Bone mineral density

Frequently asked questions

Patrick J Phillips
MBBS, MA, FRACP, MRACMA, GradDipHealthEcon, is Senior Director of Endocrinology, Osteoporosis Centre, The Queen Elizabeth Hospital, Woodville, South Australia.
patrick.phillips@nwahs.sa.gov.au

George Phillipov
BSc, MSc, PhD, is Research Laboratory Director, Osteoporosis Centre, The Queen Elizabeth Hospital, Woodville, South Australia.

How do you interpret a BMD report (*Figure 1a*)

Measurements of bone mineral density (BMD) are used to diagnose osteoporosis, assess future fracture risk, and monitor treatment. However a busy general practitioner reading a complicated report may find it difficult to interpret. This primer addresses frequently asked questions about BMD and aims to help GPs extract the key points from BMD reports.

How is BMD measured?

Only BMD measurements by dual energy X-ray absorptiometry (DEXA) or quantitative CT radiography (QCT) are recognised by the Australian Department of Health and Ageing for Medicare reimbursement. Dual energy X-ray absorptiometry, unlike QCT, is a planar measurement where bone mineral content (BMC, g) is estimated and then related to the scanned region area (cm2) to provide the BMD (g/cm2), ie. BMD = BMC ÷ area. Quantitative CT radiography also measures bone mineral content but relates it to the scanned volume (cm3). Most BMD measurements are done by DEXA.

What are the numbers in the report?

For reimbursement, both the lumbar spine and proximal femur must be measured. Values for individual vertebrae and various combinations therein are reported and the operator may exclude some vertebrae that appear to give misleading results. For example, a crushed vertebra or the presence of an osteophyte may result in a significantly elevated BMD for that vertebra in comparison to adjacent vertebrae. Various sites in the hip are assessed (Ward's triangle, femoral neck, trochanter and total hip). The following 'numbers' are reported:

- absolute BMD (g/cm2): calculated by comparing the X-ray attenuation measurements for the patient to measurements of the manufacturer's calibration standard
- T-score: the number of standard deviations (SD) that the absolute BMD is above or below the mean value for a healthy, same sex, young adult population (typically 20–35 years when peak bone mass occurs)
- Z-score: the number of SDs the absolute BMD is above or below the mean value for a healthy, age and sex matched population.

Which numbers are important?

- Measurement site:
  – spine: normally this value represents the average of several vertebrae, typically L2–L4 or L1–L4. However if spinal degeneration is present, specific vertebrae (if possible) may be excluded
  – hip: the total hip or femoral neck measurement
- Absolute BMD value: allows comparison between measurements at different times
- T-score: relative BMD status with respect to a young adult population. Defines World Health Organisation categories[1] (eg. normal, osteopaenia, osteoporosis) and also defines eligibility for some Department of Health and Ageing subsidies (T-score <–2.5).
- Z-score: relative BMD status with respect to a age matched population. Assesses whether there is likely to be an underlining cause of an abnormal BMD (over and above the effects of aging and sex). Also defines eligibility for some Department of Health and Ageing subsidies (Z-score <–1.5).

As a general rule one SD approximates to 10% of total BMD. Thus a T-score of –1 implies that BMD is about 10% less than the mean of a young, healthy, same sex population. *Figure 1b* gives an interpretation of the BMD report in *Figure 1a*.

What happens to BMD with age?

For women, menopause is associated with decreased oestrogen levels, which in turn lead to increased bone resorption. During the decade 50–60

years, women lose about 10% of their hip BMD, compared to only 2% for men (*Figure 2*).[2] After age 70 years, men start to lose BMD at a similar rate to women. The young adult BMD mean for men is about 10% higher than that for women.

Bone Density Report The Osteoporosis Centre

140 EX ER YCE DI N PK Female 71 yr DR A

	Result	BMD g/cm2	Y-ADULT T-Value	Age Matched Z-Value		Date
L2-L4	OSTEOPOROSIS	0.785	-3.52	-0.81	-5.0%	26/06/98
L2-L4	OSTEOPOROSIS	0.826	3.09	-0.52		25/10/95
L Femur	OSTEOPOROSIS	0.659	-2.70	-0.48	-2.9%	26/06/98
L Femur	OSTEOPOROSIS	0.679	-2.54	-0.36		25/10/95

HIP FRACTURE PROBABILITY (during next 10 yr)
If no previous fracture after the age of 50 yr --> 8.3 %
With a previous fracture after the age of 50 yr --> 12.2 %

|Glucocorticoid Therapy|Post-Menopausal|Monitoring Osteoporosis
|Malabsorptive Disorder

SPINE COMMENTS: Degeneration evident

Figure 1a. DEXA BMD patient report

How well does BMD predict fracture risk?

Very well. Bone mineral density predicts fracture[3] considerably better than the widely accepted risk factor LDL cholesterol predicts fatal heart attacks[4] (*Figure 3*). The relationship however, is complicated by the effects of gender, age and previous fracture history.

BMD alone

For each SD decrease in femoral neck BMD the relative risk of hip and vertebral fracture increases by 2.6 and 1.8 respectively. However, for each SD decrease in spine BMD, the relative risk of vertebral and hip fracture increases 2.3 and 1.6 times respectively. Accordingly, the best estimate of fracture risk at any particular site is given by BMD measurement at that site. Given that hip fractures have the most serious consequences, hip BMD is the more important measurement.

Age and gender

The 10 year risk of forearm and hip fracture is affected by both age and gender (*Figure 4*).[5] The increase in fracture risk with advancing age in both genders is partly the effect of BMD. However age becomes progressively more important after 65 years, particularly in women (*Figure 5*).[6]

Previous fracture

As noted, low bone density is associated with an increased fracture risk and this is markedly increased by a previous history of fracture. For example, results from the placebo arm of the MORE trial show that women with an initial baseline vertebral fracture(s) had a 5.6 times increased likelihood of sustaining a new vertebral fracture, compared to only a 2.6 increased likelihood for women with baseline hip osteoporosis.[7] Predicting fracture risk is complex, however low BMD becomes more important with advancing age and is compounded by fracture history.

General

This is a 71 year old women who is having a BMD follow up after a period of 32 months. She has a malabsorptive disorder and is taking glucocorticoids, which significantly increase the risk of bone loss. The latter situation prompted her initial DEXA referral in 1995

Spine

Her initial and follow up scans of the L2–L4 vertebrae show she has osteoporosis (T-score ≤–2.5) and her BMD has decreased 0.041 g/cm2 or 5%. This is within measurement variability and suggests that no statistically significant decline in BMD has occurred during the 32 month period. Moreover, the operator's comment that spinal degeneration is present, and the fact that vertebrae have not been excluded, implies that the reliability of spine BMD measurements will be diminished

Left femur

The results confirm the spine result, that osteoporosis is present. The small decrease in BMD (0.020 g/cm2 or 2.9%) is well within measurement variability and thus we may be reasonably certain that her 32 month BMD hip change is not significant

Summary

The patient has osteoporosis at both the hip and spine, and the BMD loss over the 32 month period is not significantly greater than might be expected due to measurement variability. The Z-scores at the hip and spine (less emphasis on spine because of the noted spinal degeneration) are not overly low for both baseline and follow up scans and suggest that for this patient osteoporosis is most likely age related rather than a consequence of her malabsorptive disorder or glucocorticoid medication. Moreover, 32 months of glucocorticoid medication has resulted in no marked increase in overall bone loss at either the spine or hip

Recommendation

Maintain existing treatment schedule and return patient for DEXA scan in approximately 2 years

Figure 1b. Interpretation of patient BMD report

How reliable are BMD measurements?

There is no definitive reference bone standard,[8] consequently BMD values at the

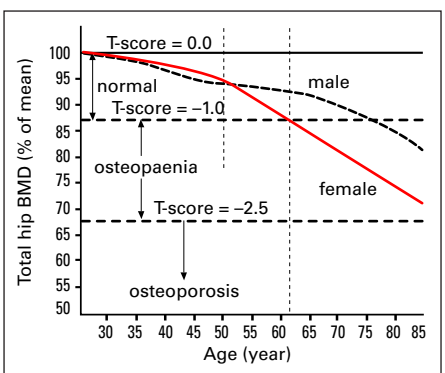

Figure 2. Change in DEXA measured total hip BMD with age for caucasian women and men (based on NHANES III database[2])

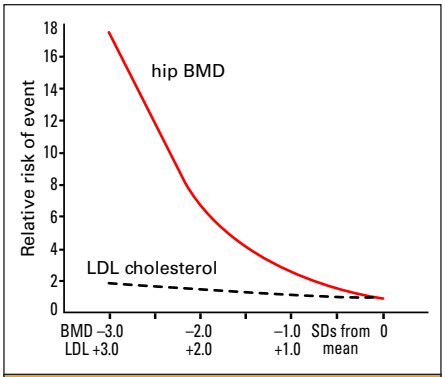

Figure 3. Increase in likelihood of hip fracture (hip BMD) or fatal myocardial infarction (LDL cholesterol) for each SD change (age adjusted)[3,4]

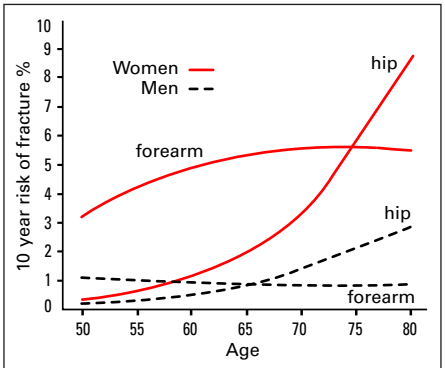

Figure 4. Differences in 10 year fracture risk rates with age at the hip and forearm between women and men[5]

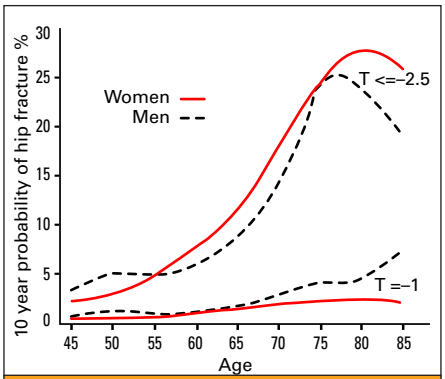

Figure 5. 10 year probability of hip fracture at different ages for both women and men[6]

same site and in the same patient may differ significantly when measured on different DEXA instruments. Conversion of BMD values to T-scores decreases some of this instrument bias, but to minimise variability (diagnostic and monitoring) determinations should be made on the same DEXA instrument.

Other factors that may affect DEXA BMD values include significant weight change and absolute body size (the BMD of slight, short people may be underestimated; for large framed tall people the opposite occurs).[9,10] The measurement variance associated with a particular DEXA machine must also be considered. Variability can be allowed for by recognising that 'real' or significant changes in serial BMD values are most likely to be associated with absolute changes greater than 0.055 and 0.045 g/cm2 at the spine and hip respectively.[11] This equates to serial BMD changes of about 4–7% depending on the baseline BMD value.

Finally, the effects of therapy on fracture risk may be considerably greater than predicted by any respective BMD change. For example re-analysis of major prospective trials, but based on individual patient data, consistently show that BMD changes explain only a small proportion the overall antifracture effect.[12,13]

Osteopaenia, osteoporosis, low BMD – what's in a name?

The 1991 original definition of osteoporosis was: 'the systemic skeletal disease characterised by low bone mass, and micro-architectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture'. This was later broadened to include the T-score concept by defining, as osteoporotic, any postmenopausal caucasian woman with a T-score ≤–2.5 at the hip.[1] To alert clinicians to the progressive decline in BMD, the category osteopaenia was also introduced as a T-score between –1.0 to –2.5. Additionally, patients with a fragility fracture, regardless of their T-score, were also defined as having osteoporosis.

When is BMD subsidised by Medicare?

The Australian Department of Health and Ageing[14] has established the following as prerequisites for reimbursement of DEXA scanning:

- the presence of clinical conditions associated with secondary osteoporosis (*Table 1*):
  - initial scan – all
  - follow up scans – minimum 1 and 2 year intervals under categories A and B respectively
  - 1 year following a significant change in therapy
  - Medicare reimbursement is unrelated to the T- or Z-score values
- No specified clinical condition is present (*Table 1*)
  - initial DEXA scan – only when there is a 'presumptive diagnosis of low BMD' defined by the presence of one or more fractures with minimal trauma
  - subsequent scans – 1 year after 'low BMD' (T-score below –2.5 or Z-score below –1.5) is established from the initial DEXA or QCT scan in which both lumbar spine and proximal femur are measured. Thereafter, every 2 years or after 1 year if a significant change in therapy occurs. If the presumptive diagnosis of low BMD definition applies – every 2 years or after 1 year if a significant change in therapy occurs.

What is needed for PBS subsidy of bone protective medication?

Bone mineral density measurements are not required. The authorisation for the bone protective medication (bisphosphonate, calcitriol or raloxifene) requires radiological evidence (plain X-ray, QCT or MRI) of fracture with minimal trauma.[15] Beneficiaries of the Department of Veterans Affairs can be prescribed alendronate (Actonel) if expected to be on continuous glucocorticoid therapy (>7.5 mg/day) prednisolone for at least 3 months and have a T-score <–1 (threshold for osteopaenia). Note that in May 2005, prescriptions of calcium supplements (Caltrate, Citracal and Cal-Sup) to treat 'osteoporosis' (never defined) were removed from the PBS.

Summary of important points

- BMD is useful to diagnose osteoporosis, assess future fracture risk and monitor treatment.
- Reports include:
  - absolute BMD: to assess change compared to previous scan

Table 1. Medical conditions associated with Medicare eligibility for DEXA measurements[14]

Category	Medical condition
A	Prolonged glucocorticoid therapy
	Conditions associated with excess glucocorticoid secretion
	Male hypogonadism
	Female hypogonadism lasting more than 6 months before the age of 45 years
B	Primary hyperparathyroidism
	Chronic liver disease
	Chronic renal disease
	Proven malabsorption disorders
	Rheumatoid arthritis
	Conditions associated with thyroxine excess

  - T-score: to define bone status as normal (≥–1 and ≤+1), osteopaenia (between –1.0 and –2.5) or osteoporosis (<–2.5)
  - Z-score: to assess likelihood of underlying medical cause of bone loss.
- BMD decreases by 10% in the decade following menopause in women not receiving hormone therapy, while the bone rate loss remains very low in men until 70 years of age.
- BMD, age, gender, and fracture history predict fracture risk, with the risk greatly increasing at older age and with fracture history.
- Patients with the medical conditions listed in *Table 1* should be referred for a DEXA scan.
- BMD should ideally be measured on the same machine to minimise variability. Changes of about 0.050 g/cm2 (ie. 4–7% depending on the baseline BMD value) are likely to be associated with clinically significant BMD change.
- BMD measurement is subsidised in those with 'presumptive low bone mineral density' (fracture with minimal trauma) and those with clinical conditions predisposing to osteoporosis (*Table 1*); every 2 years for monitoring osteoporosis, and 1 year after significant change in therapy.
- BMD is not required for PBS subsidy for bone protective medication. However, radiological evidence of fracture with minimal trauma is.

Conflict of interest: none.

References

1. The WHO Study Group. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Geneva: World Health Organisation, 1994.
2. Looker AC, Wahner HW, Dunn WL, et al. Updated data on proximal femur bone mineral levels of US adults. Osteoporos Int 1998;8:468–89.
3. Marshall D, Johnell O, Wedel H. Meta-analysis of how well measures of bone mineral density predict occurrence of osteoporotic fractures. BMJ 1996;312:1254–9.
4. Walldius G, Jungner I, Holme I, et al. High apolipoprotein B, low apolipoprotein A-I, and improvement in the prediction of fatal myocardial infarction (AMORIS study): A prospective study. Lancet 2001;358:2026–33.
5. Van Staa TP, Dennison EM, Leufkens HG, Cooper C. Epidemiology of fractures in England and Wales. Bone 2001;29:517–22.
6. Kanis JA, Johnell O, Oden A, Jonsson B, Dawson A, Dere W. Risk of hip fracture derived from relative risks: an analysis applied to the population of Sweden. Osteoporos Int 2000;11:120–7.
7. Delmas PD, Genant HK, Crans GG, et al. Severity of prevalent vertebral fractures and the risk of subsequent vertebral and nonvertebral fractures: results from the MORE trial. Bone 2003;33:522–32.
8. Lu Y, Ye K, Mathur AK, Hui S, Fuerst TP, Genant HK. Comparative calibration without a gold standard. Stat Med 1997;16:1889–905.
9. Tothill P. Dual energy X-ray absorptiometry measurements of total-body bone mineral during weight change. J Clin Densitom 2005;8:31–8.
10. Nielsen SP. The fallacy of BMD: a critical review of the diagnostic use of dual X-ray absorptiometry. Clin Rheumatol 2000;19:174–83.
11. Phillipov G, Seaborn CJ, Phillips PJ. Reproducibility of DXA: potential impact on serial measurements and misclassification of osteoporosis. Osteoporos Int 2001;12:49–54.
12. Li Z, Chines AA, Meredith MP. Statistical validation of surrogate endpoints: is bone density a valid surrogate for fracture? J Musculoskelet Neuronal Interact 2004;4:64–74.
13. Watts NB, Cooper C, Lindsay R, et al. Relationship between changes in bone mineral density and vertebral fracture risk associated with risedronate: greater increases in bone mineral density do not relate to greater decreases in fracture risk. J Clin Densitom 2004;7:255–61.
14. Department of Health and Ageing. Medicare Benefits Schedule Book. Canberra: Commonwealth of Australia, 2004;127–8.
15. Department of Health and Ageing. Schedule of Pharmaceutical Benefits for Approved Pharmacists and Medical Practitioners. Canberra: Commonwealth of Australia, 2005;233–5.

afp CORRESPONDENCE email: afp@racgp.org.au