review article

Bone Density Testing in Clinical Practice

E. Michael Lewiecki
João Lindolfo C. Borges

New Mexico Clinical Research & Osteoporosis Center (EML), USA, and Universidade Católica de Brasília (JLCB), Brazil.

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ABSTRACT

The diagnosis of osteoporosis and monitoring of treatment is a challenge for physicians due to the large number of available tests and complexities of interpretation. Bone mineral density (BMD) testing is a non-invasive measurement to assess skeletal health. The "gold-standard" technology for diagnosis and monitoring is dual-energy X-ray absorptiometry (DXA) of the spine, hip, or forearm. Fracture risk can be predicted using DXA and other technologies at many skeletal sites. Despite guidelines for selecting patients for BMD testing and identifying those most likely to benefit from treatment, many patients are not being tested or receiving therapy. Even patients with very high risk of fracture, such as those on long-term glucocorticoid therapy or with prevalent fragility fractures, are often not managed appropriately. The optimal testing strategy varies according to local availability and affordability of BMD testing. The role of BMD testing to monitor therapy is still being defined, and interpretation of serial studies requires special attention to instrument calibration, acquisition technique, analysis, and precision assessment. BMD is usually reported as a T-score, the standard deviation variance of the patient's BMD compared to a normal young-adult reference population. BMD in postmenopausal women is classified as normal, osteopenia, or osteoporosis according to criteria established by the World Health Organization. Standardized methodologies are being developed to establish cost-effective intervention thresholds for pharmacological therapy based on T-score combined with clinical risk factors for fracture. **(Arq Bras Endocrinol Metab 2006;50/4:586-595)**

Keywords: Osteoporosis; BMD; Bone density testing; Bone mass measurement; DXA, Update; Controversy

RESUMO

Densitometria Óssea na Prática Clínica.
O diagnóstico e monitoração do tratamento da osteoporose é um desafio para os médicos devido ao grande número de testes disponíveis e a complexidades da interpretação. O exame da densidade mineral óssea é uma medida não-invasiva da avaliação da saúde esquelética. A tecnologia "padrão-ouro" para o diagnóstico e monitoração é a absorciometria por raios-X duo-energética (DXA) da coluna, quadril ou antebraço. O risco de fratura pode ser previsto usando DXA e outras tecnologias em vários sítios esqueléticos. Apesar das diretrizes para a medida de da DMO e identificação daqueles que mais provavelmente irão se beneficiar do tratamento, muitos pacientes não estão sendo testados ou recebendo tratamento. Mesmo pacientes com elevado risco de fratura, tais como aqueles em terapia de longo prazo com glicocorticóides, ou mesmo aqueles com fraturas por fragilidade prevalentes, quase nunca estão sendo conduzidos adequadamente. A estratégia diagnóstica ótima varia de acordo com a disponibilidade e acesso à medida da DMO. O papel da medida da DMO para monitorar terapia ainda está sendo definido, e a interpretação de estudos seriados requer

atenção para calibração instrumental, técnica de aquisição, análise e avaliação da precisão. A DMO é geralmente descrita como *T-score*, a variação do desvio-padrão da DMO da paciente pós-menopausa comparada com a DMO de uma população de referência adulta, jovem e normal, sendo classificada como normal, osteopenia ou osteoporose, de acordo com os critérios estabelecidos pela Organização Mundial de Saúde. Metodologias-padrão estão sendo desenvolvidas para estabelecer os custos-efetividade dos limiares de intervenção para terapia farmacológica baseado no *T-score* combinado com fatores clínicos de risco de fraturas. **(Arq Bras Endocrinol Metab 2006;50/4:586-595)**

Descritores: Osteoporose; DMO; Densitometria óssea; Medida da massa óssea; Atualização em DXA; Controvéria em DXA

OSTEOPOROSIS CAUSES NO SYMPTOMS until a fracture occurs. Osteoporosis or low BMD is estimated to occur in about 44 million American men and women, accounting for 55% of the population age 50 and over (1). The prevalence of this disease in Brazil is not known. Fractures of the spine and hip may result in chronic pain, deformity, depression, disability, and death. About 50% of patients with hip fractures will never be able to walk without assistance and 25% will require long-term care (2). The mortality rate five years after a fracture of the hip or a clinical vertebral fracture is about 20% greater than expected (3), with mortality rates higher for men than women (4). The direct cost of osteoporotic fractures in the USA was about $17 billion per year in 2001 (5). The Surgeon General's "Report on Bone Health and Osteoporosis" (6) and the National Osteoporosis Foundation's (NOF) "Physician's Guide to Prevention and Treatment of Osteoporosis" (7) identify osteoporosis as a major public health concern, and emphasize the importance of using bone mineral density (BMD) testing as a clinical tool to diagnose patients at high risk of fracture before the first fracture occurs. This review is intended to provide a simple resource to assist clinicians in the use of BMD testing for management of osteoporosis.

MEASUREMENT OF BMD

Instruments for measuring BMD can be classified according to the technology used, or the part of the skeleton evaluated. Dual-energy X-ray absorptiometry (DXA) instruments measure bone mineral density (BMD) at the spine and proximal femur. With appropriate software, many DXA instruments can also measure forearm BMD, total body BMD, and total body composition. DXA measures areal BMD (aBMD) in g/cm^2 by using ionizing radiation with photon beams of two different energy levels. The differences in attenuation of the beams passing through body tissues of variable composition allow the instrument to provide a quantitative measurement of bone density. Bone is composed of mineral, principally calcium hydroxyapatite, embedded in type I collagen and specialized proteins that make up the bone matrix. Bone mineral absorbs much more radiation than soft tissue. The amount of X-ray energy that is absorbed by bone mineral calcium in a section determines the measured bone mineral content (BMC). BMC divided by the area or volume of the bone estimates BMD. In laboratory studies, there is a high correlation (R^2= 0.4-0.9) between BMD and the force needed to break a bone (8,9). Other determinants of bone strength include size (larger bones are stronger), macroscopic structure (long bones with greater cross-sectional areas are more resistant to bending), microscopic structure (microscopic cracks and loss of normal trabecular architecture weaken a bone), and the composition of bone proteins (abnormal collagen weakens bones).

DXA is the preferred method for the diagnosis of osteoporosis and monitoring BMD changes over time. Biomechanical studies have shown a strong correlation between mechanical strength and BMD measured by DXA (9). Accuracy and precision of DXA are excellent (10). Radiation exposure with DXA is very low (11). In epidemiological studies there is a strong relationship between fracture risk and BMD measured by DXA (12). Most randomized clinical trials showing a benefit with drug therapy have selected subjects based on BMD measured by DXA (13). There is a relationship between decreases in fracture risk with drug therapy and increases in BMD measured by DXA (14). Finally, the World Health Organization (WHO) diagnostic classification of BMD is based primarily on reference data obtained by DXA (15), and does not apply to other technologies for measuring BMD.

Quantitative computed tomography (QCT) measures volumetric BMD (vBMD) in mg/cm^3 with special software in a standard CT machine. QCT is able to distinguish between cortical and trabecular bone compartments, and can measure BMD at the spine and hip. Accuracy and precision with QCT are not as good as with DXA (16). QCT may be used to monitor BMD of the spine in patients who have marked structural changes in the posterior elements of

the spine, such osteoarthritis. It can also be used to assess the risk of fracture (17), although issues of cost, accessibility, and radiation exposure render it less attractive than other technologies used for this purpose. The primary role of QCT is for clinical research to evaluate bone structure, bone size, and changes in cortical and trabecular bone compartments that occur with drug therapy.

Conventional X-ray techniques are insensitive and subjective in the evaluation of bone density at any skeletal site, requiring 30-40% bone loss before a problem is detected. The best use of X-ray in the management of osteoporosis is to diagnose fractures, monitor the healing of fractures, and evaluate for skeletal disorders that alter the radiographic appearance of bone (e.g., multiple myeloma, osteomalacia). If an X-ray is suggestive of low bone density, a quantitative measurement of BMD by DXA is recommended.

BMD testing at peripheral skeletal sites, such as the calcaneus, forearm, finger, or tibia, can be done with technologies that include peripheral dual-energy X-ray absorptiometry (pDXA), peripheral quantitative computed tomography (pQCT), and quantitative ultrasound (QUS). The technologies for pDXA and pQCT are the same as DXA and QCT, respectively, with appropriate adaptation for smaller dedicated instruments. BMD at the finger can also be measured by radiographic absorptiometry (RA), a technique using a conventional X-ray machine in combination with a standardized aluminum wedge to obtain a quantitative measurement. Peripheral devices are generally accurate and precise. The lower the BMD or QUS parameter with a peripheral device, the greater the risk of fracture. A low or borderline low measurement should trigger consideration of measuring BMD at the central skeleton by DXA to establish a diagnostic classification, determine the need for pharmacological therapy, and serve as a baseline for monitoring the effects of therapy. While peripheral skeletal sites may potentially play a role in monitoring the BMD response to anabolic therapy, clinical applications have not yet been defined. The WHO classification of BMD for diagnosis should not be applied to T-scores measured with technologies other than DXA, or at skeletal sites other than the spine, hip, or mid-forearm, because of T-score discordance and lack of large population studies to determine device-specific prevalence and fracture risk (18,19). Peripheral skeletal sites should not be used to monitor the effects of antiresorptive therapy, since the rate of change in BMD and ultrasound parameters is generally too small to be clinically useful (18). The acquisition, analysis, and interpretation of BMD tests require training, experience, and continuing education to keep up with advances in the field. BMD studies that are improperly performed or interpreted may lead to inappropriate patient management decisions.

INDICATIONS FOR BMD TESTING

BMD testing should be considered for anyone at risk for fracture, provided the results are likely to influence patient management decisions. Initial BMD testing can confirm a clinical suspicion of high fracture risk, establish diagnostic classification, estimate fracture risk, and serve as a baseline for monitoring BMD changes over time. Serial BMD tests showing a change or stability of BMD may provide helpful clinical information, assuming the comparisons are technically valid and the clinician is knowledgeable regarding clinical implications. Many organizations have published guidelines or evidence-based reviews on the indications for BMD testing, including the American Association of Clinical Endocrinologists (20), International Society for Clinical Densitometry (ISCD) (21), North American Menopause Society (22), National Institutes of Health (23), National Osteoporosis Foundation (7), United States Preventive Services Task Force (24) and the Brazilian Society for Clinical Densitometry (SBDens) (25). These guidelines vary according to the populations addressed, clinical risk factors considered, definition of fragility fracture, methodologies used, and weighting of levels of medical evidence vs. expert opinion. Although clinical risk factors are often used to select patients for BMD testing, they are not a substitute for a BMD test, and in fact cannot accurately predict which individual patients have low bone density (26). Of all the published guidelines, those of the ISCD (table 1) are the most comprehensive.

DIAGNOSIS OF OSTEOPOROSIS

DXA BMD results are usually reported as standardized values called T-scores and Z-scores. Both of these rely on the standard deviation (SD) variability or the patient's BMD compared to the mean BMD of a reference population. BMD ranging from the 5th to the 95th percentile of a population covers about 4 SDs. SDs varies according to technique and the reference population used to define normal values. For hip and spine BMD, 1.0 SD corresponds to about 10% of the mean value for the reference population.

Table 1. ISCD indications for bone density testing (21).

Women aged 65 years and older.
Postmenopausal women under age 65 years with risk factors for osteoporosis.
Men aged 70 years and older.
Adults with fragility fracture.
Adults with a disease or condition associated with low bone mass or bone loss.
Adults taking medication associated with low bone mass or bone loss.
Anyone being considered for pharmacological osteoporosis therapy.
Anyone being treated for low bone mass to monitor treatment effect.
Anyone not receiving therapy in whom evidence of bone loss would lead to treatment.
Women discontinuing estrogen should be considered for bone density testing according to the indications listed above.

A Z-score is the number of SDs below or above the mean BMD value for people of the same age. A Z-score of 0.0 means that the patient has a value that is exactly at the mean for age. A Z-score of -2.0 means that the patient has a BMD at that skeletal site, by that method of measurement that is 2.0 SDs below the mean BMD value of others the same age. A low Z-score (< -2.0 or -3.0) has been suggested by some as a determinant for proceeding with additional evaluation for secondary causes of osteoporosis. While this approach seems intuitive, there is no evidence to validate it. Low BMD of any magnitude may be associated with contributing factors other than hormone deficiency and aging.

A T-score is the number of SDs below the mean BMD for young-adults (usually 20 to 40-year-old). A T-score of 0.0 means that the patient has a BMD value that is the same as the mean BMD for the young-adult reference population. A T-score of -2.5 means that the patient has a BMD value at that skeletal site and by that method of measurement that is 2.5 SDs below the mean BMD of the young-adult reference population. Since BMD declines with age, T-scores are consistently lower than Z-scores in patients over the age of 40 years, with the difference increasing with advancing age. For example, a 70-year-old patient who has a Z-score of +1.0 at the hip (above average for women of the same age) will have a T-score of about -0.8 (below average compared with young women).

The WHO classification of BMD into categories of normal, osteopenia, osteoporosis, and severe osteoporosis (table 2) has been widely used since its introduction in 1994 (15). This classification has been very successful at increasing public awareness of osteoporosis and has provided a method for clinicians to diagnose osteoporosis before the first fragility fracture occurred. The WHO classification is based on the T-score, which is calculated according to the following equation, with BMD values expressed as g/cm^2.

$$\text{T-score} = \frac{(\text{Patient's BMD}) - (\text{Mean Young-Adult BMD})}{(1\ \text{SD of Young-Adult BMD})}$$

This equation shows that differences in the young-adult reference population can alter the T-score, even when the patient's BMD is the same. The absence of a generally recognized standard reference population, expect perhaps for the National Health and Nutrition Examination Survey III (NHANES III) for the hip (27), is in part responsible for discordance of T-scores measured with instruments made by different manufacturers, using different skeletal sites, in different world regions. The WHO did not specify which skeletal sites and regions of interest (ROI) should be measured, which technologies can be used to obtain the measurement, which reference populations are appropriate, or how the classification applies to those who are not postmenopausal Caucasian women. Given that these issues have a profound effect on the clinical applications of bone densitometry, the ISCD and SBDens periodically convene position development conferences to consider the medical evidence and make recommendations for patient care. The topics selected for consideration are often chosen because there is no overwhelming medical evidence, yet guidance for clinical practice is needed. The methodology for establishing the Official Positions of the ISCD is reviewed elsewhere (28). The ISCD recommends that patients having DXA studies be routinely measured at the lumbar spine and hip, and at the non-dominant forearm if indicated (e.g., obesity exceeding weight limit of table, hyperparathyroidism, or if spine or hip are not valid sites for measuring BMD) (19). The lowest T-score of the lumbar spine, total proximal femur, femoral neck, or 33% radius (one-third radius), if measured, should be used for diagnostic classification. The preferred lumbar spine ROI is L1-L4. One or two vertebral bodies may be excluded from analysis if there are structural abnormalities that invalidate BMD measurement. Either hip may be measured, since discordance according to side

Table 2. World Health Organization classification of Bone Mineral Density (15).

Classification	T-score
Normal	-1.0 or greater
Osteopenia	Between -1.0 and -2.5
Osteoporosis	-2.5 or less
Severe Osteoporosis	-2.5 or less with a fragility fracture

is usually small (29). The lateral spine, Ward's area of the hip, peripheral skeletal sites, and other forearm ROIs should not be used for diagnostic classification because they were not considered by the WHO. The ISCD recommends that the WHO classification for diagnosis of osteoporosis be applied to postmenopausal women of all ethnicities and to men age 65 and older (30). Densitometric criteria alone should not be used to diagnose osteoporosis in premenopausal women, men under age 50, and children. In children, Z-scores, not T-scores, should be used, since it is not appropriate to compare the BMD of a growing child to an adult, and the relationship between BMD and fracture risk in children is not clear. While diagnostic classification with T-scores is useful for population studies and has greatly improved patient care, additional parameters of bone strength should be considered to estimate the risk of fracture and determine the need for pharmacological therapy.

PREDICTION OF FRACTURE RISK

The relationship between BMD and fracture risk is conventionally quantified by the relative risk (RR) per SD (RR/SD), which is the increase in risk associated with a 1.0 SD decrease in the BMD measurement. For example, an RR/SD of 1.4 means that fracture risk increases by 40% for each 1.0 SD decrease in BMD. A larger RR/SD implies a stronger predictive value of BMD for fracture risk. Factors other than BMD also determine fracture risk. Non-BMD skeletal factors that may be associated with bone strength include bone turnover (31), architecture (size and shape, or bone geometry) (32,33), microarchitecture (e.g., trabecular number, thickness, perforation, and connectivity; cortical porosity) (34,35), damage accumulation (36), matrix properties (37), mineralization (38), and crystal characteristics (39). With the exception of bone turnover and architecture, none of these are measurable in clinical practice. BMD testing, on the other hand, is widely available and well correlated with fracture risk (12). Non-skeletal risk factors for fracture, such as frailty and falls, can be easily evaluated in the office setting (40). Some risk factors are mediated in both skeletal and non-skeletal ways. For example, advancing age is associated with loss of BMD and with increasing frailty and falls. Vitamin D deficiency can cause loss of BMD as well as loss of muscle strength, increased body sway, and falling (41). Many clinical risk factors for hip fracture have been identified, including personal history of any type of fracture over age 50, maternal history of hip fracture, self-rated fair or poor health, and difficulty rising from a chair (42). The best validated risk factors for vertebral fractures are low BMD, advanced age, and previous fracture of any type (43).

Although RR or RR/SD is a convenient way of reporting the results of observational studies and clinical trials, a high RR does not necessarily indicate a high probability of fracture. For example, a 50 year-old woman and an 80 year-woman with the same hip T-score of -2.5 have the same relative risk for hip fracture (17.6, comparing each patient to an age-matched population with T-score= 0.0, assuming that relative risk increases by 2.6 for each SD decrease in BMD) (12), yet the 10-year probability of hip fracture is 10 times higher in the older woman (19.4% compared to 1.9%, based on Swedish population data) (44). Expressing fracture risk as the probability of osteoporotic fracture over a specified period of time is more clinically useful than RR, providing clinicians with a better tool for managing patients.

INTERVENTION THRESHOLDS FOR TREATMENT

Most current treatment guidelines rely on the use of T-score plus risk factors for fracture. In general, treatment is recommended when the T-score is below -2.5 or -2.0, or when the T-score is higher and risk factors are present or a fragility fracture has occurred. Guidelines differ in the populations addressed, T-score cutoffs used, and risk factors that are identified. Methodologies that calculate cost-effective intervention thresholds based on fracture probability and numerous economic/disutility assumptions may eventually replace treatment recommendations that are currently

in use. The NOF (45) and WHO (46) have published models for applying cost utility analysis to a combination of BMD and clinical risk factors for fracture to establish cost-effective thresholds for pharmacological therapy. Application of such models to clinical practice would allow physicians to more effectively target patients most likely to benefit from pharmacological therapy and help to close the treatment gap — the difference between the number of patients who could benefit from treatment and those who are treated. Validation of modifiable risk factors that are independent of BMD and application of country-specific economic assumptions will allow this methodology to be adapted to a wide range of circumstances. Cost-effectiveness is one of many considerations for clinicians making management decisions in individual patients.

MONITORING CHANGES IN BMD

When comparing DXA studies, great care must be taken to assure that the comparison is valid and that an apparent difference is a real biological change, not a measurement error. Comparison of measurements made with different instruments, especially ones made by different manufacturers, should not be made due to variable technologies used to generate and detect the dual photon beam, different edge detection algorithms, different ROIs, and variable mathematical assumptions on body thickness and composition. Visual assessment of the skeletal image is necessary to determine that 1. positioning is comparable, 2. no artifact is present, 3. the same sides are being compared for hip and forearm, 4. labeling of the lumbar spine vertebral levels is the same, and 5. marked bone edges are similar. The measured areas (cm^2) of compared ROIs should be very similar. Absolute BMD and not T-scores should be compared, since T-scores values may change due to changes in reference databases, which may occur without the awareness in the interpreter due to upgrades of the software. In order to distinguish the likelihood that a true biological change in BMD has occurred and not an error that is inherent in the measurement itself, a "precision assessment" must be performed. This is done according to established methods (47), whereby at least 15 patients have BMD measured there times each, or 30 patients have BMD measured two times each, with subsequent calculation of the precision error and least significant change (LSC) with a 95% level of confidence. A change in BMD that equals or exceeds the LSC is considered to be statistically significant (48). A loss of BMD on pharmacological therapy is cause for clinical concern, suggesting the possibility of poor adherence to therapy, inadequate calcium or vitamin D intake, intestinal malabsorption, or other disease process not previously recognized (49). An increase or stabilization of BMD is associated with reduction in fracture risk (14), although other parameters of bone strength, particularly changes in bone turnover markers (50), are correlated with changes in fracture risk as well. Patients started on pharmacological therapy are often retested in 1-2 years in order to determine that there has been no loss of BMD, and retested at longer intervals once response to therapy has been shown. Patients at very high risk for bone loss, such as those on glucocorticoid therapy, may need to be tested as often as every 6 months, until stability of bone mass has been demonstrated.

DXA REPORTING

The quality and clinical utility of DXA reports generated by bone densitometry facilities is variable. To address this issue, the ISCD has recommendations for the minimum components of a DXA report (21). These include identifying the manufacturer and model of the instrument, scan mode, patient name and demographics (date of birth, sex, medical record number), referring provider, indication(s)/risk factors, comment on technical quality and limitations of the test, skeletal site (with side if appropriate) and ROI measured, BMD results in g/cm^2, T-score and Z-score (when appropriate), WHO diagnostic classification (when appropriate), a statement about fracture risk, and recommendations regarding the necessity and timing of a repeat study, if indicated. A follow-up study should identify the comparator study (location, date, manufacturer, model), the validity of the comparison, the change in BMD in g/cm^2 and percent if it equals or exceeds the LSC (based on measurement of precision and calculation of the LSC at a 95% level of confidence), or a comment that there is no significant change (stability of BMD) if the difference in BMD is less than the LSC.

NOMENCLATURE

As the field of bone densitometry has evolved, different terms, acronyms, and methods of expressing data have developed. In order to facilitate communication of research data and clinical information, the ISCD has

made recommendations for standardization of nomenclature (51). These include using DXA (not DEXA), T-score (not T score, t-score, t score, or italics with any of these), Z-score (not Z score, z-score, z score, or italics with any of these), expressing T-scores and Z-scores with one decimal place (e.g., -2.3, not -2 or -2.34), and BMD with three decimal places (e.g., 0.846 g/cm^2, not 0.85 or 0.8472 g/cm^2).

BODY COMPOSITION BY DXA

DXA is unquestionably the method of choice for the assessment of bone mass. Recent generations of DXA instruments also have the capability of assessing soft tissue mass, thereby providing a three-compartment model of body composition, i.e., bone mineral, fat, and bone-free lean masses. Although hydrodensitometry has long been considered the reference method of assessing body composition, assumptions regarding the constancy of the constituents of fat-free mass may compromise its validity in some populations. Because DXA appears to be less dependent on assumptions regarding biological consistency, it has the potential to provide a more accurate assessment of body composition across populations than dose hydrodensitometry, and therefore is widely considered to be the reference method. DXA has been shown to provide precise measures of body composition. Many disease processes affect bone and soft tissue at the same time. The comprehensive view of body composition provided by whole body DXA makes it an attractive technique for a variety of clinical research and practice applications (52), as listed in table 3. A model disease for the use of body composition testing is the Metabolic Syndrome, a cluster of metabolic abnormalities related to a state of insulin resistance which is often associated with a high-risk overweight/obesity phenotype. Because such cluster increases the risk of coronary heart disease (CHD) and type 2 diabetes. Numerous consensus groups have attempted to provide recommendations to identify in clinical practice patients with these atherogenic/diabetogenic metabolic abnormalities. Although there has been a proliferation of scientific papers and conferences on the Metabolic Syndrome, the ideal body composition is still not well understood. Hendel et al. investigated the relationships between body composition by DXA, fat distribution, sex hormone, and other cardiovascular risk factors in overweight postmenopausal women (53). Androgenicity, cigarette smoking, and alcohol consumption and age correlate independently and positively with a central fat distribution (figure 1). 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 (54). 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. studied obese and overweight women and men, using DXA to evaluate abdominal fat and CT to evaluate subcutaneous abdominal fat (55). 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 (56). Therefore, DXA is a practical, widely available and precise tool for the measurement of body composition.

Table 3. Clinical applications of whole body DXA in adults.

1. Nutritional disorders
Obesity
Metabolic Syndrome
Overweight
Anorexia nervosa
2. Gastrointestinal disorders
Crohn'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
Hyperthyroidism
6. Bone disorders
Osteoporosis
Paget's disease
Osteopetrosis
7. Pulmonary diseases
COPD
Fibrosis cystic
8. Drugs and substances
Glucocorticoids
Hormones
Parenteral nutrition
9. Other disorders
Diabetes
AIDS
Sympathetic dystrophy syndrome
Amyotrophic lateral sclerosis
Tetraplegy
Duchenne muscular dystrophy

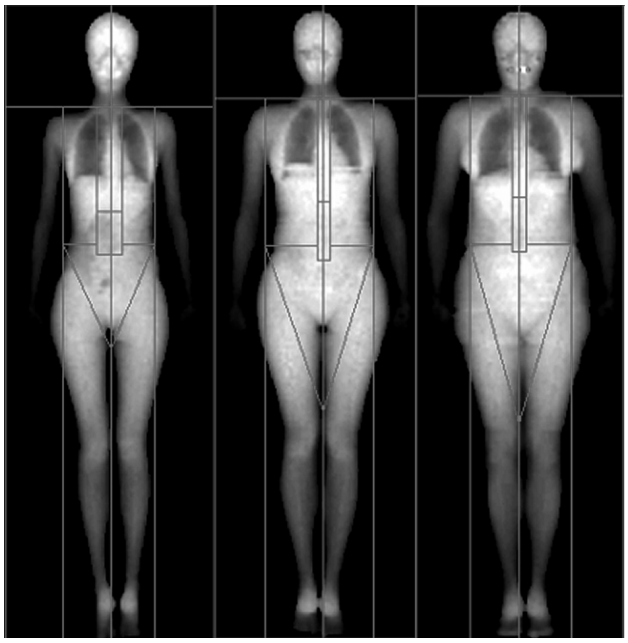

Figure 1. Changes in abdominal (central) fat can be seen and measured using total body bone densitometry. This figure shows the scan of three Caucasian females (ages 12, 21, and 42).

CONCLUSIONS

BMD testing is a clinical tool that can diagnose osteoporosis or low BMD before the first fracture occurs. Combining BMD with clinical risk factors for fracture provides a better assessment of fracture risk than BMD or clinical risk factors alone. Selection of patients for treatment should be based on fracture risk. Methodologies are emerging for setting intervention thresholds based on the probability of fracture and cost-effectiveness models. The acquisition, analysis, and interpretation of BMD tests require trained and skilled staff. Precision assessment according to established protocols is necessary to determine whether significant changes in BMD have occurred over time. 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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Address for correspondence:

E. Michael Lewiecki
New Mexico Clinical Research & Osteoporosis Center
300 Oak St. NE, Albuquerque, New Mexico 87106
USA
Fax: 505-884-4006
E-mail: lewiecki@aol.com