Position statement on the reporting of dual energy x-ray absorptiometry (DXA) bone mineral density scans

National Osteoporosis Society

August 2002

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Foreword

This document provides clear guidance to physicians providing a DXA scanning service on how spine and femur bone mineral density scans may be reported to GPs and other referring physicians. Its use will facilitate improved communication between primary and secondary care and may help to alleviate confusion for the patient.

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Position statement on the reporting of dual energy x-ray absorptiometry (DXA) bone mineral density scans

DXA scanning of the axial skeleton is the accepted technique for the diagnosis of osteoporosis. The following statement has been prepared to outline the current advice from the National Osteoporosis Society (NOS) on the interpretation of DXA scans on patients referred by registered medical practitioners.

This position statement applies to DXA scans of the proximal femur and PA lumbar spine only and is based on relevant scientific literature in peer-reviewed journals as of September 2001. It will be reviewed on a biannual basis or as required in the light of new research findings.

This statement was prepared for the NOS by Professor I Fogelman, Professor J Adams, Dr J McCrea, Ms SA Steel and Dr GM Blake and represents the consensus view of the members of the Bone Densitometry Forum. The statement is endorsed by the NOS Council of Management.

August 2002

Key recommendations

1 Bone mineral density (BMD) measurements by DXA at the lumbar spine and proximal femur remain the current 'gold standard' for the diagnosis of osteoporosis and intervention with treatment.

2 This report aims to give guidance to physicians providing a DXA scanning service on how spine and femur BMD scans may be reported to primary care doctors and other physicians referring patients for bone densitometry studies.

3 The basis of the recommended reporting system is the World Health Organisation (WHO) study group definitions of osteoporosis, osteopenia and normal, based on BMD T-scores ≤ -2.5, between -2.5 and -1, and ≥ -1 which identify patients with high, intermediate and low risk of fracture respectively.

4 The WHO definitions of osteoporosis, osteopenia and normal, apply only to BMD measurements of the spine, proximal femur or forearm and should not be applied to other DXA measurement sites or measurements made with technologies other than DXA.

5 Although the clinical diagnosis of osteoporosis is based on T-scores, Z-scores can be helpful in scan interpretation, especially in the elderly.

6 Care is necessary when using reference ranges for the calculation of T-scores and Z-scores that the data used are relevant and accurate for the population concerned, taking into account the gender and ethnic origin of the patient. It is recommended that femur BMD measurements are interpreted using the total hip region of interest with the reference range derived from the third US National Health and Nutritional Examination Survey (NHANES III).

7 GE-Lunar DXA scanners have a default setting that reports a weight-corrected Z-score. It is recommended that to standardise reporting and maintain consistency between scanners from different manufacturers this default setting is changed so that Z-scores are reported without weight correction.

8 Before reporting a DXA spine study, careful visual scrutiny of the scan image is essential to exclude artifacts such as degenerative disease, vertebral fractures or metal artefacts that may affect T-score and Z-score values. In elderly subjects the spine scan may be of little value if there is extensive degenerative disease. When reporting a femur study the scan images should be inspected for the correct rotation and abduction of the leg and correct placement of the standard femur regions of interest.

9 When reporting follow-up studies the scan images should be carefully checked to ensure that the positioning of the patient and placement of the regions of interest are consistent. Statistically significant BMD changes require a change of at least 4.5% in spine or total hip BMD.

10 The proposed structure of DXA reporting is as follows:

- The report should begin with the BMD, T- and Z- scores for the spine and femur.
- Where appropriate the use of one of three standardised reports is recommended based on whether the spine and femur T-scores indicate osteoporosis, osteopenia or normal BMD.
- Where necessary the report should end with a free text comment to provide for additional interpretation and recommendations or to qualify the standard reports.

Background

Bone densitometry is now well established in clinical practice and it is generally accepted that DXA is the 'gold standard' technique for the measurement of bone mineral density (BMD). The ability to measure BMD has had a major impact on our ability to diagnose osteoporosis and assist in decisions about treatment. There are countless articles and reviews relating to DXA but at a practical level there is often confusion among different physicians as to what precisely a DXA result means and how to apply this to therapeutic decision-making for an individual patient. The purpose of this report is to address these issues and to provide some guidance on standardised reporting of DXA studies. At the present time recommendations will only be made in respect of the spine and the hip.

DXA

Over the past decade, DXA has established itself as the most widely used method of measuring BMD because of its advantages of good precision, short scan times and stable calibration in clinical use. DXA equipment allows scanning of the spine and hip, usually regarded as the most important measurement sites because they are common types of osteoporotic fractures and cause substantial impairment of quality of life, morbidity and mortality. A measurement of hip BMD has been shown to be the most reliable way of evaluating the risk of hip fracture[1,2].

Additionally, since the vertebral bodies are rich in metabolically active trabecular bone, the spine is regarded as the optimum site for monitoring response to treatment[3]. Note that the relationship between bone density and fracture is described by a continuous gradient of risk. Figure 1 shows the relationship between hip bone density and risk of osteoporotic fracture when moving from the highest (I) to the lowest (IV) quartile of BMD[4].

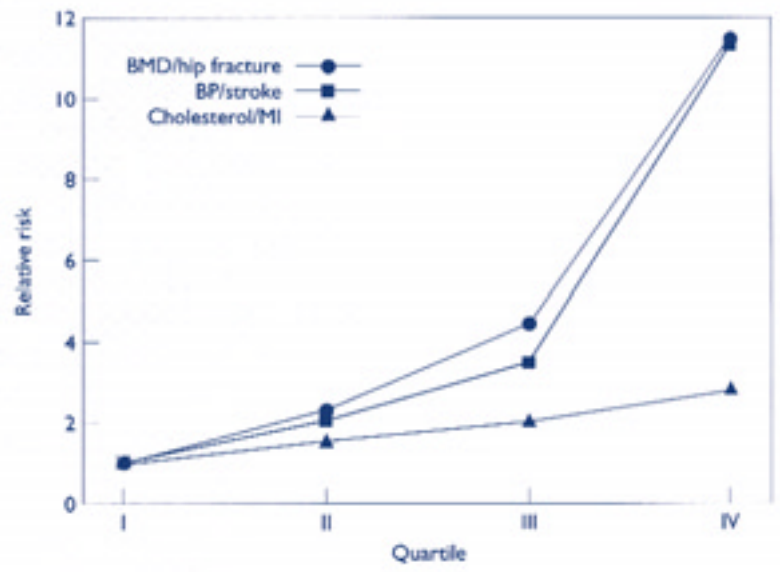


Figure 1. Comparison of the relationship between hip BMD and the risk of hip fracture with the relationships between blood pressure and the risk of stroke and serum cholesterol and the risk of myocardial infarction. In each case the population is divided into quartiles and the relative risk of the higher risk quartiles plotted relative to the lowest risk quartile (figure reproduced from Ref [4] with permission).

The fundamental principle behind DXA is the measurement of the transmission through the body of X-rays of two different photon energies[5]. Since the attenuation coefficient depends on atomic number and photon energy, measurement of the transmission factors at two energies enables the 'areal' densities [i.e. the mass (g) per unit projected area (cm^2)] of two different types of tissue to be inferred. In DXA scans these are taken to be bone mineral (hydroxyapatite) and soft tissue respectively. The radiation dose to the patient from a DXA scan is very low (1 to 10 μSv)[6] and is comparable to the average daily dose from natural background radiation (7 μSv).

Definition of osteoporosis using BMD

In recent years the widespread availability of bone densitometry systems has led to working definitions of osteoporosis that are increasingly based on measurements of bone mineral density (BMD). In particular, in 1994 a World Health Organisation (WHO) study group recommended a definition of osteoporosis based on a BMD measurement of the spine, hip or forearm expressed in standard deviation (SD) units called T-scores[7,8].

The WHO report also proposed a state of reduced BMD intermediate between normal bone density and osteoporosis called osteopenia. It is important to note that these WHO definitions were derived from BMD data from epidemiological studies of Caucasian women in their sixties who had sustained hip fractures and were never intended as treatment thresholds for individual patients.

The T-score is calculated by taking the difference between a patient's measured BMD and the mean BMD of healthy young adults at the age of peak bone mass, matched for gender and ethnic group, and expressing the difference relative to the young adult population SD:

$$\text{T-score} = \frac{\text{Measured BMD} - \text{Young adult mean BMD}}{\text{Young adult standard deviation}}$$

A T-score result therefore indicates the difference between the patient's BMD and the ideal peak bone mass achieved by a young adult.

The WHO definitions of osteoporosis and osteopenia were originally developed for white females and are based on T-score values such that a woman with a T-score = –2.5 at the spine, hip or forearm is classified as having osteoporosis, a T-score between –2.5 and –1 is classified as osteopenia, while a T-score = –1 is regarded as normal. A fourth state of 'established osteoporosis' was also proposed, denoting osteoporosis as defined above, but in the presence of one or more documented low trauma or fragility fractures, usually of the wrist, spine or hip.

The WHO study group definitions of osteoporosis, osteopenia and normal are intended to identify patients with high, intermediate and low risk of fracture respectively. It is important to recognise that the WHO criteria refer only to BMD measurements of the spine, hip or forearm. These definitions cannot automatically be applied to other BMD measurement sites, to other technologies such as quantitative computed tomography (QCT) or quantitative ultrasound (QUS), or to patients other than Caucasian women e.g. men, and to non-Caucasians. In particular the use of T-scores is inappropriate in children.

The rationale for the WHO definition of osteoporosis is that it captures around 30% of all Caucasian post-menopausal women[9]. This figure approximates to the lifetime risk of fracture for a 50-year-old woman. Furthermore, there is evidence from several recent clinical trials that a T-score of –2.5 is a threshold below which treatment produces a reduction in fracture risk[10,11]. In comparison, it can be argued that the WHO definition of osteopenia captures too high a percentage of women to be clinically useful and nowadays this term is being used less often, particularly in the context of making therapeutic decisions. In contrast, the WHO definition of osteoporosis has had a major influence on clinical practice, to the extent that the question: 'Does this patient have osteoporosis?' is now regarded as a T-score issue.

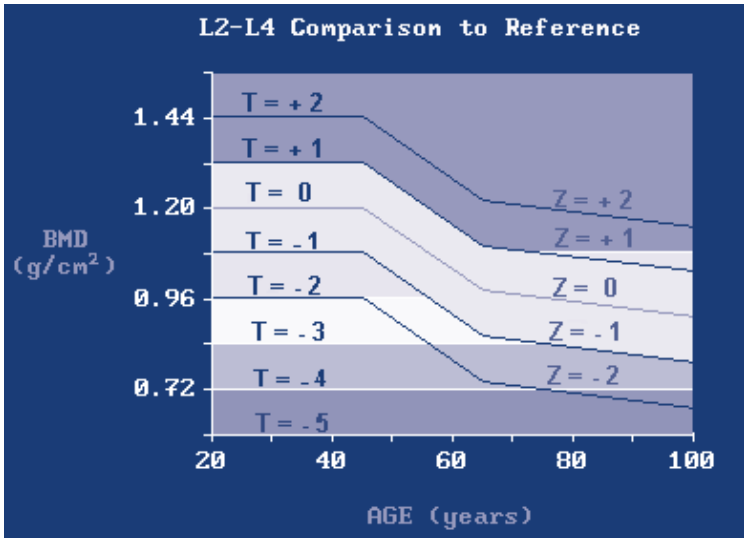
Alongside the T-score, another useful way of expressing BMD measurements is in Z-score units[12]. Like the T-score, the Z-score is expressed in units of the population SD. However, instead of comparing the patient's BMD with the young adult mean, it is compared with the mean BMD expected for the patient's peers, e.g. for a healthy normal subject matched for age, gender and ethnic origin:

$$\text{Z-score} = \frac{\text{Measured BMD} - \text{Aged matched mean BMD}}{\text{Aged matched standard deviation}}$$

GE-Lunar DXA scanners have a default setting that reports a weight-corrected Z-score. It is recommended that to standardise reporting and maintain consistency between scanners from different manufacturers, this default setting is changed so that Z-scores are reported without weight correction. (a)

(a) To turn off the weight correction on GE-Lunar systems click on the Tools menu bar. Then choose Use Options followed by Reference Data. For each site (i.e. spine, femur) make sure that the weight box is clear. If there is a tick in the box, click on the box to remove it. If the scanner is part of a network then this adjustment must be checked on all the scanners in the network.

Figure 2. Caucasian female spine BMD reference data for GE Lunar DXA scanners with lines of constant T-score and Z-score superimposed.



Although not as widely used as T-scores, Z-scores nevertheless remain a useful concept because they express the patient's risk of sustaining an osteoporotic fracture relative to their peers. T- and Z- scores are compared and contrasted in Figure 2 which shows Caucasian female reference data.

Epidemiological studies of the relationship between BMD and fracture incidence are interpreted using a 'gradient of risk' model in which fracture risk increases exponentially with decreasing BMD[13]. The findings are expressed in terms of the relative risk (RR), which is the increase in fracture risk for each 1 SD decrease in BMD. Results for RR values by fracture site and BMD measurement site have been derived in a recent meta-analysis of prospective studies[1]. Typically, every reduction of 1 SD in BMD equates to a 1.5 to 2.5 increase in the likelihood of fracture. It follows therefore that patients with a Z-score < –1 are at a substantially increased risk of fracture compared to their peers with a Z score of 0.

Reference ranges

If the WHO criterion of a T-score = –2.5 is used to define osteoporosis, then it is apparent that any errors in the mean BMD or population SD of the reference group might lead to significant differences in the apparent incidence of osteoporosis when applied to other populations. The great majority of centres providing a scanning service use reference ranges provided by the equipment manufacturers, and issues over the accuracy of these ranges have caused controversy in the past, especially for femur BMD[14]. In view of the large number of new devices that are being introduced for the assessment of the skeleton the accuracy of the reference data provided is an important issue.

While there is reasonably close agreement between the principal DXA manufacturers for spine BMD T-scores and Z-scores, for femur reference data the controversy has been largely resolved after a report by the International Committee for Standards in Bone Measurement (ICSBM)[15] which recommended that hip BMD measurements should be interpreted using the total hip region of interest (ROI) (Figure 3) and by employing the hip BMD reference ranges derived from the third US National Health and Nutritional Examination Surveys (NHANES III)[16].

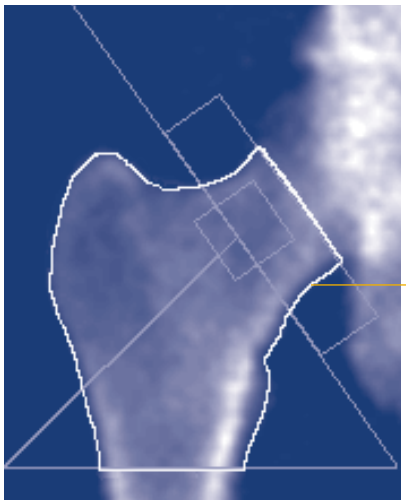


Figure 3. The total hip ROI is shown as the area within this line

The NHANES III survey studied a nationally representative sample of more than 14,000 men and women with approximately equal numbers of non-Hispanic white, non-Hispanic black and Mexican Americans. Data were gathered using Hologic QDR 1000 DXA scanners operated from mobile trailers so that subjects from all regions of the United States could be included. The ICSBM report recommended use of the total hip ROI, instead of the previously widely used femoral neck site because of its larger area and therefore improved precision, and the fact that it is the hip region most readily implemented on all manufacturers' systems.

Many centres have already acted upon these recommendations and the total hip ROI is increasingly being used for scan reporting. It is important to note that these changes affect the percentage of patients who are diagnosed as having osteoporosis at the hip. Using the total hip ROI and the NHANES III reference range, significantly fewer patients will be diagnosed as having osteoporosis than when using the femoral neck ROI and the manufacturer's reference range with Hologic instruments[17]. While it is possible to debate the best choice of measurement site and reference range, it is important to recognise the advantages of a consistent approach and to have universally accepted DXA BMD criteria for the diagnosis of osteoporosis.

One advantage of presenting bone densitometry results in terms of T- and Z- scores is that they avoid the confusion caused by the raw BMD figures that differ for different manufacturers' equipment[18]. The ICSBM Committee has addressed this latter issue by publishing equations which allow each manufacturer to express their BMD values in a consistent fashion in standardised units (sBMD: units mg/cm^2)[15,19]. The ICSBM report also included figures for the NHANES III total hip reference data converted into sBMD values. It should be noted, however, that sBMD values have not been widely adopted for everyday clinical practice.

Scrutiny of the DXA scan image

Lumbar Spine

A careful visual scrutiny of the scan image is important in the interpretation of DXA studies to ensure that the findings are not affected by anatomical artefacts. For spine scans these include degenerative disease (Figure 4) vertebral fractures (Figure 5) and metal artefacts (Figure 6). Their effect on scan interpretation may be assessed by noting the trend in T- score or Z- score results at each vertebral level.

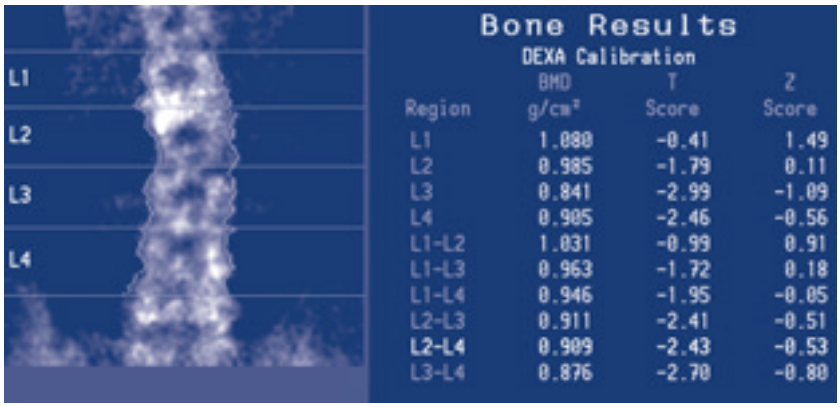


Figure 4. Spine DXA scan from a GE Lunar DPX densitometer showing changes in BMD in L1 and L2 due to osteoarthritis. The effect of OA on BMD can be seen from the trends in T-score and Z-score values from L1 to L4 shown in the first four lines of the BMD report.

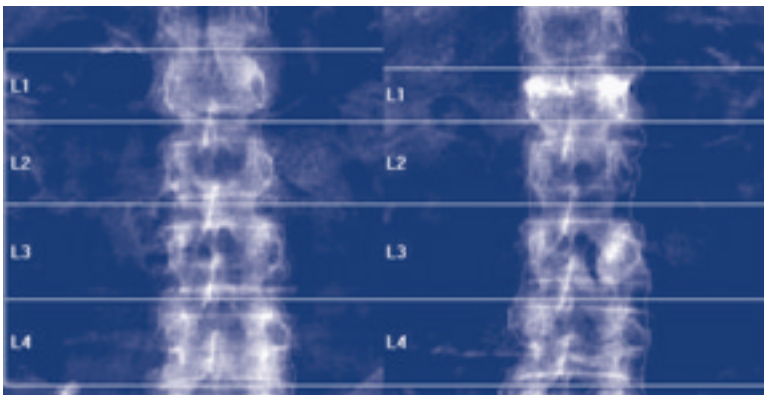


Figure 5. Spine DXA scans from a GE Lunar Expert-XL densitometer showing the development of a vertebral crush fracture in L1 between November 1996 and November 2000

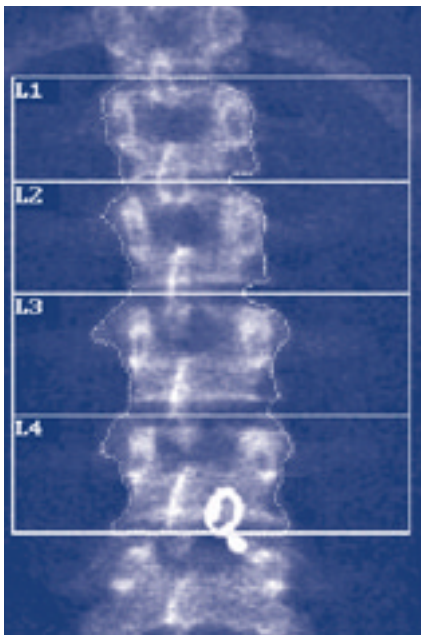


Figure 6. Spine DXA scan from a Hologic QDR4500 densitometer showing the effect on BMD of a gold navel ring superimposed over L4.

If the BMD of an individual vertebra is falsely elevated by an artefact, the affected vertebra(e) should be excluded from analysis and from the reference range plot of BMD against age. If new vertebral fractures are suspected, either by the scan appearance or a change in vertebral height or if there is a large discrepancy in BMD between vertebrae, the referring clinician should be advised about the need for further investigation e.g. with plain radiographs to identify the cause of this difference.

For spine scans it is also important to check that the correct vertebrae have been chosen for analysis. Scan analysis may sometimes be performed by mistake on L1 – L3 or L3 – L5 instead of L2 – L4 [in the case of Lunar machines] and on T12 – L3 or L2 – L5 [in the case of Hologic machines]. Another source of confusion is patients with abnormal segmentation e.g. 6 lumbar vertebrae[20].

In elderly subjects the spine scan may be of little diagnostic value if there is extensive degenerative disease. In such patients a more reliable measure of skeletal status may be obtained from the BMD of the hip and/or a peripheral measurement e.g. forearm or calcaneus.

Proximal Femur

Careful scrutiny of the scan image is also important for femur studies. The hip can show a range of anatomical variants, some of which may make the correct placement of the standard ROI boxes difficult e.g. a short femoral neck, Paget's disease of the femur or exuberant osteoarthritis. Incorrect rotation or abduction of the leg is also a major source of error[21]. Correctly positioned and correctly analysed hip DXA scans are shown in Figure 7 for Hologic and Lunar densitometers respectively. Sometimes optimum hip positioning cannot be obtained even by the most experienced technicians, due to patient limitations e.g. painful osteoarthritis, previous stroke etc.

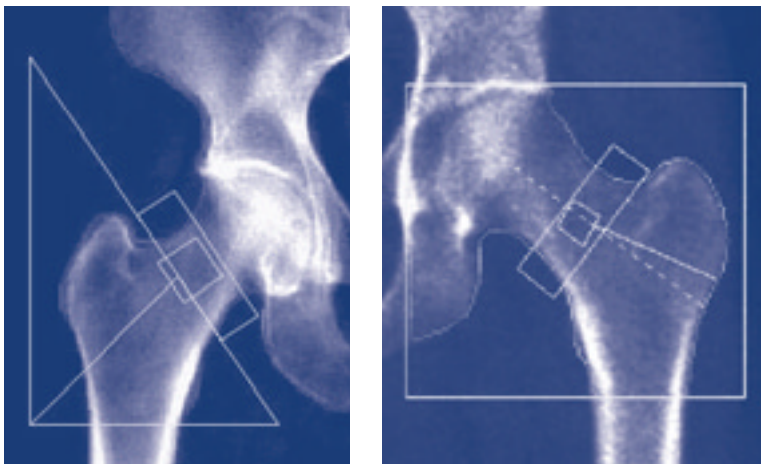


Figure 7. Correctly positioned and correctly analysed femur DXA scans for: (A) a GE Lunar densitometer; (B) a Hologic QDR densitometer.

Both spine and femur scans need to be checked to ensure that the bone edge markers are correctly positioned. The densitometer algorithms which calculate these are not infallible and manual correction of bone edge markers and intervertebral markers may need to be performed in some cases. The adjacent soft tissue, used in the calculation of the soft tissue baseline, should also be free of artefact. The patient's date of birth must be entered correctly into the densitometer database since this will affect the calculation of the Z-score.

Inspection of scan images is particularly important when interpreting follow-up studies. A visual comparison should always be made with previous studies. For the spine, a check should be made that the same vertebrae have been used in the analysis. For the femur scan, it is important that the angles of rotation and abduction of the hip are the same and that the ROI boxes have been placed in a consistent manner.

Repeat scans should be performed on the same machine using the same scan mode. The patient's weight also needs to be checked since major weight change can also affect the scan result due to changes in body fat[22]. It is important to remember that a change in software since a previous scan, or a new X-ray tube, may substantially alter the precision of the scanner and add additional variation to the measurements which must be allowed for when calculating 'least significant change' (see over).

A proposed structure for DXA reporting

The clinical indications for performing BMD measurements are summarised in the Appendix (see page 15). The remainder of this document outlines a scheme for reporting BMD scans of the spine and femur. The basis for scan reporting is the WHO definition of osteoporosis, i.e. a T-score = –2.5 and this is also the threshold for treatment which has been recommended in the recent RCP Guidelines[23] in the case of post-menopausal women.

The use of T-scores for other patient groups, i.e. pre-menopausal women, men and children is discussed below. It should be noted that while three standard reports are suggested, any system should have the flexibility to provide individual reports and some of the issues relating to this system will be discussed below.

It is important to begin by reporting BMD, T- and Z- scores:

Spine = ... g/cm2	**T-score =**	**Z-score =**
Femur = ... g/cm2	**T-score =**	**Z-score =**

These figures may then be interpreted with the help of one of three standard reports:

1. **If the T-scores for the spine and total hip BMD are both greater than –1.0**

   Standard report reads:

   The results are normal and the patient should be reassured.

2. **If at least one T-score for the spine or total hip BMD is less than –1.0 but both are greater than –2.5**

   Standard report reads:

   The results show osteopenia and treatment may be considered if:

   (a) the patient has previously had a low trauma fracture;

   (b) is receiving glucocorticoid therapy; or

   (c) has a low BMD for age (Z-score of less than –1).

   Even if no treatment is given lifestyle advice to improve BMD should be provided and BMD re-measured in 3 to 5 years.

3. **If at least one T-score for spine or total hip BMD is less than –2.5**

   Standard report reads:

   The results confirm osteoporosis and treatment is indicated

It should be noted that while three standard reports are suggested, any system should have the flexibility to allow for individual reports. A comments box is therefore included to provide for additional reports or to qualify the standard reports.

Additional reporting issues

The reporting suggestions outlined above are intended primarily for post-menopausal women up to the age of 70 or 75 years. They do not cover all situations and, for example, are inappropriate for children and pre-menopausal women. Some caution in interpretation is also required when dealing with men or individuals of other races. The rules do not work so well in the elderly, as the majority of individuals over the age of 75 will have osteoporosis based on the WHO definition, while a Z-score of –1 is too low a threshold in this population. However, in the elderly bone density is often only one of several factors that should be taken into account when making a decision as to whether treatment for osteoporosis is appropriate.

Although there is strong evidence for a reduction in fracture risk with anti-resorptive drugs only in patients with vertebral fractures or with a T-score less than –2.5, several authorities (the Royal College of Physicians in the UK and the National Osteoporosis Foundation in the USA) have proposed that the T-score threshold of –2.5 be raised for patients with a history of low-trauma fractures[23] or in patients receiving corticosteroid therapy[24]. For women over the age of 65 years all those with low bone density for age (Z-score of less than –1) will have a T-score of less than –2.5. However, below the age of 65 years some of these women will have a T-score in the osteopenic range. Because of the strong evidence for a reduction in the rate of bone loss with anti-resorptive drugs for patients with osteopenia, some authorities have proposed that women in this latter group should be offered treatment to prevent bone loss. These are the reasons for the special categories included in the osteopenia report above.

Follow-up DXA scans have traditionally been performed to monitor response to anti-resorptive treatment. The appropriate interval between serial BMD scans is determined from the concept of the ‘least significant change’ in BMD. For any change in BMD to be ‘true’ with 95% confidence, the measured change must exceed 2.8 (or 2v2) times the precision error (or coefficient of variation) of the measurement[25]. Although the coefficient of variation for PA spine and total hip BMD measurements is often quoted as 1% it is important to realize that this is an idealised figure which applies only to short-term precision measurements (i.e. repeated measurements made over periods of a few hours or days) in young adults with normal BMD and normal weight for height. In practice the relevant figure for precision is the long-term precision error measured over months or years. Patel et al[26] reported long-term precision errors of 1.6% for PA spine and total hip BMD, thereby producing a figure of 4.5% for the least significant change. This figure may be significantly larger, however, in patients with osteoporosis or obesity (i.e. BMI > 30 kg/m^2) and care is therefore required when interpreting BMD changes in such subjects. Since it is unlikely that such a significant change in BMD will be detectable in less than two years, BMD scans are normally not repeated more frequently than every two years.

Referring physicians should be aware that in all cases patients require advice about a healthy well-balanced diet to ensure adequate calcium and vitamin D intake. Other lifestyle issues such as exercise, avoidance of smoking and moderation in alcohol consumption also need to be discussed. In a patient with osteoporosis it is important to exclude potential secondary causes of bone loss such as thyrotoxicosis, primary hyperparathyroidism, hypogonadism especially in males, inflammatory bowel disease, gluten-sensitive enteropathy (which may often be asymptomatic) and myeloma, although such diseases are uncommon.

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Appendix

Referral Criteria for DXA

Clinical indications for BMD measurement are shown in the table below which is reproduced from the Royal College of Physicians guidelines[27]:

Risk Factors providing indications for the diagnostic use of bone densitometry

1. **Presence of strong risk factors**

- **Oestrogen deficiency**

  Premature menopause (age < 45 years)
  Prolonged secondary amenorrhoea (> 1 year)
  Primary hypogonadism

- **Corticosteroid therapy**

  Prednisolone > 7.5 mg/day for 1 year or more

- **Maternal family history of hip fracture**

- **Low body mass index (< 19 kg/m²)**

- **Other disorders associated with secondary osteoporosis**

  Anorexia nervosa
  Malabsorption syndrome
  Primary hyperparathyroidism
  Post-transplantation
  Chronic renal failure
  Hyperthyroidism
  Prolonged immobilisation
  Cushing's syndrome

2. **Radiographic evidence of osteopenia and/or vertebral deformity**
3. **Previous fragility fracture, especially of the hip, spine or wrist**
4. **Loss of height, thoracic kyphosis (after radiographic confirmation of vertebral deformities)**

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