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A population study of the screening potential of assessment of trabecular pattern of the femoral neck (Singh index): the Chingford Study

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Abstract

The trabecular pattern of the femoral neck (Singh index) has been used as a measure of osteopenia and fracture risk but the value of this method is controversial. This study assessed the usefulness of the Singh index (SI) by using dual energy X-ray absorptiometry (DXA) as the "gold standard". 659 Caucasian women (45–70 years) from an age–sex register of a general practice had their femoral neck and lumbar spine bone densities measured by DXA and had antero–posterior hip X-rays performed which were then categorized into six osteopenia grades using the SI method. The intraobserver and interobserver reproducibility of this method was good (kappa = 0.64 and 0.61, respectively). The SI grades correlated significantly with body mass index ($r = 0.35$) and age ($r = 0.17$) ($p < 0.001$). The mean femoral neck and lumbar spine bone densities were significantly higher with increasing SI grade even after adjustment for age and body mass index ($p < 0.001$). The proportion of subjects below the fracture threshold (2 SD below mean peak bone mass) decreased with increasing SI grade, ranging from 100% in SI grade 2 to 16.8% in SI grade 6. There was, however, wide overlap of bone densities between the grades. Using the criteria "osteoporosis ⩽ SI grade 4", the sensitivity and specificity of the SI method diagnosing low bone mass was 35.1% and 90.0%, respectively. These data suggest that the SI is a reproducible tool which may detect differences in bone mass between populations or subgroups within populations, although caution should be used in classifying individual patients because of the wide variation in bone density. The method has a low sensitivity but a relatively high specificity in diagnosing low bone mass.

Osteoporotic fractures are a major public health problem in developed countries in terms of morbidity, mortality and cost, with bone mineral density (BMD) being a major determinant of future fracture risk [1, 2]. Therapies for prevention and treatment of osteoporosis are now available, making the diagnosis of low bone density a desirable goal [3].

Dual energy X-ray absorptiometry (DXA) is presently thought to be the optimum method of measuring bone mass but is expensive and confined to only a few specialist centres. Conventional radiography is widely available and inexpensive but has a low sensitivity in diagnosing osteopenia and traditionally it is thought that at least 30% of bone mass must be lost before osteopenia is radiologically detectable [4–6].

A radiological method of grading of the trabecular bone content of the femoral neck was proposed in 1970 [7] and since then this trabecular pattern (Singh index) has been used as a measure of bone loss and osteopenia grading, although there is considerable controversy concerning its usefulness [8–20]. The aim of this study was to compare the Singh index (SI) gradings with bone density measurements using DXA as the "gold standard" in a population of "normal women".

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Methods

The subjects used were from the Chingford population study which has been described in detail elsewhere [21]. The study involves 1003 Caucasian women seen initially in 1988–1990. The population is similar to the UK in terms of social class, height, weight and smoking habits. Radiographs and bone densitometry of the hip were obtained at the second annual visit. Complete data on X-rays and bone densitometry were available on 659 women (mean age 52.8 (SD = 5.8); range 45–70 years). Ethical approval was obtained from the Waltham Forest District ethical committee.

DXA (Hologic QDR/1000W) was used to measure bone density of the lumbar spine (LSBMD) (L1–L4) and the femoral neck (FNBMD). The precision of this method in our hands has coefficients of variation of 0.66% and 1.38%, respectively (based on repeated observations of 20 subjects). Other regions of the proximal femur were also measured including Ward's triangle, trochanteric, intertrochanteric and "total hip".

Antero–posterior hip radiographs were performed by the same radiographer using the same equipment with a standard focus to film distance of 100 cm and 15° internal rotation. The hip radiographs were categorized into six osteopenia grades using the Singh index method [7] (Figure 1) by a trained observer blinded to the BMD and other clinical data. The intraobserver and interobserver reproducibility (kappa) of this method was calculated by two observers, blinded to each other's and their own first findings, reading 25 radiographs of varying SI grades twice, 1 month apart, and the results analysed using a kappa statistical package adapted for a personal computer [22].

The results were analysed using the statistical package SPSS. Mean BMDs in each SI grade were calculated. Osteoporosis for the purposes of this study was defined as bone mass less than 2 standard deviations below the mean peak bone mass (fracture threshold), which in the population studied = 0.695 g cm^{-2} for femoral neck. This fracture threshold was used to calculate the sensitivity and specificity of the Singh index method in diagnosing low bone mass.

Results

The intraobserver and interobserver reproducibility (kappa) of the SI method of grading osteopenia was 0.64 (95%CI = 0.58–0.70) and 0.61 (95%CI = 0.55–0.67), respectively.

The distribution of the SI grades is shown in Table I. No subject was classified as SI grade 1 and only two subjects as grade 2. The SI grades significantly correlated with body mass index (BMI) ($r = 0.35$, $p < 0.001$), age ($r = -0.17$, $p < 0.001$), FNBMD ($r = 0.36$, $p < 0.001$) and LSBMD ($r = 0.33$, $p < 0.001$). The mean FNBMDs were significantly lower with decreasing SI grades (Table I) ($p < 0.001$), with FNBMD in SI grade 2 being 31.0% (95%CI = 26.4–35.6%) lower than in SI grade 6. This decrease in FNBMDs remained significant after adjustment for body mass index and age using analysis of covariance ($p < 0.001$). Similarly the mean BMDs of all areas of the hip measured and the LSBMD were significantly lower with decreasing SI grade (Table I) ($p < 0.001$). Using multiple regression analysis, age, BMI and SI were significantly independently associated with FNBMD ($p < 0.001$). SI explained 13% of the total variance in FNBMD after adjustment for age and BMI.

Within each SI grade there was a wide variation of

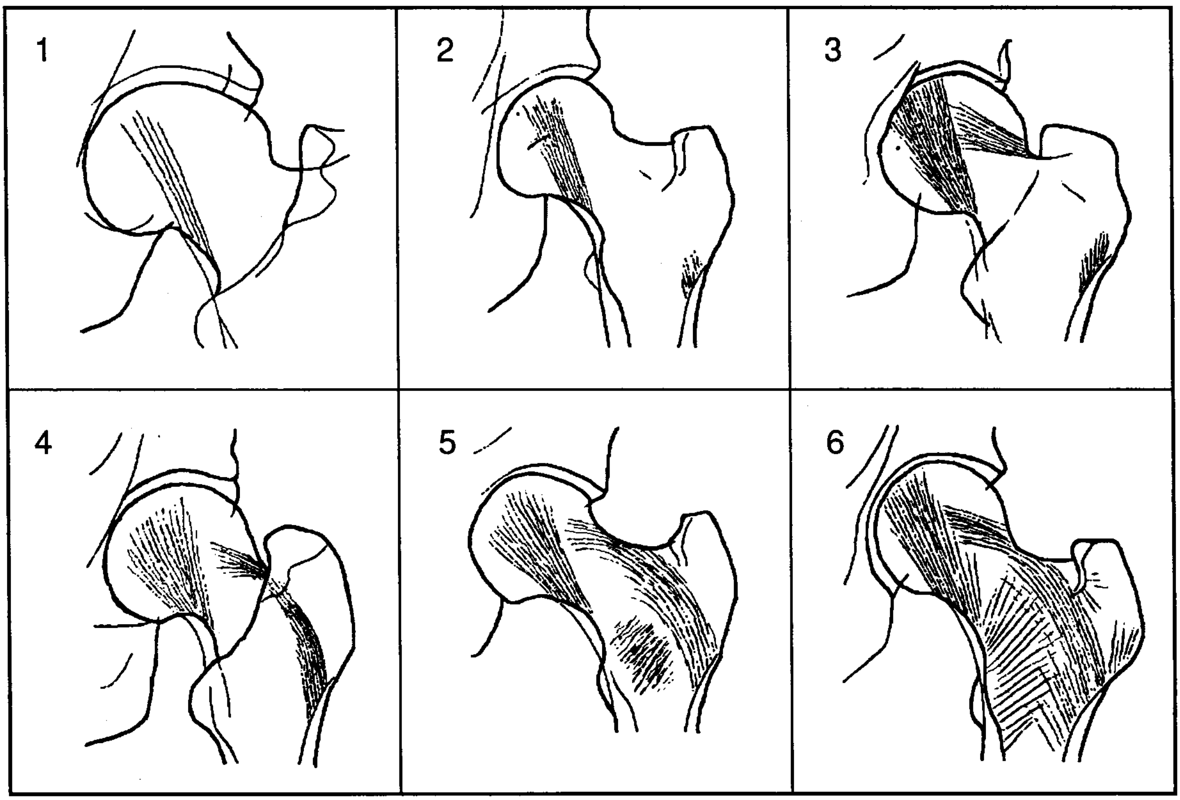

Figure 1. Trabecular pattern of the femoral neck: the Singh index grades.

Table I. Singh index (SI) by proximal femur and lumbar spine BMDs and percentage below fracture threshold (FT)

SI grade (*n*)	SI 1 (0)	SI 2 (2)	SI 3 (33)	SI 4 (89)	SI 5 (220)	SI 6 (314)
Femoral neck BMD	—	0.561	0.682	0.707	0.747	0.813
(SE)		(0.022)	(0.018)	(0.011)	(0.007)	(0.007)
% below FT	—	100	60.6	51.7	33.2	16.8
(*n*)		(2)	(20)	(46)	(73)	(53)
Trochanteric BMD	—	0.527	0.617	0.637	0.670	0.717
(SE)		(0.003)	(0.019)	(0.011)	(0.007)	(0.006)
Intertrochanteric BMD	—	0.817	0.909	0.978	1.026	1.100
(SE)		(0.002)	(0.025)	(0.016)	(0.011)	(0.009)
Ward's BMD	—	0.417	0.510	0.541	0.572	0.645
(SE)		(0.040)	(0.022)	(0.013)	(0.008)	(0.008)
Total hip BMD	—	0.692	0.786	0.828	0.874	0.936
(SE)		(0.012)	(0.022)	(0.013)	(0.007)	(0.008)
Lumbar spine BMD	—	0.857	0.890	0.890	0.956	1.025
(SE)		(0.013)	(0.023)	(0.012)	(0.008)	(0.008)

FNBMDs (Figure 2). The proportion of subjects below the fracture threshold decreased with increasing SI grade, ranging from 100% in SI grade 2 to 16.8% in SI grade 6 (Table I). Assuming for the purposes of this study that the DXA method of measuring bone mass is the gold standard and defining osteoporosis as BMD below the so called "fracture threshold", and using SI criteria "osteoporosis = SI grade 4 or less" the sensitivity and specificity of the SI method in diagnosing osteopenia are 35.1% and 90%, respectively (Table II). There is some debate on whether SI grade 4 represents clinically significant bone loss or whether it could be within normal limits for slight individuals [8]. If the SI osteoporosis criterion is changed to "osteoporosis = SI grade 3 or less" the sensitivity of the SI method in diagnosing osteopenia decreases to 11.3% but the specificity increases to 97.2%.

Discussion

The trabeculae in the upper end of the femur of normal individuals are arranged along the lines of compression and tension stresses produced in the bone during weight bearing. Singh et al devised their index of osteopenia grading after showing a good correlation between histological osteopenia grading of iliac crest biopsies and trabecular pattern grading of contralateral hip X-rays in 35 patients aged over 50 years [7]. Further studies assessing the SI histopathologically and correlating it with fractures and bone mineral content and density have shown conflicting results.

Using ashing studies on 62 excised femoral heads, Cooper et al found a positive correlation between the weight to volume ratio of the ash and the SI grade [9]. Wilkinson et al found a good correlation between the SI

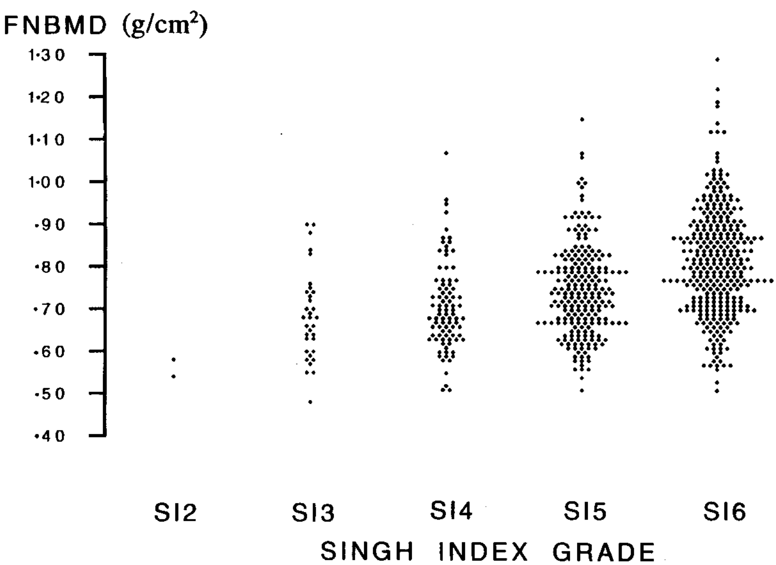

Figure 2. FNBMD by SI grade.

Table II. Diagnosing osteopenia: DXA method (defined as BMD below fracture threshold) by X-ray (Singh) method (defined as grade 4 or less)

		DXA method		
		OP	No OP	
X-ray method	OP	68	56	124
	No OP	126	409	535
		194	465	659

OP, osteopenia.

and force required to fracture the femoral neck in eight post mortems [10]. However, Robertson was unable to find a positive correlation between the SI and mineralized bone area in iliac crest bone biopsies on 100 subjects [11] and Wicks et al found the SI to be an unreliable predictor of bone content in 155 femoral heads [12].

Dequeker et al in a group of 90 women and Horsman et al in 116 women showed that the SI could distinguish hip fracture patients from age matched controls [13, 14]. Cooper et al showed that below the age of 75 years there was a steep increase in relative risk of hip fractures with reduced bone mass measured by the SI, whereas above that age the increase in risk was small, suggesting that in the latter age group a tendency to fall may be more important [15]. The SI has also been shown to separate people with spinal osteoporosis from controls, suggesting that trabecular bone loss may have an important causal role in vertebral fractures [16, 17]. However, Pogrund et al found the SI less useful. They could not correlate the SI with incidence of hip fracture and found the SI to be a less sensitive indicator of spinal osteoporosis than semi-quantative assessment of spinal X-rays [18]. Dequeker et al also failed to confirm a good correlation between vertebral compression fracture and the SI [13].

Khairi et al found that the bone mineral content (BMC) at radial sites (as measured by single photon absorption (SPA)) in 106 elderly women was significantly lower in patients with SI grade 4 or less when compared with grades 5 and 6. However, a 2–3 year follow-up of the patients showed that the radial bone mineral content was more useful than the SI grades in fracture prediction (all sites) [19]. Kranendonk et al found no significant correlation between SI and BMC of the radial shaft (measured by SPA) in 78 women [20]. Sartoris et al found no significant correlation between the SI and BMD measured by dual energy scanned projection radiography in 168 subjects [17]. Although Hubsch et al found a good correlation of SI with DXA measured BMD in a group of 18 male patients with suspected osteoporosis, there was a poor correlation in 98 females with suspected osteoporosis and in a group of 40 control subjects [23].

The evidence to date is therefore conflicting. Our study, which is more than twice as large as any previous such study in terms of numbers, shows a clear significant correlation between the Singh index grades and the DXA measured bone mineral density of the femoral neck as well as other areas of the proximal femur and the lumbar spine.

Our data show that the SI method of diagnosing osteopenia has a low sensitivity but a relatively high specificity, especially if a criterion is used where only SI grades 1–3 are considered "abnormal". Singh index grades 6 and 5 are thought to show normal bone histologically and are found in a normal population, whereas grades 1–3 represent stages of osteopenia. Grade 4 is ambiguous and may either be due to mild mineral loss or be within normal limits in small-framed subjects [8]. In the original description of the Singh grades, histologically grade 4 was considered to be the borderline between normal and osteoporotic subjects [7]. Our data are consistent with the above view. In SI grade 3 or less, 62.9% of subjects had a bone density below the fracture threshold whereas in SI grades 5 and 6 (combined) the proportion was 23.6%. In SI grade 4 the bone density in just over half of the subjects was below the fracture threshold.

The SI may be useful as an independent indicator of bone strength. Gluer et al have recently suggested that a combination of the SI, femoral neck and shaft cortex thickness and trochanteric region width can predict hip fracture at least as strongly as femoral neck bone density [24]. Hip axis length has also been suggested as an independent risk factor for hip fracture [25] and the SI together with hip axis length may also be a useful combination in hip fracture prediction.

In conclusion, our study suggests that the Singh index is a simple and reproducible epidemiological tool for measuring bone mass which may detect differences between populations or subgroups within populations, although caution should be used in classifying individual patients because of the wide overlap of bone mineral density between grades. The method has a low sensitivity but a relatively high specificity in diagnosing low bone mass. Any subject with a low SI grade (4 or less) should be considered for bone densitometry. The Singh index, which is dependent on bone structure, has a potential additive role in conjunction with bone mineral density measurements and other geometric and morphometric measurements in predicting fracture and this requires further study.

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