11 BMD: Interpretation and Normal Ranges

Introduction

Bone mineral density measurements are frequently used in clinical practice to assess fracture risk. The utility of these measurements depends on making the correct interpretation. This involves comparison to an appropriate reference range and making allowance for independent factors affecting fracture risk.

Interpretation of Results

Correct interpretation of a BMD measurement will be influenced by the reason for the measurement. In this section we will consider the interpretation of measurements made for the following purposes:

- To diagnose osteoporosis
- To evaluate fracture risk
- To determine whether treatment is required

Section 13 addresses the interpretation of changes in BMD assessed from serial measurements.

In order to make a meaningful interpretation, the BMD result must be expressed unambiguously, and compared to a relevant reference range. We need to understand the relationship between BMD and fracture risk, and take account of additional factors that affect the risk of fracture independently of BMD itself.

Expression of BMD results

BMD results may be expressed in various ways, which may each be useful in different circumstances:

- **Absolute BMD (in the case of DXA in g/cm$^2$)**
  Absolute BMD values are frequently reported but are only meaningful in the context of what is normal for a measurement made at the same site in an individual with the same characteristics.

- **As a standard deviation (SD) score**
  Results expressed as an SD score compare the individual’s result to a reference range, which should be for individuals of the same gender and ethnic background. Comparison may be to an age-matched population, in which case it may be referred to as a Z score, or to a population of healthy young adults, in which case it is referred to as a T score.

- **As a percentage**
  Results are again expressed in relation to an appropriate reference range. Results expressed as a percentage are commonly used to explain results to a patient since most people are familiar with the concept of percentages. Results shown in this way may, however, be misleading. In
order to calculate a percentage, the mean value for the reference population is used as the denominator and as the mean BMD decreases with age, the range of values comprising the “normal range” will increase with aging.

- **As a percentile**
  Expressing results as a percentile score avoids the difficulty associated with the use of percentages, and is also a familiar concept to many patients but as it is not readily available for BMD measurements, this approach is not generally used in practice.

The use of measurements expressed as SD scores are therefore used most frequently for clinical decision-making. Conventionally, the reference range is defined for any population as the range of values encompassing 95% of the population in question. This is equivalent to the 2.5th to 97.5th percentile, or to the mean +/- 2 SD.

![Figure 1: Diagnosis of Osteoporosis](image)

**Diagnosis of Osteoporosis**
The standard quantitative definition of osteoporosis was developed by the WHO and is based on the use of T scores (figure 2). Bone density which is 2.5 SD or more below the young normal mean (T score <-2.5) may be classified as showing osteoporosis, while a BMD T score between –1 and –2.5 may be classified as showing osteopenia. The WHO definition may be applied to postmenopausal women using DXA measurement at the spine, hip or forearm. It was not developed for other groups and should not therefore be applied to measurements made in men or pre-menopausal women. Furthermore, it may not be used for measurements made using other techniques, such as QUS or QCT, as the relationship between mean T score and age differs between techniques. If the T<-2.5 threshold is used for measurements made using a different technique this can result in an incorrect proportion of the population being defined as osteoporotic.
WHO definition of osteoporosis in terms of T-scores

Figure 2

Reference Ranges
The use of an appropriate reference range is critical to the correct interpretation of any BMD measurement. For most clinical measurements it is reasonable to use the manufacturer’s database that matches the patient’s gender and ethnic background. For this purpose it should be noted that “Asian” reference databases originating in the US refer to an oriental population rather than individuals from the Indian subcontinent, for whom the “White” database may in fact be more appropriate. It appears that much of the difference in BMD between ethnic groups relates to differences in skeletal size.

There have been shown to be significant differences in T scores generated by different manufacturer’s scanners. This results from several factors, including differences in edge detection, and definition of regions of interest. There also appear to be differences in the inclusion criteria for the “normal population” between manufacturers. The main discrepancies are for measurements of the proximal femur. This has largely been overcome by the adoption of the NHANES database for this site, now available from all DXA manufacturers. Similarly, studies have show that the manufacturer’s databases may not be entirely applicable to UK populations and for this reason some centres have generated a local reference database, relevant to the local case mix.

Particular care needs to be given to the interpretation of BMD measurements in children and teenagers. It is clearly inappropriate to use T scores prior to the time of peak bone mass acquisition. BMD measurements in children are most usefully expressed as Z scores and may also require normalization for skeletal size in children who are small for age. Interpretation should be against a validated paediatric database, and should ideally be made by a clinical team with experience of using BMD measurements in children. This topic is addressed in detail in the position statement developed by the NOS.
Evaluation of fracture risk

It is well established that a decrease in BMD of 1 SD is associated with an increase in fracture risk in the order of 2 fold. The relationship is site-specific, in that a measurement of BMD at the proximal femur provides the optimal assessment of the risk of hip fracture. The relation between BMD and fracture risk is also stronger for some fractures e.g. spine and hip, than others e.g. forearm.

Overall, BMD measurement explains the majority of the variability in fracture risk between individuals. A number of other factors contribute independently to an individual’s risk and these should be considered as part of any fracture risk assessment.

Factors independently increasing fracture risk include:

- Previous low trauma fracture
- Increasing age
- Low BMI
- Current smoking habit
- Family history of fracture
- Glucocorticoid therapy

For example, at any level of BMD, the risk of fracture increases by approximately 100% between the ages of 50 and 80 (figure 3)

Figure 3 – Interrelationship between age and BMD on fracture risk in postmenopausal women. Adapted from Kanis JA et al, Osteoporosis Int 2001: 12:989-995
Thus it may be seen that the current absolute risk of fracture is considerably lower in a 50 year old lady with a BMD T score of −3.0 compared to that in an 80 year old lady with the same level of BMD. There is currently considerable interest in developing methods to incorporate the information from all the risk factors identified within an individual to estimate their 5 or 10-year risk of fracture. It is likely that this approach will become clinically available within the next few years. In the meantime, it is important for these additional factors to be considered in deciding how high the risk of fracture is.

**Intervention thresholds**

From the previous section, it can be seen that the decision to treat in an individual needs to take account, not only of BMD, but also other independent risk factors affecting fracture risk. In practice, the factors having the most influence are a prior history of fracture, age and the current use of glucocorticoids. For example, in the secondary prevention of fractures in postmenopausal women, guidance issued by NICE suggests treatment with a bisphosphonate in all women over 75 years of age, regardless of BMD, but only in those with osteoporosis between the ages of 65 and 75, and those with very low BMD or osteoporosis plus other age-independent risk factors below the age of 65.

On the other hand, guidelines from the Royal College of Physicians for the treatment of individuals taking glucocorticoids recommend that intervention is considered at higher levels of BMD (T score −1.5) since in this situation fractures occur at higher levels of BMD.

**Summary**

BMD measurements are extremely useful in clinical practice to diagnose osteoporosis, assess fracture risk, and aid treatment decisions. In order to interpret measurements responsibly it is important to ensure that they are compared to an appropriate reference range and considered in light of the whole clinical scenario.
Bibliography

7. Bisphosphonates (alendronate, etidronate, risedronate), selective oestrogen receptor modulators (raloxifene) and parathyroid hormone (teriparatide) for the secondary prevention of osteoporotic fragility fractures in postmenopausal women. NICE HTA 87 (www.nice.org.uk)