Metacarpal bone mass in the white and coloured populations of the Cape

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Summary

Morphometric measurements (radiogrammetry) of metacarpal cortical bone from fine-grain radiographic film using a magnifying eyepiece (magnification radiogrammetry) is a simple, inexpensive, reproducible and well-accepted method for assessing appendicular bone mass. Normal values for different countries and ethnic groups must first be established before this method can be applied in clinical practice. The need for normative data in South African coloured and white populations prompted this study.

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A decreased bone mass (osteopenia) is regarded as the most important, although not the sole, cause of fractures in man.[1-11] Radiological osteopenia does not usually denote a specific diagnosis, but identifies those individuals at risk and indicates the need for further investigations (e.g. biochemistry, undecalcified bone histology) in order to define the underlying skeletal disorder (e.g idiopathic or secondary osteoporosis, osteomalacia, hyperparathyroidism). The need for an accurate, preferably non-invasive method for the *in vivo* quantitation of bone mass is apparent. Bone mass is, however, not a static parameter, and about 15 - 20% of skeletal tissue is lost between middle and old age in 'normal' men and women.[1-6] Since sex, race and population differences may exist in the pattern of this age-dependent bone loss, it has become necessary to establish normative data for the bone mass of a given population and area before the clinical diagnosis and management of patients with suspected metabolic bone disease can be undertaken.[1-6] It was the lack of such published data for the white and coloured populations of the Cape which prompted this study.

Visual inspection of a standard radiograph is the simplest means of estimating bone mass. This method is, however, subjective and inaccurate since more than 30% of skeletal mass must be lost before osteopenia can be detected by casual inspection.[3] Likewise, use of the 'Singh index' (pattern of femoral neck trabeculae) or 'spine index' (ratio of central to peripheral height of vertebral bodies) are unreliable for the early detection of uncomplicated osteopenia. Morphometric measurements (radiogrammetry) of cortical bone from standard X-ray films (conventional radiogrammetry) are also easy to perform and yield more reliable information.[3-8] Magnification radiogrammetry (usually employing industrial fine-grain radiographic film and a simple magnifying eyepiece) further improves accuracy and is also useful in conditions where bone loss is caused predominantly from intracortical, and not endosteal, resorption.[3] The tubular bones of the appendicular skeleton, including the metacarpals, proximal radius, humerus and femur are best suited for the determination of cortical thickness or derived (e.g. ratio of cortical thickness to external shaft width) cortical measurements. The most widely used radiogrammetric measurement is undoubtedly that of the mid-shaft of the second metacarpal. Introduced by Barnett and Nordin,[4] this technique was later extensively studied by Garn *et al.*,[5,6] and others.[7,8]

Subjects and methods

A total of 1 141 white (281 females, 278 males) and coloured (273 females, 309 males) subjects, aged 10 - 80 years, were studied. Subjects were recruited from the hospital staff, visitors or selected outpatients. Before entering the study each subject completed a questionnaire; individuals with known bone disease, endocrinopathies, long-term chronic systemic diseases or patients receiving medication were excluded from the study; no patient had been subjected to prolonged immobilisation or had sustained a fracture during the 6-month period before the study.

Fine-detail postero-anterior hand radiographs were taken at a uniform 1 m tube to film distance. We used a CGR X-ray tube with a 0,2 mm focal spot and 2 mm A1 equivalent total filtration, Kodak min R films, and single emulsion fine-grain screens. Processing was done with a Kodak RP X-Omat processor.

Before any measurements were taken, the hand radiograph was examined for signs of subperiosteal resorption (suggestive of hyperparathyroidism) or abnormal intracortical striations (a sign of increased bone turnover). Furthermore, any signs of chronic disease, including rheumatoid arthritis, osteo-arthritis, gout or previous fractures, disqualified the use of the radiograph.

The length of the second metacarpal bone of each hand was measured with a millimetre rule (Fig. 1). Using a 6-power magnifier with a built-in millimetre scale (Leitz measuring magnifier with mm scale; divisions 0,1 mm), the outer shaft (D) and medullary (d) diameters were measured (to the nearest 0,05 mm) at the midpoint of the shaft at right angles to the long axis of the bone (Fig. 1). These measurements permitted simple calculation of the combined cortical thickness (C = D – d) and the Barnett-Nordin index (C/D x 100) in each case. The Barnett-Nordin index, a parameter of relative bone mass, compensates largely for differences in skeletal size and for variations in tube-to-film or hand-to-film distance. The readings of the two hands were averaged.

The reproducibility of measurements was also evaluated by calculating the Spearman correlation coefficients for interobserver and intra-observer variations.

Results

The mean (± SD) external shaft width (D), medullary diameter (d), combined cortical thickness (C), and Barnett-Nordin index (C/D x 100) values obtained in the white and coloured male and female groups are shown in Tables I - IV and Fig. 2.

It is clear that in all groups studied the external shaft diameter (D) increased with advancing age because of periosteal apposition of bone (Fig. 2). The metacarpal cortical thickness (C) achieved its peak value at age 25 - 35 years and after age 40 - 50 years C declined steadily. The rate of bone loss was more pronounced in

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COMBINED CORTICAL THICKNESS :

$$C = D - d = C_1 + C_2$$
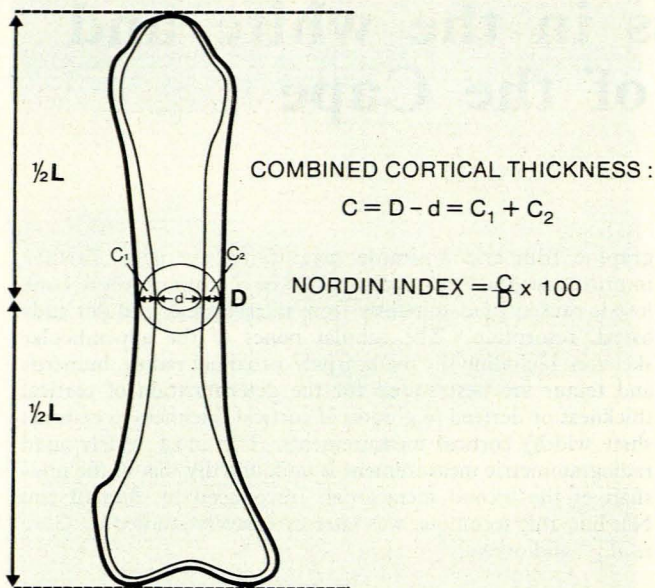
$$\text{NORDIN INDEX} = \frac{C}{D} \times 100$$

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Fig. 1. Measurement of the external shaft diameter (D) and the width of the marrow cavity (d) at the midpoint of the second metacarpal bone, allows simple calculation of the combined cortical thickness (C = D − d = C₁ + C₂) and the Barnett-Nordin index (C/D x 100).

women than in men and, while it levelled off in older males, it decreased progressively in females (Fig. 2).

In comparing the mean combined cortical thickness (C) of the coloured and white males, significantly ($P < 0,02$) lower values were obtained in the coloured population (Fig. 2). Similar lower values ($P < 0,02$) were documented in coloured females aged 20 -50 years, compared with white females of similar age. The mean external shaft width (D) of the coloured population was, however, also lower, resulting in comparable Barnett-Nordin indices in these two population groups.

Fig. 3 compares the Barnett-Nordin indices obtained in the white male and female subjects with published normal values for the USA, Guatemala and El Salvador.[12] It is clear that there is a trend for the relative cortical thickness values documented in the present study to be lower than those reported for the other three population groups. This was evident in males at all ages, and in females below the age of 50 years; in older females no difference in the Barnett-Nordin indices of the four populations was apparent (Fig. 3).

The reproducibility of measuring C was found to be satisfactory, as evidenced by the good correlation coefficients for interobserver ($r = 0,89$) and intra-observer ($r = 0,90$) variations.

Discussion

Osteopenia, a term coined by Meema and Meema[3] to denote a significant decrease in the bone mass of subjects of a particular age, sex and race, is usually the result of osteoporosis, although

TABLE I. METACARPAL BONE MASS DATA — WHITE MALES (MEAN ± SD)

Age (yrs)	No. of subjects	D (mm)	d (mm)	C (mm)	Barnett-Nordin index (%)
10-19	42	8,90 ± 0,93	4,79 ± 0,93	4,11 ± 0,87	46,20 ± 8,65
20-29	45	9,42 ± 0,79	4,31 ± 1,00	5,11 ± 0,72	54,53 ± 8,37
30-39	31	9,58 ± 0,82	4,35 ± 0,87	5,24 ± 0,58	54,92 ± 6,84
40-49	42	9,68 ± 0,70	4,37 ± 0,98	5,31 ± 0,73	55,06 ± 8,14
50-59	35	9,45 ± 0,65	4,49 ± 0,69	4,96 ± 0,55	52,60 ± 5,66
60-69	45	9,76 ± 0,94	5,17 ± 1,05	4,59 ± 0,62	47,35 ± 7,13
70-90	38	9,70 ± 0,73	5,01 ± 0,98	4,68 ± 0,88	48,38 ± 9,17

D = external shaft diameter; d = marrow cavity width; C = combined cortical thickness (D − d); Barnett-Nordin index = C/D x 100.

TABLE II. METACARPAL BONE MASS DATA — WHITE FEMALES (MEAN ± SD)

Age (yrs)	No. of subjects	D (mm)	d (mm)	C (mm)	Barnett-Nordin index (%)
10-19	40	7,81 ± 0,68	3,77 ± 0,78	4,05 ± 0,69	51,90 ± 8,49
20-29	47	7,91 ± 0,63	3,10 ± 0,92	4,79 ± 0,68	61,02 ± 9,63
30-39	31	8,36 ± 0,52	3,20 ± 0,90	5,16 ± 0,75	61,93 ± 9,82
40-49	41	8,25 ± 0,61	3,23 ± 0,84	5,02 ± 0,63	61,09 ± 8,45
50-59	43	8,32 ± 0,58	3,78 ± 0,79	4,53 ± 0,54	54,80 ± 7,56
60-69	36	8,33 ± 0,55	4,29 ± 0,80	4,04 ± 0,69	48,55 ± 8,22
70-90	44	8,47 ± 0,78	5,26 ± 0,90	3,21 ± 0,97	37,50 ± 13,77

TABLE III. METACARPAL BONE MASS DATA — COLOURED MALES (MEAN ± SD)

Age (yrs)	No. of subjects	D (mm)	d (mm)	C (mm)	Barnett-Nordin index (%)
10-19	47	8,36 ± 0,88	4,27 ± 0,90	4,10 ± 0,76	49,12 ± 8,49
20-29	54	8,90 ± 0,69	4,19 ± 1,01	4,72 ± 0,60	53,39 ± 8,63
30-39	39	9,10 ± 0,83	4,22 ± 1,17	4,88 ± 0,72	54,18 ± 9,77
40-49	40	8,89 ± 0,70	4,00 ± 1,08	4,88 ± 0,73	55,36 ± 10,07
50-59	49	9,12 ± 0,77	4,49 ± 1,00	4,63 ± 0,63	51,14 ± 8,11
60-69	42	8,89 ± 0,70	4,47 ± 0,81	4,42 ± 0,62	49,85 ± 7,04
70-90	38	9,30 ± 0,85	5,00 ± 1,05	4,29 ± 0,87	36,36 ± 9,23

TABLE IV. METACARPAL BONE MASS DATA — COLOURED FEMALES (MEAN ± SD)

Age (yrs)	No. of subjects	D (mm)	d (mm)	C (mm)	Barnett-Nordin index (%)
10-19	37	7,38 ± 0,61	3,39 ± 0,70	3,98 ± 0,62	54,09 ± 7,90
20-29	60	7,80 ± 0,62	3,38 ± 0,84	4,43 ± 0,53	57,11 ± 8,63
30-39	38	7,96 ± 0,68	3,15 ± 0,96	4,81 ± 0,66	60,82 ± 9,80
40-49	47	8,01 ± 0,56	3,49 ± 0,88	4,52 ± 0,60	56,70 ± 8,76
50-59	44	8,06 ± 0,61	3,65 ± 0,82	4,41 ± 0,66	54,91 ± 8,43
60-69	32	8,15 ± 0,59	4,33 ± 0,96	3,83 ± 0,79	47,14 ± 10,17
70-90	15	8,02 ± 0,68	4,65 ± 0,75	3,37 ± 0,50	42,14 ± 6,28
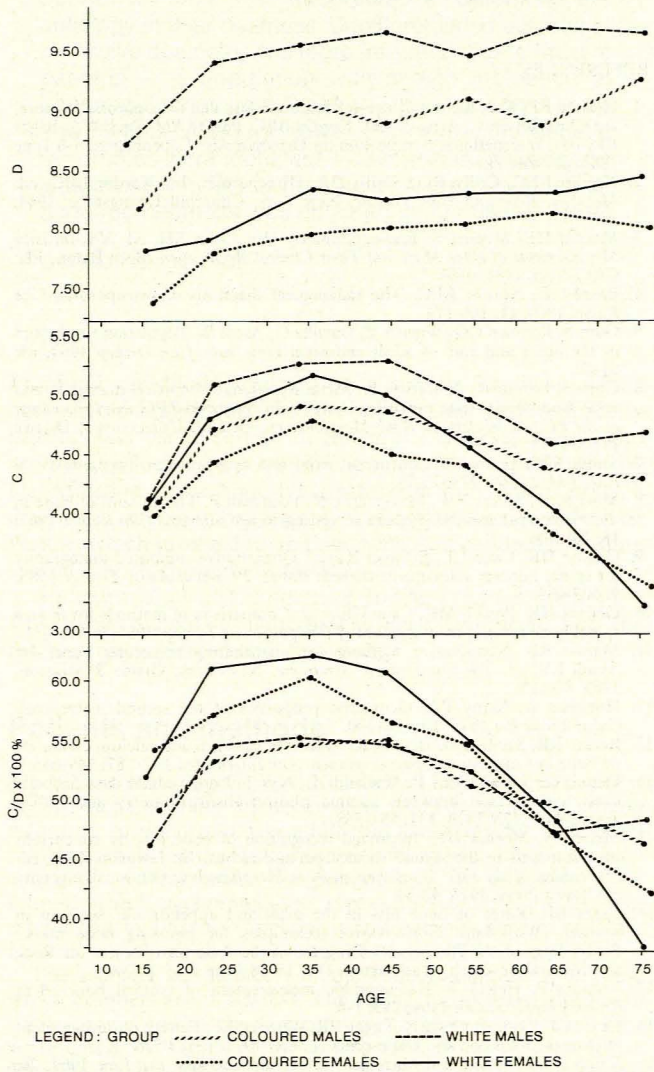
Fig. 2. Mean values for the external shaft diameter D (top), the combined cortical thickness C (middle), and the Barnett-Nordin index C/D x 100 (bottom), in the four groups studied (//// = coloured males; .... = coloured females; ---- = white males; ——— = white females).
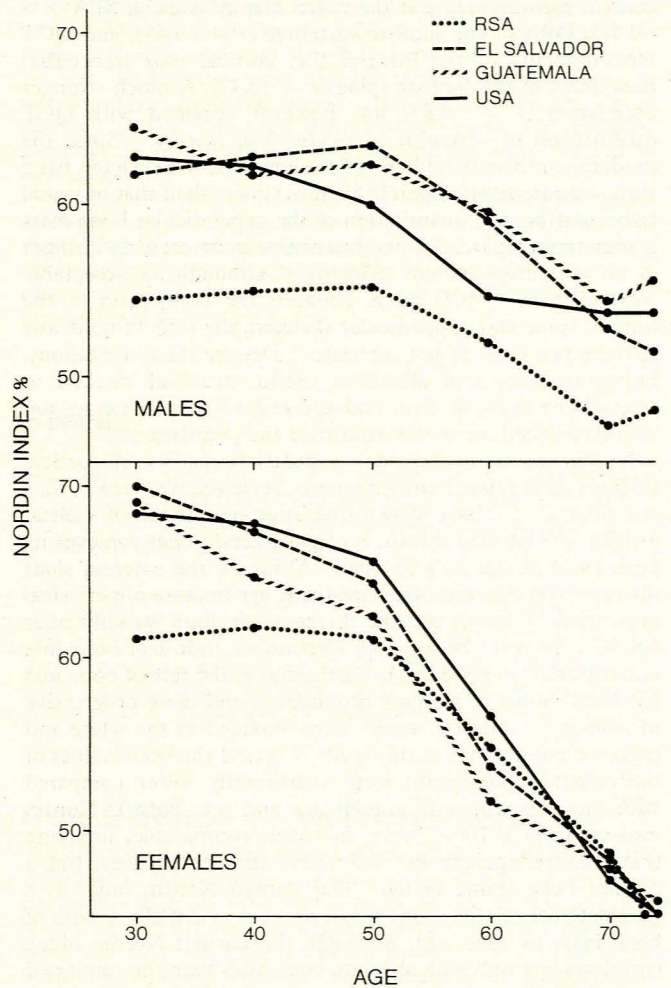

Fig. 3. Comparison of the Barnett-Nordin indices (C/D x 100) obtained in white South African males and females with published normal values for the USA, El Salvador and Guatemala.

osteomalacia, hyperparathyroidism or combinations of these so-called metabolic bone diseases may also be involved. A variety of *in vivo* techniques have recently been developed to quantify bone mass and to confirm the presence of osteopenia. The use of total- and partial-body neutron activation, Compton scattering, ultrasonography and nuclear magnetic resonance imaging is still in an experimental stage.[3] Single and dual photon absorptiometry (SPA/DPA) and quantitative computed tomography (QCT) are, however, more established techniques, used to quantitate bone mass with a precision and accuracy error of less than 5%.[9-11] Moreover, DPA and QCT are also capable of measuring the predominantly trabecular bone mass (with its high level of metabolic activity, resulting in earlier changes in bone mass) of the axial skeleton. These methods are, however, expensive and not readily available at most centres.

Mid-metacarpal radiogrammetry is a simple, inexpensive, universally applicable and reproducible method to measure appendicular cortical bone mass, with little intra- and inter-observer error, as shown by us and others.[3-8] The combined cortical thickness is reasonably well correlated ($r = 0,68$) with

absolute bone mass,[12] and radiogrammetry is generally adequate for the study of age-related bone loss, particularly in women.[13,14] The diagnostic sensitivity of this method can be further improved by concurrent measurements in two bones, such as the second metacarpal plus the radius.[15] Magnification radiogrammetry, used in this study, improves accuracy and also allows quantitative evaluation of intracortical porosity and the detection of high turnover osteopenia (e.g. in hyperparathyroidism, thyrotoxicosis, chronic acidosis, immobilisation and acromegaly), where bone loss occurs predominantly from increased intracortical resorption.[3]

In correlating various techniques with the radiological severity of vertebral fracture,[10] radiogrammetry ($r = -0,51$) has been shown to compare favourably with bone mineral content measurements at the radial diaphysis using SPA ($r = -0,41$), DPA of the lumbar vertebrae ($r = -0,47$), and QCT measurements of the integral (i.e. cortical plus trabecular) bone mass of the lumbar spine ($r = -0,47$). A much stronger correlation ($r = -0,83$) was however obtained with QCT quantitation of vertebral *trabecular bone density*.[10] Since the predominantly cortical bone of the appendicular skeleton has a turnover rate approximately 8 times slower than that of spinal trabecular bone,[10] quantitation of the appendicular bone mass is sometimes regarded as too insensitive to detect early changes in an individual patient. Moreover, although an acceptable correlation ($r = 0,7$) exists between the bone mass of the lumbar spine and appendicular skeleton, the *rates* of bone loss at these two sites do not correlate.[16] Despite these limitations, radiogrammetry still affords a useful, practical method to assess bone mass *in vivo*, and age-related normal ranges are well established for several countries and populations.[3-6,15-18]

Numerous cross-sectional population studies of cortical thickness and related measurements, reviewed by Garn *et al.*[5,6] and others,[3,7,8,12] have shown that after completion of skeletal growth, the cortical thickness of peripheral bones achieves its peak value at age 30 - 35 years. Although the external shaft diameter (D) increases with advancing age because of periosteal apposition of bone, cortical thickness declines steadily after age 45 - 50 years because age-dependent endosteal bone loss outstrips any increase in D. Furthermore, the rate of bone loss has been shown to be more pronounced and more progressive in women.[3-15] Similar results were obtained in the white and coloured populations in this study. Cortical thickness values of the coloured population were significantly lower compared with those of whites of similar age and sex. Barnett-Nordin indices (C/D x 100%) were, however, comparable, implying that coloured people not only have thinner cortices, but a smaller bone frame *in toto*. The Barnett-Nordin index is a parameter of relative bone mass, i.e. it is essentially a ratio of bone mass to bone size. Although the Barnett-Nordin index correlates less well with absolute bone mass than the combined cortical thickness,[12] sex, racial and methodological differences are largely eliminated making this a more suitable parameter for comparative purposes. A trend for the Barnett-Nordin indices documented in this study to be lower than those

reported for populations in the USA and Central America was also observed. Although the reason for this apparent disparity is unclear, and could involve differences in methodology, subject populations studied and/or true metacarpal bone mass, it does underscore the need to establish normative data for the bone mass of a given population and area.[1-6,19]

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