**Position Paper**

**An Update on the Diagnosis and Assessment of Osteoporosis with Densitometry**

J. A. Kanis¹ and C.-C. Glüer² for the Committee of Scientific Advisors, International Osteoporosis Foundation

¹Centre for Metabolic Bone Diseases (WHO Collaborating Centre), University of Sheffield Medical School, Sheffield, UK; and ²Medizinische Physik Klinikum für Diagnostische Radiologie, Universitätsklinik Keil, Germany

**Abstract.** In 1994 the WHO proposed guidelines for the diagnosis of osteoporosis based on measurement of bone mineral density. They have been widely used for epidemiological studies, clinical research and for treatment strategies. Despite the widespread acceptance of the diagnostic criteria, several problems remain with their use. Uncertainties concern the optimal site for assessment, thresholds for men and diagnostic inaccuracies at different sites. In addition, the development of many new technologies to assess the amount or quality of bone poses problems in placing these new tools within a diagnostic and assessment setting. This review considers the recent literature that has highlighted the strengths and weaknesses of diagnostic thresholds and their use in the assessment of fracture risk, and makes recommendations for actions to resolve these difficulties.

**Keywords:** Definition of osteoporosis; Densitometry; Diagnosis; Risk assessment; Risk factors

**Introduction**

An increasing awareness of osteoporosis and the development of treatments with proven efficacy is likely to increase the demand for management of patients with osteoporosis. This in turn will require widespread facilities for its diagnosis and assessment. Measurements of bone mineral are a central component since this forms an integral component of the definition of osteoporosis.

The internationally agreed description of osteoporosis is ‘a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fractures’ [1]. The definition captures the notion that low bone mineral density is an important component of the risk of fracture, but recognizes that other abnormalities in the skeleton contribute to skeletal fragility. In addition, a variety of nonskeletal factors contribute to fracture risk [2–4]. Thus, the diagnosis of osteoporosis by the use of bone mineral density measurements is at the same time an assessment of a risk factor for the clinical outcome of fracture. There is a useful analogy with hypertension since blood pressure is used to diagnose hypertension which is in turn a major risk factor for stroke.

In 1994, an expert panel of the World Health Organization recommended thresholds of bone mineral density in women to define osteoporosis [4,5] that have been widely but not universally accepted by the international scientific community and by regulatory agencies [6–8]. Osteoporosis in postmenopausal Caucasian women is defined as a value for bone mineral density (BMD) or bone mineral content (BMC) more than 2.5 standard deviations below the young average value (Fig. 1). Severe osteoporosis (established osteoporosis) uses the same threshold, but in the presence of one or more fragility fractures.

The diagnostic threshold identifies approximately 15–20% of postmenopausal women as having osteoporosis...
when measurements using dual-energy X-ray absorptiometry (DXA) are made at the spine or the hip (Table 1) [5]. Given an approximately linear loss of BMD with age, and because of the Gaussian distribution of BMD values, the incidence of osteoporosis increases exponentially after the age of 50 years, as is also the case for many osteoporosis-related fractures. When measurements are made at the three sites most vulnerable to fracture (the hip, spine and wrist) approximately 30% of postmenopausal women would have osteoporosis (see Table 1). This approximates the average lifetime risk of these fractures.

Since the introduction of working definitions of osteoporosis, much attention has focused on their application to epidemiology, clinical trials and patient care. This paper reviews briefly the current strengths and particular the limitations of diagnostic criteria. A major concern has been the poor concordance of measurements made at one site with measurements at another site, either with the same or different technologies. Many of these problems are due to errors of accuracy.

### Errors of Accuracy

The objective of the diagnostic use of BMD is to measure as accurately as possible the true value which it was intended to measure. The "true value in terms of the diagnosis of osteoporosis has been variously defined as the amount of skeletal calcium, bone density or BMD at the site measured or at another site. None of the absorptiometric techniques measure true bone density, but rather an areal bone density, in part due to the two-dimensional nature of the scan [9]. It is uncertain whether algorithms to adjust for this would improve the diagnostic or prognostic use of measurements [10,11]. Indeed, the two-dimensional nature of the scan captures an element of bone size that has an independent contribution to bone strength. A much greater limitation relates to other systematic errors.

Variable soft tissue densities are a particular problem with absorptiometric techniques applied to the spine and hip. The correction for fat makes a number of assumptions [12], particularly the assumption of homogenous disposition of fat in the body. Estimates of accuracy errors range from 2% for measurements at the forearm to 10% or more at other sites such as the spine measured laterally [13]. Absorptiometric techniques at the spine (anteroposterior) and hip which are most commonly used for diagnosis, incur accuracy errors of approximately 5%.

The accuracy of various techniques should be considered alongside the variance of measurements in the population to be examined, which ranges from 10% to 50% depending on the technique and site used for measurement and any normalization procedure applied. For absorptiometric techniques the variance (CV%) is no greater than 20%. It is evident, therefore, that techniques with high accuracy errors, say in the order of 5%, stratify individuals less certainly the smaller the population variance. For this reason it is expected that even if in reality there were perfect correlations between BMD at different sites, such errors of accuracy would result in large classification errors where thresholds of measured BMD are utilized to dichotomize the population.

Systematic inaccuracies also occur, particularly at the spine since the vertebrae are irregular in shape and apparent density and mineral content will depend in part upon the algorithm used for edge detection. Moreover, the underlying assumptions about the average fat to lean body mass ratio differ between manufacturers. Therefore different machines, even at the same site, give different results. For example, values for BMD at the lumbar spine using the Hologic device give values approximately 1 SD lower than values using the Lunar machine [14]. Notwithstanding, there are close correlations between the two methods at the spine [15]. A considerable advance has been the standardization of hip and spine measurements between different types of DXA equipment [15,16].

A further source of error relates to biologic variability. Bone is not a homogeneous structure and different sites have variable proportions of cancellous and cortical

---

**Table 1.** Proportion (%) of white women with osteoporosis by age adjusted to 1990 US white women defined as a bone mass below 2.5 SD of the young adult reference range at the spine, hip or midradius.

<table>
<thead>
<tr>
<th>Age range (years)</th>
<th>Any site</th>
<th>Hip alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>30–39</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40–49</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50–59</td>
<td>14.8</td>
<td>3.9</td>
</tr>
<tr>
<td>60–69</td>
<td>21.6</td>
<td>8.0</td>
</tr>
<tr>
<td>70–79</td>
<td>38.5</td>
<td>24.5</td>
</tr>
<tr>
<td>80+</td>
<td>70.0</td>
<td>47.5</td>
</tr>
<tr>
<td>≥50</td>
<td>30.3</td>
<td>16.2</td>
</tr>
</tbody>
</table>

**Fig. 1.** Diagnostic thresholds for women based on the distribution of bone mineral density in the young healthy female population.