeutic agents.

Summary

It is increasingly being recognized that Sarcopenic Obesity (SO) represents a distinct sub-category of obesity in which the relative loss of muscle mass exacerbates the ill-effects of excess adipose tissue.

SO is a progressive condition associated with ageing especially in modern sedentary societies. It is reversible by high levels of exercise.

Models to describe the theoretical basis underlying the metabolic and health impairments associated with SO are being progressively refined (eg 19).

Segmental BIA offers a practical means of assessing appendicular skeletal muscle mass (ASMM) and body fat (BF) and hence can form the basis of assessments of SO.

Standardised definitions of SO are required so that studies across different populations can be compared more easily.

Future research will continue to refine our understanding of how to combat SO and hence how to maintain optimal health as people live longer.

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This report was commissioned from Prof Andrew M. Prentice, PhD, FMedSci.

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The views presented are his own and do not imply endorsement by MRC or LSHTM.

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