Review Article

Clinical Applications of Body Composition Measurements Using DXA

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Abstract

Dual-energy X-ray absorptiometry (DXA) scanning was primarily developed for the diagnosis of osteoporosis and was initially applied to studies of the clinically important sites of the lumbar spine, femoral neck, and forearm. The rapid adoption of DXA has led to the development of different, competing generations of equipment. Improvements have been achieved through advances in X-ray generation and detection technology, modification of data acquisition protocols, and implementation of more sophisticated image analysis algorithms. As a result, DXA has been extended to allow the study of the total skeleton and its regional parts, as well as soft-tissue composition measurement. The three major components of the body: fat mass, lean mass, and bone mineral mass, can now be easily measured using a single whole body DXA scan with high precision and low scanning time.

The comprehensive view of body composition provided by DXA makes it an attractive technique for a variety of clinical applications such as the prevention of cardiovascular and metabolic diseases, clinical management of different chronic diseases, and monitoring of the impact of treatment regimens on body tissues.

In this article we review the contribution DXA has made to the understanding of body composition in clinical studies in adults.

Key Words: Adults; body composition; clinical applications; review; whole body DXA.

Introduction

Dual-energy X-ray absorptiometry (DXA) devices were primarily developed for the diagnosis of osteoporosis. Bone mineral density (BMD) measurements in the proximal femur, the lumbar spine, or the forearm provide a means for the diagnosis of

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osteoporosis, the prediction of fracture risk *(1–2),* and the monitoring of therapies *(3).* In addition to BMD assessment, DXA devices are capable of measuring body composition of the total body or body regions.

The main measurement technique is based on the differential attenuation by bone, fat, and lean tissue of transmitted photons at two energy levels *(4).* The transmission at two energy levels allows the derivation of two different components such as fat and lean mass in regions without bone. In regions with bone the two components, bone and soft tissue, are measured, and the composition of the soft tissue needs to

Table 1
DXA Devices for Body Composition and Total Body BMD Measurements

Manufacturer	Model	Imaging geometry	Scanning time (min)	Effective dose (μSv)	Patient dose[b] (μSv)
Hologic	QDR 4500	Fan	3	2.6 (3.4[a]) (14)	–
	Delphi W	Fan	6.8	–	–
	Delphi A	Fan	3	–	–
Lunar	DPX-MD	Pencil	10–15	–	0.2
	DPX-IQ	Pencil	6–10	–	0.2
	Expert	Fan	4	75 (15)	–
	Prodigy	Pencil/Fan	5	–	0.37

[a] Effective dose in brackets includes ovaries.
[b] Patient doses according to the manufacturer.

be estimated with respect to the adjacent tissue values. Therefore, a body-composition scan of the total body measures three compartments of the body: fat and lean body mass, as well as total body bone mineral. Proteins, glycogen, mineral, and water (including water and organic materials of the bone) are included in the component of lean tissue *(5)*.

The DXA output provides information about the following masses (in grams): fat, lean tissue, and bone mineral content (BMC) of the total body and body regions. The fat content is given in percentage. Additionally, regional and total body BMD (in g/cm^2) are provided.

A variety of alternative techniques for body composition measurements are available and have been reviewed by Jensen *(6)*. Anthropometry, for example, predicts fat content by measuring skinfold thickness (ST) and body circumferences. Total body water (TBW) can be measured by isotope dilution technique (injection or drinking of tritium or deuterium solution). A person's average body density can be estimated by underwater weighing. Total body potassium (TBK) counting predicts lean body mass by measuring the naturally radioactive isotope potassium ^{40}K. Other available techniques include neutron activation analysis, bioelectrical impedance analysis (BIA), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography. Many of these techniques are restricted to a small number of laboratories. In contrast, DXA devices are widely available owing to the widespread

use of BMD measurements in osteoporosis. DXA body-composition measurements show a high correlation with the abovementioned techniques *(7–9)*, and are rapidly gaining interest and acceptance in clinical practice.

This article provides an overview of the different areas for which body-composition measurements with DXA have been instituted in clinical practice. Our research was based, in part, on a review of the current literature on body composition in adults.

DXA Devices

DXA technology has improved significantly in the last few years, especially scanning times. Whereas a few years ago a body-composition scan required more than 15 min, new DXA devices are capable of scanning the total body in less than 5 min. Reduced scanning times are more convenient for patients and technical staff and have contributed to increased acceptance of DXA measurements in body composition research and clinical practice.

Table 1 lists current DXA devices that are equipped with a body-composition mode. In addition to these devices, older models such as the QDR 1000 and QDR 2000 (Hologic Inc., Bedford, MA, USA), XR-26 (Norland Inc., Fort Atkinson, WI, USA) are still being used in clinical practice.

For whole body scanning, it is imperative that all parts of the body (also arms and feet) are included in the scan field for precise measurements. However,

there are some limitations with respect to the size of the imaging table and the X-ray dosage. For example, patients taller than 1.82 m (6 ft) may not fit entirely on the table. The accuracy of the measurement is then slightly reduced. In very obese patients, e.g., over 135 kg (300 lb), the X-ray dosage may not be sufficient for imaging the abdomen. Some devices offer special modes for obese patients with increased dosage or longer scanning times.

To assess lean and fat mass composition, the DXA systems use different calibration techniques. The XR-26 and QDR systems rely on external calibration, using wedges made of aluminum and Lucite (polymethylmethacrylate) calibrated against stearic acid as 100% fat, and diluite saline solution as 100% lean tissue *(10)*. The DPX systems use a plastic polyoymethylen (Delrin) as 40% fat equivalent and water (~5% fat) as standard measurement *(4)*. Therefore, when comparing body-composition measurements between various DXA devices, results of fat and lean tissue show high correlations but also systematic differences owing to different calibration *(11)*. Tothill et al. *(12)* compared three DXA devices of different manufacturers and found deviations in fat values of 6% in the total body and up to 13% in the trunk. Differences were also found when comparing two distinct DXA models of the same manufacturer *(13,14)*.

Deviation in measurement results between the devices can also be explained by the variations in the technology. Differences exist in hardware (X-ray voltage, higher and lower energy spectra using switching kilovolt or K-edge filters, different detectors) and in software (algorithms for edge detection, assumptions regarding distribution of soft tissue above bone). Additionally, the imaging geometry (pencil- and fan-beam) may cause deviation in measurement results. A pencil-beam (collimated by a pinhole collimator) is coupled to a single detector and scans the total body in a raster. In contrast, a fan-beam (slit collimator) is coupled to a multidetector linear array. Fan-beam systems use only three (QDR 4500) or four (Expert) parallel sweeps across the patient for a complete total body scan. The advantage of these techniques is the improved scanning time of 3 or 4 min. Fan-beam systems have a higher X-ray flux, and thus image quality is also improved. As a consequence, radiation doses for patients are

higher, and the technical staff should be appropriately protected *(15,16)*. An overview of the patients' radiation exposure using various DXA device is given in Table 1. Considering the annual dose equivalent from natural background radiation (2400 μSv per annum), and from other imaging procedures such as dental bitewing (60.0 μSv), chest X-ray (50.0 μSv), and thoracic and lumbar lateral spine X-ray (820.0 μSv), the radiation exposure from whole body DXA is relatively low.

In comparison to pencil-beam systems, fan-beam geometry causes projection and magnification artifacts. The projected area depends on the tissue height above the scanning table. The influence on body-composition data is still under investigation; however, improved correction algorithms are being implemented. The Prodigy, listed in Table 1, uses a thin fan beam that requires multiple raster scans similar to pencil-beam systems.

Quality control in bone densitometry is essential not only for clinical drug trials or epidemiological studies in which multiple densitometers are involved, but also in routine clinical practice. To ensure consistent performance, a quality-control scan with a known standard is carried out daily, and the measurement is then compared with previous scans in a quality-control database. The standard used for these daily quality-control scans differs with the manufacturer and may consist of anthropomorphic phantoms or geometric objects of known density.

Different standards for body-composition measurements, such as the Variable Composition Phantom (VCP), have been evaluated recently *(18)*.

DXA devices are proven to have long-term stability and provide high precision in BMD scans of 1–2% and in body-composition scans of 2–6% *(12,17)*.

Clinical Applications

Precise and accurate measurements of body composition are useful in achieving a greater understanding of human energy metabolism in physiology and in different clinical conditions, and in evaluating interventions. Many disease processes affect bone and soft tissue at the same time. Therefore, the comprehensive view of body composition provided by

Table 2
Overview of the Main Field of Clinical Applications of
Whole Body DXA in Adults

1. **Nutritional disorders**
   Obesity
   Overweight
   Anorexia nervosa
2. **Gastrointestinal disorders**
   Chrohn's disease
   Celiac disease
   Gastrectomy
3. **Hepatobiliary disorders**
   Cirrhosis
   Gallstones
4. **Renal disorders**
   Chronic renal failure
   Hemodialysis
   Transplantation
5. **Endocrinological disorders**
   Hypopituitarism
   Acromegaly
   Cushing's syndrome
6. **Bone disorders**
   Osteoporosis
   Paget's disease
   Osteopetrosis
7. **Pulmonary diseases**
   COPD
   Fibrosis cystic
8. **Drugs and substances**
   Corticosteroids
   Hormones
   Parenteral nutrition
9. **Other disorders**
   Diabetes
   AIDS
   Sympathetic dystrophy syndrome
   Amiotrophic lateral sclerosis
   Tetraplegy
   Duchenne muscular dystrophy

whole body DXA makes it an attractive technique for a variety of clinical research and practice applications (Table 2).

Following is a discussion of DXA's contribution to the understanding of body composition, including bone mineral measurements, in different fields of clinical applications in adults.

Nutritional Disorders

Total body DXA accurately estimates the body composition and the composition of weight loss in obese subjects *(19),* as well as other clinical conditions in both overweight *(20–22)* and obese *(22–23)* subjects, and can be used for monitoring such a condition during therapeutic interventions.

Hendel et al. investigated the relationships between body composition by DXA, fat distribution, sex hormone, and other cardiovascular risk factors in overweight postmenopausal women *(19).* Androgenicity, cigarette smoking, and alcohol consumption correlate independently and positively with a central fat distribution. Furthermore, atherogenic levels of lipids and lipoproteins were independently related to central fat distribution, androgenicity, and low levels of estrogens. Carey et al. investigated the relationship between abdominal fat and insulin sensitivity by DXA in normal and overweight women *(21).* In this study, abdominal adiposity appeared to be a strong marker and may be a major determinant of insulin resistance in women. Goodpaster et al. *(22)* studied obese and overweight women and men, using DXA to evaluate abdominal fat and CT to evaluate subcutaneous abdominal fat. They concluded that subcutaneous fat as a component of central adiposity is also an important independent marker of insulin resistance in obesity. A relationship between fat distribution, glucose tolerance, and gallstone pathogenic factors was also demonstrated in obesity with the direct measurements of fat mass by DXA *(23).*

Nutrition plays an important role in skeletal mineralization. The nutrients known with certainty to be important are calcium, vitamin D, protein, and calories. Therefore, any form of malnutrition may also affect total skeleton mineralization.

It is well known that women with anorexia nervosa develop osteoporosis *(24).* However, after weight gain an increase in total body fat and lean mass as well as an increase in total BMC was observed in these patients *(25).* Contrary to the symptoms associated with undernutrition, patients with anorexia tended to remain energetic and shown high activity levels. There are indications that in such patients a high level of physical activity may result in an increase of total bone mass *(24,26).*

Gastrointestinal Disorders

Malnutrition is a common presenting feature in patients with active Crohn's disease *(27)*. Analysis of body composition is important in states of acute and chronic illness to quantify the magnitude of the malnutrition. Such knowledge allows the clinician to assess the extent of nutritional depletion, which in turn provides objective guidelines for the type and amount of required nutritional support. Patients with active Crohn's disease have diminished total body fat. Fat stores are the most severely affected, being 70% of normal value *(27)*. It has been reported that DXA provides an accurate measurement of body fat, compared with other methods of study, in malnourished subjects with Crohn's disease *(28)*.

Malabsorption in patients with celiac disease may lead to alteration of nutritional state and calcium balance. It is well-known that a gluten-free diet may eliminate subjective symptoms and steatorrhea, but does not restore normal body composition. In fact, untreated patients show lower body weight, fat mass, lean tissue mass, and BMD at the lumbar spine and total skeleton measured by DXA *(29)*. After treatment, only lean mass seems to be restored *(29,30)*.

Total gastrectomy is another condition known to be complicated by both reduction of bone mineralization *(31)* and nutritional disorders. However, Liedman et al., using whole body DXA in a prospective clinical study, reported a reduction of the body fat, but they did not find an increased prevalence of osteoporosis in patients after total gastrectomy, even after long-term follow-up *(32)*.

Hepatobiliary Disorders

Malnutrition frequently occurs in patients with liver disease and may represent a risk factor influencing both their short- and long-term survival *(33)*. The potential role of DXA in the assessment of body composition in cirrhotic patients is of particular interest, not only because it can provide additional and more precise information on their nutritional status, but also because the estimation of metabolically active body compartments by means of body-composition analysis is essential for physiological processes standardization, such as energy expenditure and protein turnover *(34)*.

Two different patterns of tissue loss may be found in cirrhotic patients: in women, lean tissue is maintained while fat stores are reduced, as in early starvation; in men, lean tissue is reduced and body fat is normal, as seen under conditions of stress *(35)*. The reason for a gender difference in tissue loss in cirrhotic patients could be related to the abundance of fat stores in females, which are progressively used to cope with the metabolic needs until muscle mass remains the exclusive energy store *(35)*.

Factors influencing muscle mass, such as nutritional depletion, altered protein turnover, and physical inactivity, may also, in part at least, negatively affect bone mineralization *(35)*.

Finally, in a study of hepathobiliary disorders by DXA a significant association was reported between increases of abdominal fat mass and gallstone development *(23)*.

Renal Disorders

A number of factors may lead to malnutrition in patients with chronic renal failure. Malnutrition is a major factor in the greatly increased morbidity and mortality that occurs in these patients *(36)*.

It has been reported *(37)* that change in body weight induced by hemodialysis has no influence on whole body or regional BMC and fat tissue mass measurements by DXA. On the contrary, a change in the measurement of whole body lean-tissue mass is strongly correlated with change in body weight after hemodialysis. These findings agree with prior results of studies investigating the effect of hemodialysis on body composition by DXA and support the view that DXA is a useful tool for estimating short-term changes in body composition, such as those induced by hemodialysis *(38,39)*.

In patients undergoing renal transplantation, rapid changes in body composition occur, with variations in fat distribution *(40)* and bone mineralization *(41)*. In such patients, the widespread use of corticosteroids for immunosuppression, together with the negative input of surgery and immobilization, could be associated with nutritional deterioration, the potential for an increase of body fat, and loss of lean tissue and bone mineral mass.

Endocrinological Disorders

Growth hormone (GH) is one of the main energy metabolism and body-composition regulators *(42)*.

GH deficiency in young adults causes a change in body composition with increased fat mass and reduced lean mass *(43)*. Toogood et al. reported that even in the elderly, in whom GH secretion is normally very low, the additional imposition of GH deficiency owing to organic disease may cause changes in body composition with significant biological impact *(44)*. GH replacement therapy in hypopituitary adults may alter body composition through its well-known lipolytic, anabolic, and anti-natriuretic actions. A short-term study has shown that GH replacement therapy tends to normalize soft-tissue body composition *(43)*. A long-term study has demonstrated that the beneficial effects of GH therapy on body composition, i.e., a reduction in body fat and an increase in lean mass, are preserved for at least 4 yr in hypopituitary adults *(45)*. An increase of whole body BMC and BMD in hypopituitary patients with adult-onset GH deficiency after 2-yr treatment was also reported *(46)*.

In acromegaly, body composition is characteristically altered by an increase in lean mass and a corresponding reduction in fat mass *(42)*. Treatment with the somatostatin analog, octreotide, reduces hormonal effects on target tissue. Short-term octreotide therapy reduces GH levels, leading to a significant reduction in lean mass as assessed by DXA *(47)*. Acromegaly may induce abnormalities in bone metabolism. Kayath and colleagues *(48)* reported that osteopenia occurs in a minority of patients with acromegaly and is predominant in the spine. The authors did not find any correlation between duration of hypersomatotropism, GH/IGF-1 levels, and BMD, and they concluded that the majority of these patients have preserved BMD despite the presence of hypogonadism.

Estimating body-composition changes is of interest in Cushing's disease, which is characterized by redistribution of fat from peripheral to central parts of the body owing to an excess of adrenocortical steroids. Patients with this syndrome show reduced amounts of fat and lean-tissue masses in the arms and a slight reduction of total BMD and BMC compared with obese subjects and similar to nonobese controls owing to depletion of selective protein depots, as seen in hypercortisolism *(49)*.

Bone Disorders

There is a great need for a simple method to identify persons at low risk of developing osteoporosis, because bone densitometry is too expensive and time-consuming for general use in an unselected population. Such a method would allow low-risk individuals to be excluded from screening with BMD measurements and/or increase the years between follow-up bone mass measurements. Fat mass is decreased in osteoporotic patients and may have an important protective role on the skeleton *(50)*. It was reported that women weighing more than 71 kg have a very low risk of being osteopenic compared to women weighing less than 64 kg. Therefore, weight could be used to exclude women from a screening program for postmenopausal osteoporosis *(51)*. In a large study designed to compare body composition and BMD in Chinese women with vertebral fracture, it was found that not only fat mass but also lean mass, height, and BMD at all sites were significantly lower in fractured patients than normal controls *(52)*.

Paget's disease is characterized by an increase in bone turnover, often at multiple skeletal sites that are more susceptible to deformity or fracture than normal bone. Whole body DXA measurements allow regions of interest to be defined, so that the BMD of focal areas within the skeleton can be assessed. It was reported *(53)* that pagetic bone is more dense than nonpagetic bone before treatment. With risedronate treatment, whole body BMC increases because there has been an increase at pagetic and nonpagetic sites. That the greatest increases in BMD occur at trabecular sites affected with Paget's disease probably reflects, in part, the larger volume of the pre-treatment remodeling space in trabecular compared with cortical bone *(53)*.

The diagnosis of osteopetrosis is based on qualitative description of standard radiographs showing universal osteosclerosis. However, this technique does not permit the degree of osteosclerosis to be measured. Whole body DXA was used to quantify the osteosclerosis in the two subtypes of autosomal dominant osteopetrosis *(54)*. In both types, BMC and BMD were markedly increased at the axial as well as at the appendicular skeleton compared to normals. Moreover, the authors have suggested that

measurements of whole body BMC and BMD may be useful to complete the radiologic examination of such patients, and in order to establish future therapeutic regimes, DXA might be helpful in monitoring effects on skeletal mass.

Pulmonary Diseases

The measurements of lean mass and fat mass reserves in individuals with chronic obstructive pulmonary disease (COPD) can aid in designing an adapted nutritional regimen, e.g., nutritional support in malnutrition and food restriction in obesity, improving the clinical management of this condition *(55).* Body weight and lean mass abnormalities can affect the health-related quality of life (HRQL) in COPD patients. It was demonstrated that although body weight and lean mass abnormalities influence HRQL, their effects appear to be mediated through increased levels of dyspnoea in patients with symtomatic obstructive lung disease *(56).* It was also shown that respiratory muscle strength is closely associated with body weight and lean mass in patients with COPD. The comparison of respiratory muscle strength with lean body mass should be useful for studying the mechanism of respiratory muscle weakness in patients with COPD *(57).*

In cystic fibrosis, the combination of pulmonary dysfunction, which can increase energy requirements, and malabsorption, caused by pancreatic insufficiency and reduced bile-salt concentration, make it difficult to provide adequate nutrition. Knowledge of body composition is important in states of acute and chronic illness where an individual may not be able to consume an adequate diet to meet nutrition needs. Such a knowledge allows clinicians to provide nutrients needed for maintenance and repair *(58).* In addition, in cystic fibrosis, bone mineral status may be impaired, although the pathogenesis of this bone mineral deficit is still uncertain. The reduction of lumbar spine, femoral, and whole body BMD observed in these patients suggests a reduction in both cortical and trabecular BMD. Bachrach and colleagues have proposed that either osteopenia or osteoporosis be included as health risks for adults with cystic fibrosis and that bone mineral status of such patients be assessed on a routine basis *(59).*

Drugs and Substances

Glucocorticoids negatively affect bone mineralization, lipids, and glucose metabolism and can therefore modulate whole body composition. In patients affected by giant cell arteritis, 2-yr treatment with high doses of prednisolone during the first 6 mo and lower doses thereafter resulted in a significant increase in total body fat as well as in trunk fat that remained after switching to a low-dose glucocorticoid schedule *(60).* In female patients with systemic lupus erythematosus, the severity of disease and corticosteroid exposure were independently associated with a negative effect both on total body BMD and on lean mass *(61).*

A number of hormones *(62–65)* have been shown to modulate body composition measured by whole body DXA. The menopause is associated with an increase in total body fat and decline in lean body mass. Oral estradiol/dydrogesterone and tibolone prevent total body fat changes, whereas transdermal estradiol/oral dydrogesterone and tibolone prevent lean mass changes. Furthermore, oral estradiol/ dydrogesterone prevents the shift to a central, android fat distribution *(62).* Tamoxifene, an anti-estrogenic agent used in patients with advanced breast cancer, may lead to an increase in fat content in women who are undergoing this treatment *(63).* The administration of testosterone enanthate for 6 mo as contraception in healthy men resulted in a modest reduction in fat mass and small increases in lean mass, muscle strength, and bone density *(64).* Exogenous androgens increase lean body mass and modulate abdominal fat distribution in obese postmenopausal women *(65).*

GH is a potent anabolic agent that tends to normalize body composition as shown in several studies on GH-deficient hypopituitary adults *(43,45–46).* In addition, a low dose of biosynthetic GH can elevate insulin-like growth factor (IGF)-I levels in GH-deficient adults and has a pronounced physical impact and a decline in fat mass, without the side effects seen at higher dosage schedules *(66).*

Total parenteral nutrition (TNP) may be subject to the inadequate provision of certain nutrients and the resulting nutritional complications may affect bone, lean mass, and fat mass. However, it was reported that patients receiving home TNP present a stable

body composition with no significant change in lean mass, fat mass, or total BMC after a mean period of 20 mo. Individual changes in body weight and lean mass were correlated with change in home parenteral nutrition energy supply *(67)*.

Other Diseases

DXA has recently been used to study the body composition of patients affected by diabetes *(68)*, acquired immunodeficiency syndrome (AIDS) *(69,70)*, and different neurological conditions such as sympathetic dystrophy syndrome *(71)*, amyotrophic lateral sclerosis *(72)*, tetraplegy *(73)*, and Duchenne muscular dystrophy *(74)*.

Patients with noninsulin-dependent diabetes mellitus (NIDDM) and those with insulin-dependent diabetes mellitus (IDDM) may present an alteration of fat distribution that can result in premature cardiovascular risks *(75)*. It was shown that abdominal adiposity seems to be a strong marker and may be a major determinant of insulin resistance in overweight women *(23)* and that fat distribution becomes more abdominal with age and with menopause *(76,77)*. In a controlled study *(68)*, it was reported that patients with IDDM have significantly less total body and abdominal fat than those affected by NIDDM, irrespective of age and menopausal status. In postmenopausal patients with IDDM, total body fat and abdominal fat were lower than those found in normal subjects, whereas these were higher in premenopausal patients with NIDDM as compared to normal subjects.

AIDS is characterized by progressive weight loss and severe inanition. It was demonstrated that women lose significant lean body mass in the late stages of wasting. However, in contrast to men, women exhibit a progressive and disproportionate decrease in fat mass relative to lean mass at all stages of wasting, consistent with gender-specific effects in body composition in AIDS wasting *(69)*. A longitudinal study on changes in body composition in AIDS showed a reasonable agreement among DXA, TBW, BIA, and ST *(70)*. The authors demonstrate that weight loss is composed of a large proportion of lean mass compatible with undernutrition and do not support the hypothesis of excessive lean mass catabolism in such a disease, suggesting that this information should be considered in the design of future intervention studies for AIDS-related wasting.

Patients affected by reflex sympathetic dystrophy syndrome exhibited, before treatment, decreased lean and bone masses, and increased fat mass as compared to the unaffected limb after 1-yr treatment. In patients whose clinical manifestations had subsided, increased bone and lean masses were observed as well *(71)*.

Whole body DXA analysis has been shown to reliably detect body-composition changes in amyotrophic lateral sclerosis *(72)* and can be used to provide a basis for appropriate nutritional advice throughout disease progression.

An increase in lean mass with a concomitant decrease in fat mass was described in tetraplegic patients after 8 wk of electrically stimulated leg cycling *(73)*.

The patients, affected by Duchenne muscular dystrophy, exhibit total bone osteopenia and elevated body fat, owing not to obesity, but probably to fatty infiltration of skeletal muscles, known to occur in this disease. A significant correlation between muscle function and the percentage of regional variation of lean mass was also demonstrated *(74)*.

Conclusions

The advent of whole body DXA has allowed rapid, noninvasive bone measurements and body-composition estimates with low radiation exposure for many clinical applications. Regional and total body DXA have been of growing interest in different fields of medicine because it offers an interesting alternative to other time-honored reference methods mainly used by nutrition specialists. DXA is simple to perform, less dependent on operator skills and experience, highly reproducible, and widely available.

In the clinical management of patients affected by different chronic diseases, whole body DXA may provide further information about the natural history of the disease, and more importantly, may offer a noninvasive method for determining appropriate nutritional support during disease progression. It can also be used to evaluate and monitor the response to therapeutic interventions.

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