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Review Article

The role of the Radiology Technologist in the assessment of DXA unit precision error and Least Significant Change/LSC

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Abstract

Osteoporosis is the most frequent bone disease, and it is considered to be a major burden for public health. Current trends show that osteoporosis rates increase all around the world, proving that osteoporosis is becoming a global socio-economic problem. Dual-energy X-ray absorptiometry (DXA) is an established method for the diagnosis of osteoporosis, treatment monitoring, and fracture risk assessment. Recent advances in DXA technologies have improved the accuracy and repeatability of the measurements and results of this method. However, there is a chance of BMD measurement and interpretation errors that may result in a non-accurate diagnosis or even inappropriate management of the patients. The errors that may happen in the installation and maintenance of the equipment involved in the examination, as well as the inadequate knowledge and lack of experience of the Radiology Technologist are considered as malpractice and may lead to misdiagnosis. This study aims to highlight the role of the radiologic technologist in the detection of the least significant change (LSC) in the DXA method, as well as the identification of possible errors in this diagnostic examination, to improve the quality and accuracy of diagnosis and provide better guidance of the patients.

Keywords: Dual-energy X-ray absorptiometry, DXA method, minimal significant change, Osteoporosis, Radiologic technologists

Introduction

The Role of Radiology Technologist

Radiology Technologists (RT) have a key role in terms of the accuracy of all imaging procedures, as the RT holds the main position in the Radiology department. RTs organize the workplace, plan, conduct and evaluate radiological processes according to defined competencies, ensuring the quality of radiological procedures provided and the patient's and other individuals' safety[1]. High level of knowledge of anatomy and physiology of the human body It is more than a necessity for the RTs, while they should have general and specialized knowledge on certain pathologies and clinical conditions. In addition, RT should be able to perfectly handle technologies included in medical imaging, as well as the new software, knowledge which should be upgraded according to the advances in the field. As there are several protocols and different imaging methods, RT should be familiar with these but also get expertise in certain imaging fields. As a member of the multidisciplinary team, RT should be able to make decisions and evaluate the imaging parameters based on the patient's needs, thus optimizing the imaging results.

Of course, one of the main points where the RT is involved in his duties is the accuracy of the diagnostic examination, according to which all the RT should proceed to any imaging. There is a thin line between accurate imaging results and minimal radiation dose, which requires high skill in radiographic technique. RTs are required to use their abilities

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to produce a quality image with a single exposure. Otherwise, repeating the examination process to get safe results or a clear image may involve the patient in unnecessary radiation, while the additional cost of the examination to the department and the health system chain may be a burden[2,3].

For the abovementioned reasons, RT coordinators have a dual mission, provide a high level of service along with sustainable solutions through providing maximum effectiveness of care and productivity of the staff involved. Global socio-economic recession and the rates of reimbursement have brought up the need for better management of the health cost-outcome rate, whilst the radiology departments have been affected as well. There is evidence that advanced technologies can minimize the cost and increase the quality of the radiology department[4,5].

Osteoporosis and Osteopenia

Bone remodeling is a function that occurs during the whole lifespan of the human body. However, this balance is not always stable. In childhood and adolescence osteoblastic formation predominates and, thus, a progressive increase in bone mass occurs. This increase reaches its peak value at the age of 20 years approximately[6]. Noteworthy, if an adult does not reach the maximum bone mass (peak bone mass) in adolescence, then he is at risk of developing osteoporosis, regardless of the other risk factors. Among adults of both sexes, around the age of 40 and beyond, we have a normal gradual loss of bone mass. 2% is estimated as the normal rate of bone loss per year[7]. This explains why age is a major risk factor for osteoporosis. The acceleration of the rate of bone loss from any factor intensifies the progressive weakening of the bones and may lead to osteopenia and, finally, osteoporosis[8,9].

Osteopenia by itself does not appear with obvious signs and symptoms, whilst osteoporosis is. The reduced bone density in osteoporosis affects bone strength from the mechanical perspective, making the human skeleton prone to fracture. In the development of osteoporosis, there is often a long latent period before the appearance of the main clinical event, pathological fractures. The first symptom of osteoporosis is frequently an episode of acute back pain, usually caused by a vertebral fracture. Patients often report groin or thigh pain, which after the examination is proved to occur by a hip fracture. To make the correct medical diagnosis, the evaluation of the extent and severity of bone loss is needed, while secondary forms of bone loss should be excluded. The correct diagnosis arises out of a combination of medical history, examination, laboratory tests, and measurement of bone density via Dual-energy X-ray Absorptiometry[10].

Osteoporosis is classified as primary, secondary, and idiopathic. Primary osteoporosis is asymptomatic, fractures are caused by small wounds located on the vertebrae of the neck, the intertrochanteric region of the femur, and at the distal end of the bone[7]. Primary osteoporosis includes the osteoporosis that occurs after menopause and osteoporosis of old age[11].

Secondary osteoporosis occurs in cases of various diseases, such as incomplete bone genesis, mucopolysaccharidosis, sickle cell anemia, thalassemia, hemophilia, gonadal dysgenesis, Klinefelter syndrome, Turner syndrome, Gauser disease, Cystic fibrosis, syndrome Ehlers Danlos, Menke Osteoporosis Imperfecta (imperfect genesis), RileyDay[12]. It may also occur in the case of a wide variety of neoplasms, including lymphoma, leukemia, metastatic disease, and multiple myeloma. In other cases, secondary osteoporosis may be caused by deficiency factors, caused by scurvy, malnutrition, malabsorption syndrome, anorexia nervosa, protein deficiency, and alcoholism. Other cases of secondary osteoporosis include biochemical collagen disorders, such as osteogenesis imperfecta, Marfan syndrome (genetic abnormality in genes), or endocrine disorders, such as hyperthyroidism, Diabetes Mellitus Type 1, hypogonadism, hyperparathyroidism, Cushing's disease (increased cortisol production). Finally, certain types of medicines may lead to secondary osteoporosis, including thyroid hormone replacement, long-term treatment with corticoids, anti-elliptic therapy, chemotherapy that is used for transplants, furosemide, heparin, antacids with aluminum, anticonvulsants, antipsychotics, anti retrogrades[13]. In terms of classification, immobility osteoporosis is also considered as secondary osteoporosis and it is caused due to immobility of patients due to bone fractures or due to bone atrophy. This type of osteoporosis may be short and mainly occurs in the hip joint. Other important causes of secondary osteoporosis include hypogonadal diseases, such as anorexia nervosa, hyperprolactinemia, premature menopause, androgen insensitivity, and Turner and Klinefelter syndrome[12]. As it was previously referred to, malnutrition and deficiency of certain vitamins or electrolytes may lead to osteoporosis. These include the lack of magnesium, calcium, or hypoproteinemia.

Idiopathic osteoporosis mainly occurs in adolescent boys or girls and adult men of 60 to 70 years old or women of approximately 55 to 75 years old. This type of osteoporosis has a short time stay and there isn't any identified underlying pathology linked to the disease[14]. Genes are extremely important in the creation of osteoporosis. Studies show that bone mass, bone circumference, and skeleton geometry are inherited by the ancestors of each patient.

In general, osteoporosis is considered a polygenic syndrome. Studies have shown that environmental factors and numerous genes contribute to fractures and the occurrence of significant bone mass loss[15]. Genetics holds a major role in osteoporosis pathogenesis. Genes whose mutations may be related to osteoporosis fall into four groups: The gene of the vitamin D receptor. Defective synthesis of vitamin D leads to impairment of bone calcification, while genes that are related and active in bones like estrogen may also have a significant role in bone mass decrease. Osteoclasts, thus the cells that contribute to the destruction of the bone may also be affected by some defective genes and genes that relate to their receptors. Finally, the genes that help in the synthesis of collagen type I of the bones and cause serious problems such as osteopenia in pediatric patients may be the reason for skeletal development[17].

Dual-energy X-ray

Absorptiometry Dual-energy X-ray Absorptiometry (DXA) is the imaging method that is based on the quantitative assessment propagation of X-rays as they pass through the human body tissues at two different energy levels. X-ray energy is differentially attenuated (absorbed or reflected) by anatomical structures, depending on the intensity of the energy and the density and thickness of the human tissues[17]. The DXA method is the gold standard for diagnosis of osteoporosis and the assessment of bone density (bone mineral density – BMD) is performed in the lumbar spine and the proximal part of the femur, according to World Health Organization (WHO) recommendations. DXA results are also associated with the risk of fracture occurrence and the efficacy of the anti-osteoporotic treatment. At a molecular level, DXA is the reference method for the analysis of body mass composition based on a model of three parameters: fat mass (FM), muscle mass (lean mass - LM), and bone mass (body mineral content –BMC)[16]. This model makes DXA an excellent imaging method for the evaluation of mixed forms of osteoporosis and sarcopenia.

Advances in image quality and resolution of DXA, as well as in the time required to perform the examination, have extended the utility of DXA in other clinical applications as well. Bone quality can be evaluated through indirect analysis of bone micro- and macro-architecture, resulting in better estimation of fracture risk. Also, DXA can identify existing fractures, such as vertebral and atypical femoral fractures, without additional imaging exams and radiation burden. The metabolic state of the organism can also be assessed indirectly by measuring body mass composition, and, lastly, DXA can calculate the intramuscular fat, which reflects the sarcopenia state[18].

The DXA unit consists of a mobile X-ray source, an examination bed, and a detection system that detects the radiation after it passes through the patient's body. The X-ray probe is located below the examination bed and runs simultaneously with the detection system, which is mounted above the test bed and the examinee's body. A DXA X-ray beam is composed of two different photon energies (continuous and pulsed). The use of rays with discrete photon energies is preferred due to the differences in the coefficient's absorption of the mineralized bone and soft tissues[19]. X-ray attenuation decreases conversely to the photons' energy. Measurements provided result from the equation bone mineral/bone mass divided by the surface area (in square centimeters). BMD is measured in grams per square centimeter and it is significantly influenced by bone size. A specific computing algorithm is applied to calculate bone density - soft tissue absorption values are erased and bone resorption values remain[19].

BMD is expressed as standard deviation (T-score and Z-score). The T-score refers to the difference between the BMD examined and the average of a fixed population of young adults (20-30 years old) and refers to the maximum bone mass. The Z-score shows the difference between the patient's BMD and the average BMD of people of the same age and the same sex. DXA results are presented as numerical values for T-score and Z-score and as a graph that depicts these values concerning age and gender. According to WHO, a T-score value >-1 is considered normal, a value between <-1 and >-2.5 is considered indicative of osteopenia, and values <-2.5 are indicative of osteoporosis. This definition is valid when DXA measurements concern the lumbar spine, proximal femur, and forearm[20].

According to the International Society of Clinical Densitometry (International Society of Clinical Densitometry – ISCD), all the results should be interpreted in relation to total body weight, body mass index (BMI), bone mineral density (BMD), bone mass content (BMC), total mass, total muscle mass (LM), total fat mass (FM) and percent fat mass. Reports may also include fat and muscle mass, muscle mass index (LMI – total muscle mass to the square of height), the muscle mass of the limbs (ALM – LM upper limbs + lower limb LM), limb muscle mass index (ALMI – muscle mass of limbs to height squared), skeletal muscle mass index (SMI - ALM to the square of the height), visceral adipose tissue (VAT), male/female body fat percentage ratio, the ratio of fat mass to limb fat mass and the index fat mass (FMI – fat mass to the square of the height)[17].

There is a variety of DXA devices (bone densitometers) depending on the x-ray beam type they use. The pencil beam bone densitometer refers to a single X-ray beam and a single detector. These are considered reference methods because of their accuracy. However, the major disadvantage of this method is that is very time-consuming, as a single beam needs to scan the entire examination area. Recently, fan-beam DXA devices were introduced to the clinical practice, so the X-rays are picked up by multiple detectors that scan along the body surface. Modern systems use wider beams of radiation and have succeeded in faster scanning (about 3-5 minutes per area), better image quality, and spatial resolution of 0.5-0.7 mm. On the other hand, some disadvantages need to be referred to at this point: a minimum image distortion exists due to tissue enlargement in combination with greater exposure of the patient to radiation. The third-generation DXAs include narrow-angle fan beams. The narrow-angle results in multiple images. DXA examination is prone to a variety of standard errors (SE), which are classified as technical errors (incorrect positioning of the patient and errors in image processing) as well as errors due to biological diversity (hydration status affected by exercise and diet of the patient), which should be taken into account during the examination process[17]. Accuracy is more than important for this technique, as the minimum change in measurements can lead to misinterpretation. On the other hand, there are normal changes in BMD through age. The least significant change (LSC), as it is reported in the literature, represents the minor differences between successive measurements that can be attributed to normal changes[20,21].

Materials and Methods

This study aims in highlighting the importance of the radiology technologist's role in the diagnosis of osteoporosis or osteopenia through the detection of the least significant change (LSC) in the DXA method, as well as the identification of possible errors in this diagnostic testing. With adequate knowledge level and expertise, the radiology technologist may provide a better quality of service and higher accuracy of the diagnosis for the patient, while he may provide them with better guidance in their diagnostic process.

This study is a literature review based on the latest data provided from studies from all over the world, published in peer-reviewed journals. To complete this study with the minimum possible bias, the research team conducted a predefined search on electronic medical databases and literature index, including MEDLINE through PubMed, Scopus, Web of Science, Google Scholar, and Cochrane Library. Books related to the subject were also used to extract information. Finally, a search was also conducted in reference lists of related articles.

Specific predefined criteria and filters were applied to the results of this extensive search to limit the results the research team needed to go through. Only studies published in English or Greek language were included in this study so that the full text would be completely comprehended by the researchers. This study included only data that refer to RT and their duties, unrelated to the country of origin of the original study.

Results

Accuracy and Standard Error in DXA

As it has already been mentioned RT holds a key role in image quality and accuracy. The importance of high-level DXA image quality lies in the fact that the accuracy and reliability of the examination should be the maximum possible so that even the smallest changes in BMD can be detected. The first step is the performance of proper quality control, which is held by the RT. Quality test not only ensures the repeatability and accuracy of the measurement but safeguards the lifetime of the equipment and DXA device. The recommendation suggests that quality control tests should be done daily before examining any routine patient. During this procedure, a specific spinal model is used, containing the vertebrae (L1-L4). The model has specific reference values for BMD, and BMC but also T-score and Z-score values. Consequently, if the DXA measurements are within an expected range of reference, a quality control test is accepted[22]. Necessary parameters in quality control testing include the selection of the proper spinal model, which is usually recommended by the manufacturer, the baseline BMD settings, and the intra-system LSC settings. According to the ISCD recommendation, the BMD baseline is the measurement of reference model BMD, which is measured 20 times under the same conditions $\pm 1.5\%$. RT should be considered for cross-calibration when the device is replaced or the RT manages two or more devices at the same time[23].

The second step for the accuracy of the procedure refers to the strict implementation of the recommendations. Standardized examination protocols, firstly, suggest that the patient should be undressed, as clothing accessories, such as zips, metallic buttons etc, may attenuate the X-ray beam and create errors in the test measurement[24]. Then, the patient lies in the center of the examination bed, using its centerline as a baseline for accurate alignment. The cervical spine should be in a neutral position, avoiding any excessive flexion or extension and RT should consider patients' height. If the patient is too tall, he/she can be positioned in a position where the legs are included in the scan, while the head is not. However, it is necessary to include the lower jaw in the scanning area, since the lower line separating the head area is a reference point for defining the rest of the regions of interest (in whole body examination). Alternatively, the examination could be performed with bent knees or two separate tests should be held and combined. In some cases where the patient's body is too wide, a way to include the whole body is to place the arms vertically on the machine. If it still does not fit the patient's body, it can scan half the body and assess the composition of the body part which receives the X-ray beam, assuming that there is symmetry (called "half-body analysis", in body mass composition analysis examination)[17,24]. It has been shown that food intake before the examination can cause an increase in total body muscle mass. Also, physical exercise or intense activity can affect the reliability of DXA, due to changes in body fluid compartments, as it is defined by dehydration or increased blood flow and capillary dilation. Physical exercise can cause body muscle mass reduction (due to dehydration) and muscle mass increase (due to an increase in blood distribution to the extremities caused by exercise). In addition, the dehydration state may be affected by ambient temperature and water consumption, thus the estimation of the mass composition body is also affected. The standardization of the methodology (fasting patient, rested, hydrated, placed in a suitable position, and with suitable scan parameters) is necessary to obtain optimal measurements, which will be repeatable and allow safe detection of small but potentially significant changes in the test[17,25].

Common patient positioning errors include the incorrect placement of the lumbar spine in the center of the bed and the abduction or outward rotation of the hip. Common analysis errors in the lumbar spine are usually related to the incorrect numbering of the lumbar vertebrae, the placement of intervertebral markers, and the detection of bone boundaries. Analysis errors in the hip are associated with incorrect positioning of regions of interest and bone boundary detection. Common anatomic technical errors in DXA originate from degenerative lumbar lesions, compression fractures, postoperative lesions, and disseminated atheromatous calcified lesions.

In addition, some technical errors may come from medical devices, such as stents or inferior vena cava filters, contrast enhancement from the gastrointestinal system, vertebroplasty material, and external objects, such as metal buttons, bra clips, or piercings. Anatomically technical errors in the hip area include osteoarthritic alterations and heterotopic ossification, while various objects (such as coins or keys) may be found in the examinee's pockets.

Finally, the kinetics technical errors (due to the movement of the patient during examination) cause blurring of the bone boundaries in DXA images and may alter the results[19,26]. Units from different manufacturers use different bone border detection algorithms and different regions of interest for the examination of the hip, therefore the results between different systems are not comparable. Thus, it is important to use the same DXA unit and the same software in longitudinal studies[19]. In very stout patients, measurement accuracy may be influenced by technical errors of X-ray beam hardening (beam hardening artifacts). This phenomenon, most known as the photopenia effect, occurs due to the fact that when a multi-energy X-ray beam passes through the body, its photons are attenuated differently depending on the energy, and those with less energy weaken much more than those with higher energy. Therefore, the higher the density of the tissue the greater the attenuation of low photons energy is, causing a shift of the spectrum to a higher average energy. In most cases, this phenomenon is limited by proper unit adjustment, but in patients with excessively large body sizes and weights, it has been shown that it can lead to an underestimation of body fat[17]. Variations in the degree of hydration of the soft tissues may also lead to errors when calculating body mass composition. A basic assumption of DXA is that the percentage of water in non-fat body tissues is stable, although only small changes may affect the accuracy of adipose tissue estimation. Instead, situations with a major increase in the amount of water, such as edema or ascites, are likely to cause significant errors. It has been shown in experimental models that excessive hydration by administration of saline or water leads to underestimation or overestimation of fat percentage, respectively. Simulation experiments show that changes in class hydration of 1-5% result in errors in fat mass estimation with DXA up to 1%. The possibility of serious error in its assessment of fat mass exists in cases of variations in hydration between 20-25% in the total mass of soft tissue. Such sharp differences in the state of hydration are not common in clinical practice. Therefore, in the great majority of cases, this error is expected to be small and does not set serious limitations on the accuracy of the method[17]. In areas where there are few bone-free pixels, for the direct measurement of FM and LM, such as the limbs and chest, the accuracy in measuring soft tissue may be slightly less compared to areas without bone.

When performed correctly, DXA measurements are among the most accurate quantitative measurements used in hospital settings. The high level of repeatability allows physicians to rely on the results and use them to evaluate treatment results. Nevertheless, it is often observed that bone densitometry techniques cannot be perfectly reproducible, even when all the manufacturer's recommendations have been applied. Additionally, differences in measurement accuracy may occur between radiologic technologists and/or between 9 facilities using identical DXA units. Thus, knowledge of repeatability is essential to ensure the diagnostic benefits of the examination.

The precision error is then calculated as the mean square of the standard deviation (SD) between measurements. Changes in patient position during scanning and assay variability are important factors affecting the accuracy of the BMD value. When a significant number of RTs perform multiple measurements of BMD, by DXA, in one setting (hospital, university, private center), guidelines suggest the usage of average LSC (explained in detail next) of all RTs[27]. If a DXA facility has not undergone an accuracy assessment of its staff, then a quantitative comparison of repeated BMD measurements is not possible. Limits for the estimated precision error, % coefficient of variation (CV), have been established for the total hip (0.8–1.69%), spine (1.0–1.2%), and femoral neck (1.1 1–2 .2%), respectively. The minimum significant change in BMD that can be identified with 95% confidence is 2.77 x CV. Thus, if a DXA unit and RT operating have a combined accuracy of 1.0% when two scans of the same patient are taken within one year, differences in results must equal or exceed 2.77% (2.77 x 1%). If the CV index were 2.0% a significant change greater than 5.6% would be detected. Therefore, the higher the precision (via the % CV index), the greater the change recognized is, which makes precision a particularly important factor in detecting the correct results[22]. Since the rate of bone turnover in normal subjects or treated patients is slight, good measurement accuracy is necessary to detect a clinically significant change in BMD. Achieving the highest accuracy of the DXA method requires the careful position of the patient, as well as routinely analyzing the measurement results. Quality control of the unit should also be performed regularly.

Least significant change

Changes in body mass composition due to normal variations and treatment changes are often minor. Therefore, it is essential, particularly in patients who have undergone consecutive examinations of body mass composition analysis to distinguish whether the measured differences are real (due to real biological changes) or whether they should be attributed to inaccurate examination[16]. The clinical significance of such differentiation can be evaluated using the concept of "least significant change" (least significant change – LSC), which represents the minor differences between successive measurements that reflect true changes. Therefore, the LSC is correlated with RT precision assessment. According to the recent ISCD recommendation, a 95% confidence level is recommended, in which LSC is calculated by multiplying 2.77 by precision error.

The LSC value has also significant importance in the assessment of sarcopenia so that it can be distinguished whether an eventual change in muscle mass parameters is due to one true deterioration or improvement (response to treatment) of the disease. The LSC value has also been used in adults to determine the monitoring time interval (MTI) of the time which is needed to pass between two measurements in which a variation exceeding the LSC is expected to be recognized. The MTI is the ratio of LSC to the mean annual variation in muscle mass for a specific sex, age group, and measurement area. LSC should not exceed 5.3% for the lumbar spine, 5.0% for the hip, and 6.9% for the femur. Acceptable BMD accuracy error values for clinical practice were defined by a meta-analysis of published BMD accuracy studies[30]. In the studies included in this meta-analysis, precision values were reported as percent of CV (%CV) which is what is suggested in clinical practice. LSC expressed as an absolute value in grams per square centimeter may also be used for comparisons. The authors suggest that it is preferable to use %CV as it is less influenced by the baseline BMD value[30]. Various DXA calculation applications are available online and they can be used to express accuracy as grams per square centimeter or %CV. Therefore, it is possible to determine whether the RTs are using the accuracy standards.

Qualifications RTs who work in a DXA unit may have received both basic and certified training on DXA procedures. RT participates in all steps of the procedure, including the diagnostic performance, the examination quality assessment, the unit quality maintenance, the accurate implementation of DXA protocols, and the acquisition and processing of the examination data. As a member of the multidisciplinary team RT participates in all meetings about the patient's result, although the Medical Radiologist is responsible for the analysis and the final diagnosis[27]. ISCD (International Society for Clinical Densitometry) is an international scientific organization dedicated to skeletal health by promoting education on bone mass measurement and other skeletal health assessment technologies. ISCD strives to ensure proficiency and quality in skeletal health assessment through education, certification and accreditation, and bone densitometry. To highlight the essential components of a quality DXA examination, the ISCD identifies DXA Best Practices. Best practices refer to the set of key indicators consistent with a high-quality unit that assesses skeletal health. ISCD guidelines suggest the expertise of RT after specific training which includes theoretical and clinical practice training[17]. Guidelines have reported RT assessment precision normal range. Assessment precision can be performed after RT training and after they have taken practice on 100 patients[31]. Acceptable range for RT precision is: [23] - Lumbar-spine: 1.9% (LSC=5.3%) - Total Hip: 1.8% (LSC=5.0%) - Femur neck: 2.5% (LSC=6.9%) Over the years, the technology of DXA units evolves (e.g. changing the beam geometry from a "pencil beam" to a "fan beam"), while the new software is created and is constantly evolving, such as TBS/Trabecular Bone Score. Thus, the knowledge and skills of RTs should improve over time. Studies have shown that old units, outdated software, insufficient unit maintenance, inexperienced and unscientifically trained technologists-radiologists understandably have adverse effects on patient management[32].

Conclusion

Although DXA tests are accurate, non-invasive, and fast, special technical skills and experience are required from RTs who have to follow DXA protocols. An acceptable quality control program that includes procedures for both the DXA unit and RT adequacy is usually enough to guarantee a high level of accuracy and repeatability of results. According to recent studies, high accuracy of body composition measurements with the latest generation DXA units, especially for the assessment in whole body examination, the accuracy of which has shown to be higher than that of regional placement body mass exams. Nevertheless, the diversity in the regulation process and software and hardware versions between different manufacturers possibly reduces comparability between measurements performed in different units. RTs must have adequate and appropriate training in DXA techniques about osteoporosis. Furthermore, as new technologies, instructions, and guidelines are constantly changing, it is deemed necessary for RTs to demonstrate continuous professional development to ensure the high quality of the results.

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