Current applications of DXA body composition measurement

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Increasingly, measurement of body composition by dual energy x-ray absorptiometry (DXA) is being used in areas of clinical medicine where accurate information regarding fat distribution and/or muscle mass is desirable.

Dual energy x-ray absorptiometry (DXA, also referred to as DEXA) was initially developed primarily for the measurement of bone mineral density (BMD) and is now the gold standard for the diagnosis and monitoring of osteoporosis. This article describes another important application of DXA – the measurement of body composition. Increasingly, DXA is being used in this role in both clinical medicine and metabolic disorder research.

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The principles of DXA are briefly described in Box 1 below. A number of parameters that are typically included in a DXA body composition report are discussed in Box 2.[1-9]

APPLICATIONS

DXA body composition measurement provides particularly useful information regarding disease states in which fat distribution and muscle mass are both affected, such as nutritional disorders and HIV infection. It is also finding increasing application in the field of sports science and in research into human ageing.

1. HOW DOES DXA WORK? A QUICK LESSON

The common use of DXA for measurement of BMD is based on a two-compartment model of the body – that is, soft tissue and bone. The attenuation of an x-ray beam passing through the body can be described as a function of attenuation coefficients and the mass of bone and soft tissue. The DXA x-ray beam comprises two principle energies, and measurement of the x-ray attenuation at these two energy levels can be used to generate a pair of simultaneous equations that can be solved for bone mass or for soft tissue mass.

DXA body composition studies are performed generally with whole body scanning using full-sized table systems. Soft tissue pixels within a scan are identified and can themselves be considered as comprising two components – that is, fat and lean tissue. When a two-component model of soft tissue is applied (fat and lean tissue), the fat fraction of this soft tissue mass can be predicted from the ratio of soft tissue attenuation of the two x-ray beam energies.

2. DXA BODY COMPOSITION REPORT: NOTES ON THE PARAMETERS

Whole body lean mass and fat mass

DXA provides estimates of whole body lean mass (grams and %) and whole body fat mass (grams and %), which can be compared to a reference population. Lean mass includes all soft tissue parts of the body (organs, muscle and fluids) except body fat; a higher lean mass corresponds with a more muscular body.

Although currently no standard definitions of obesity are based on tissue percentage fat results, recommended values at different ages for both men and women have been published.[1] In addition, reference values have been published for a fat mass index (FMI), which is proposed as an estimate of total body adiposity (FMI = fat mass/height squared), using data for a US population.[2]

Regional assessments of percentage fat can be determined for the trunk, arms or legs from a DXA whole body scan. However, the role of this information in the management of obesity is currently undetermined.

Fat distribution and types

Studies of obesity have led to understanding of two different types of fat: visceral fat (i.e. intra-abdominal fat) and subcutaneous fat, with visceral adiposity correlating more strongly with insulin resistance and risk of cardiovascular disease (Figure 1). Most DXA scanners can obtain an index of visceral fat using a number of parameters.

The android/gynoid ratio and central abdominal fat are two commonly used parameters to assess fat distribution (Figure 2). In women, the ratio of abdominal (android) fat to pelvic (gynoid) fat mass has been found to be a strong predictor of cardiovascular risk, whereas in men abdominal fat mass is a stronger predictor.[3] A similar parameter of fat distribution is the fat mass ratio (FMR), which is the ratio of truncal fat mass percentage to the percentage of fat mass in the lower limbs (but does not exclude subcutaneous fat in the anterior abdomen and paravertebral region). The FMR is commonly used in the setting of HIV infection (see below).[4]

More recently, DXA scans software upgrades have provided estimates of visceral adipose tissue (VAT), which are obtained by subtracting an estimate of subcutaneous abdominal fat from the total fat measured in the android region of interest (Figure 1). These estimates of VAT correlate well with CT or MRI measurements,[5,6] and are likely to be adopted more widely as a parameter of central adiposity.

Whole body BMD

Whole body BMD is not widely used in adult medicine, but it is a useful parameter in paediatrics for assessing a number of diseases that impact primarily on bone (e.g. osteogenesis imperfecta) or have secondary effects on bone (e.g. cystic fibrosis). Whole body BMD measurement is free from some of the morphological anatomical changes that occur with growth.[7] The WHO T-score criterion of -2.5 for diagnosis of osteoporosis does not apply to measures of whole body BMD, which will underestimate the prevalence of osteoporosis.[8] However, if whole body BMD is low for an adult individual then further assessment with lumbar spine and proximal femoral BMD should be performed to more accurately determine fracture risk.

Resting metabolic rate

The resting metabolic rate is an index of caloric consumption at rest, and is dependent to a large extent on fat-free mass (which includes total muscle bulk). With increasing age, the resting metabolic rate gradually declines, which contributes to age-related weight gain.[9] This parameter has potential application for monitoring progress in exercise programs.

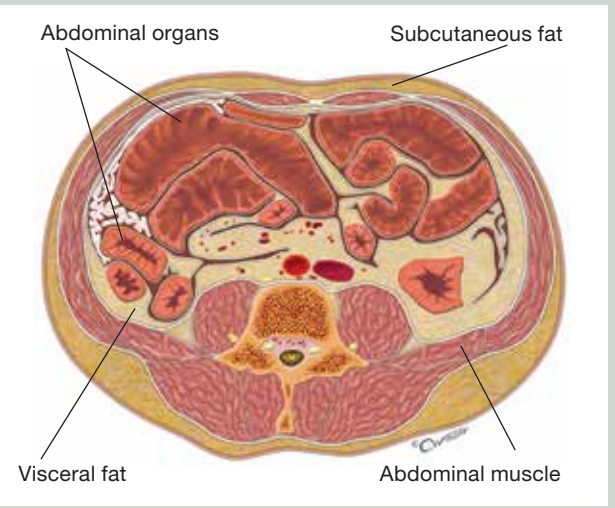

Figure 1. Visceral fat (intra-abdominal fat), which can be estimated by DXA with recent software upgrades, is more strongly correlated with insulin resistance and the risk of cardiovascular disease than subcutaneous fat. (Abdominal cross-section shown at L4.)

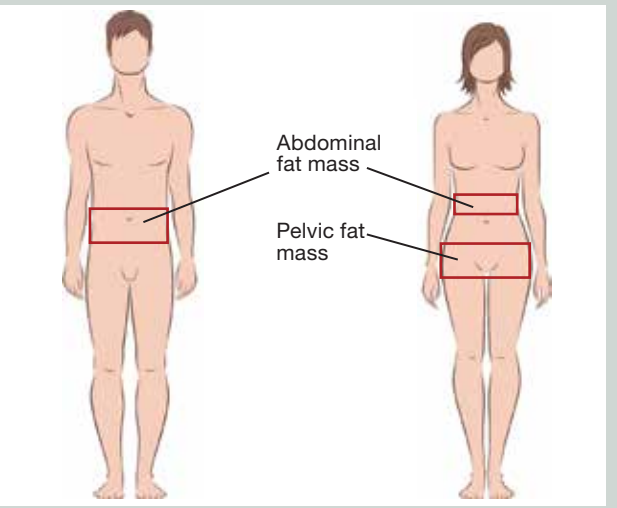

Figure 2. DXA can be used to assess body composition in different 'regions of interest'. Parameters commonly calculated for assessing fat distribution include the abdominal fat mass (shown at left) in men and the android/gynoid ratio (abdominal fat mass divided by pelvic fat mass [shown at right]) in both women and men.

Alternative technologies for body composition measurement exist, such as anthropometry, bioelectrical impedance analysis, isotope dilution, air displacement plethysmography, computed tomography (CT) and magnetic resonance imaging (MRI). However, most of these techniques are not widely available and/or are more expensive than DXA, and for CT there is the additional consideration of a significantly higher radiation dose. DXA offers the advantage of providing whole body and regional estimates of three components (bone, lean and fat mass) with high accuracy and reproducibility,[10] and it has been validated against other methods available for body composition analysis.[5,6,11] The reproducibility and low radiation dose of DXA make it a useful tool for monitoring body composition longitudinally. However, at present there is no MBS item number for DXA body composition.

Obesity

At present, over 60% of Australian adults are overweight or obese and consequently at potential increased risk of a number of diseases.[12] However, the measures that are most commonly used to assess obesity, such as simple body weight, waist circumference and BMI, provide only limited information and cannot distinguish lean tissue from fat tissue. For example, BMI correlates highly with body fat in most people, but people with a high muscle mass and little body fat will also have a high BMI. Further, the success of exercise programs (decrease in fat mass and increase in fat mass) may be underestimated using BMI alone.

These limitations have led to interest in more sophisticated measures of body composition to better assess obesity and its response to interventions. DXA provides a more reliable estimate of obesity and body composition than indirect measures such as waist circumference or BMI.[13,14] Useful parameters for assessing obesity are included in Box 2.

Anorexia and low bodyweight

Anorexia nervosa can result in a number of medical complications,[15-18] and use of DXA in the management of patients with anorexia nervosa has been described. DXA estimates of fat-free mass and fat mass may be useful, in conjunction with BMI, for assessing disease severity and need for hospitalisation.[19] Serial DXA is a useful modality for monitoring body fat percentage and bone density in affected patients.[20]

Other disorders that may result in malnutrition, such as coeliac disease and inflammatory bowel disorders, are associated with changes in body composition that may be improved by treatment. For example, coeliac disease results in lower body fat mass, lean mass and BMD in untreated patients; adherence to a gluten-free diet leads to improvement in body composition and BMD.[21] The role of DXA in the management of these conditions is yet to be determined.

HIV infection and other causes of lipodystrophy

HIV infection results in progressive loss of lean and fat mass, predominantly in the trunk (AIDS wasting syndrome). Some highly antiretroviral therapy (HAART) may result in fat redistribution, with subsequent peripheral fat atrophy and visceral lipohypertrophy,[22,23] which is associated with dyslipidaemia and insulin resistance and contribute to increased cardiovascular risk.

HIV-related lipodystrophy can be diagnosed clinically; however, DXA body composition provides a more quantitative assessment and potential for consistency in diagnosis. The FMR has been shown to be positively correlated with age, time on HAART, zidovudine and stavudine therapy.[4] One group of researchers has proposed that a FMR greater than 1.33 in women and 1.96 in men indicates the presence of lipodystrophy in patients taking antiretroviral therapy.[24] FMR-defined lipodystrophy appears to be more sensitive in determining insulin resistance than clinical defined lipodystrophy.[25] Earlier diagnosis of lipodystrophy can potentially facilitate better cardiovascular management. FMR may also be potentially useful in managing familial lipodystrophies.[26]

Ageing

The composition of the body changes with increasing age, with sarcopenia (skeletal muscle atrophy), in particular, having an association with disability that is independent of morbidity.[27] DXA has demonstrated a disproportionate loss in appendicular or leg lean mass in patients with sarcopenia, with the loss of peripheral lean mass being the main predictor of decline in one or more levels of reported disability in older men and women.[28] DXA has a major role to play in sarcopenia research, but its role in the clinical management of patients with sarcopenia is still being determined.

Sports science

DXA is being used to measure body composition in both professional and recreational athletes. Serial DXA scanning may be used to monitor changes in body composition over time in order to evaluate an athlete's training regimen (such as a desirable increase in the ratio of lean tissue to fat mass), rehabilitation after sports injury and the success of weight-loss programs. Serial DXA may also be useful for detecting negative effects of an exercise program, such as excessive loss of fat or lean mass.

SUMMARY

DXA is becoming increasingly used in areas of clinical medicine where accurate body composition analysis is required or where longitudinal tracking of lean, fat and bone mass is useful in clinical decision making and in the monitoring of treatment progress. With its advantages of relatively low cost, very low radiation and relative ease of access, the increasing use of DXA for body composition measurement can be expected to continue. MT

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A list of references is included in the website version (www.medicinetoday.com.au) and the iPad app version of this article.

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