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Structural trends in the aging proximal femur in Japanese postmenopausal women

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Abstract

Hip structure analysis (HSA) can be used to measure proximal femur geometry using conventional DXA scans of the hip. This study is the first analysis of HSA data in Japanese women to evaluate apparent age trends in the geometry of cross-sectional regions in the proximal femur.

409 Japanese women aged from 50 to 93 years of age were measured by DXA at three sites (narrow neck, intertrochanter, shaft). Using the mean value those between 50–59 years as a reference value, age trends were evaluated using groupings of 5-year intervals and those over 80 as a single group.

BMD at three measured sites and section modulus (index of bending strength) at narrow neck declined in a similar age dependent manner, but section modulus at intertrochanter and shaft showed a different pattern. The decline in section modulus at narrow neck occurs after 50–59 years of age, whereas section modulus at intertrochanter remain 70–74 years, after that began to decrease. Section modulus at shaft, an uncommon fracture location, remains fairly static through life.

In conclusion, HSA in Japanese women showed that reduction in geometric strength, as reflected by the section modulus, was not dependent on decline in BMD.
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Keywords: Age trends; Cross-sectional geometry; Hip structural analysis; Japanese; Proximal femur; Section modulus

Introduction

The hip fracture rate in aging females in Japan has increased rapidly over the recent decade [1]. Areal bone mineral density (BMD) measured by dual-energy X-ray absorptiometry (DXA) is a valuable tool for the diagnosing bone fragility [2–4], and shows significant correlation between bone loss and the risk of fracture. Although patients with fragility fractures typically have lower BMD than unfractured controls, about half of the fractures occurred in women who would not be classified as osteoporotic by BMD criteria [5,6].

A DXA scanner generates a two-dimensional (2D) projection image of a bone with pixel values expressed in mineral area mass (g/cm^2), the conventional software averages pixel values over selected regions to measure BMD. Strength of bone is however governed by structural dimensions and tissue materials properties, neither of which is directly measured in a conventional BMD measurement. Beck and Ruff have applied the hip structure analysis (HSA) method to measure proximal femur geometry using conventional DXA scans [7]. HSA has been used to demonstrate age trends, racial and gender differences, and treatment effects on osteoporosis [8–12]. Similar geometric measurements have not been conducted on Japanese women, moreover the rate of hip fracture in Japan is different from that of Western countries and underlying causes may also differ. In fact, previous reports described that Asians have lower BMD than Caucasians, although hip fracture rates are generally lower in Asians [13–16]. Lower BMD in Asians than Caucasians is mainly dependent on their small bone size [17,18] and while BMD is bone size-dependent, current practice does not account for this fact.

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The purpose of this study was to gain some insight into the proximal femur geometry in Japanese women using the HSA method using a cross-sectional sample obtained from a clinical sample.

Materials and methods

Subjects

The data of BMD was acquired from our outpatient clinic for the screening of osteoporosis on 409 Japanese women aged from 50 to 93 years of age. The subjects with a history of hip fracture, illness or on medication known to affect bone metabolism were excluded from this study.

DXA scan

DXA scans of the left hip were taken by QDR4500 (Hologic, Waltham, MA, USA). The scan was performed using a commercially available hip positioner system (HPS; OsteoDyne, Durham, NC, USA) in order to ensure consistent positioning [19]. This device keeps the subject's legs positioned in abduction and internal rotation (15°). The percentage of coefficient of variation (%CV) for the total hip BMD measurement in our laboratory was 0.7%.

Hip structure analysis (HSA)

The archived DXA images were subsequently analyzed using the HSA method. This method is described in detail in earlier publications [7]. Briefly, DXA scan files were first converted into bone mass images in which pixel values represent bone mass in grams per square centimeter; using an automated program. Structural analysis was then done in image files using a special interactive computer program. The underlying principle of the method is that a line of pixels traversing the bone axis is a projection of the corresponding cross-section from which certain geometric properties can be derived. Three measured sites were defined as: (1) narrow neck, traversing the narrowest width of the femoral neck; (2) intertrochanter, along the bisector of the shaft and femoral neck axis; and (3) shaft, at a distance of 1. 5 times minimum neck width, distal to the intersection of the neck and shaft axes (Fig. 1).

The structural variables used in the paper were as follows [20,21]:

1. Areal BMD (g/cm^2) was measured using routine methods. Mean values of BMD from narrow neck region are on the average about 14% higher than the conventional Hologic neck ROI values on the same subjects, although age trends are similar in previous reports [9].
2. Cross-sectional area (CSA, cm^2): This is defined as the surface area of bone tissue in the cross-section after excluding soft tissue (marrow) spaces. CSA is derived from the integral of the bone mass profile and is not equivalent to the total area within the periosteal envelope as widely misinterpreted. CSA is an index of resistance to forces directed along the long axis of the bone.
3. Subperiosteal diameter was measured directly from the outer margins of the mass profile after correction for image blur.
4. Section modulus (cm^3): This is an index of resistance to bending forces and is calculated as CSMI/d_{max} where CSMI is the cross-sectional moment of inertia and d_{max} is the maximum distance from either bone edge to the centroid of the profile [21]. The CSMI is derived from the integral of the bone mass profile across the bone weighted by the square of distance from the center of mass. Due to limitations of a 2D DXA image, the CSMI and section moduli derived by HSA are only relevant for bending in the plane of the DXA image.
5. An estimate of cortical thickness was derived for the buckling ratio by first modeling the cortex as concentric circular (narrow neck and shaft) or elliptical (intertrochanter) annuli. The algorithm assumes that 60%, 70%, and 100% of the measured CSA is in the cortex for the narrow neck, intertrochanter, and shaft regions, respectively. The intertrochanter model also assumes that the anteroposterior outer diameter is the outer diameter of the shaft region measured in the scan plane [21].
6. Buckling ratio describes stable configurations of thin-walled tubes subjected to compressive loads and requires an estimate of the cortical thickness. The buckling ratio is computed as the ratio of d_{max} to the estimated mean cortical thickness.

In addition to these parameters, the HSA program measures neck–shaft angle and femoral–neck length. The latter is defined as the distance from the center of the femoral head to the intersection of the neck and shaft axes.

Table 1
Group characteristics

Age group (years)	Height (cm)	Weight (kg)	Body mass index (kg/m^2)	Neck–shaft angle (deg)	Neck length (cm)
50–59	152.8±5.5	49.4±7.6	21.1±2.8	129.8±5.7	4.56±0.54
60–64	152.2±5.1	49.2±7.0	21.2±2.8	130.0±4.9	4.72±0.51
65–69	151.1±6.2	50.4±8.3	22.0±3.2	129.9±5.2	4.72±0.48
70–74	149.2±5.9	49.7±7.3	22.4±3.5	129.1±4.7	4.84±0.48
75–79	148.1±4.9	50.6±8.3	23.4±3.0	129.1±4.4	4.74±0.56
80+	146.9±5.9	47.7±7.8	22.0±2.9	130.6±4.8	4.65±0.51
Total	150.6±5.8	49.8±7.5	21.9±3.1	129.9±4.9	4.71±0.52

Values are means±SE.

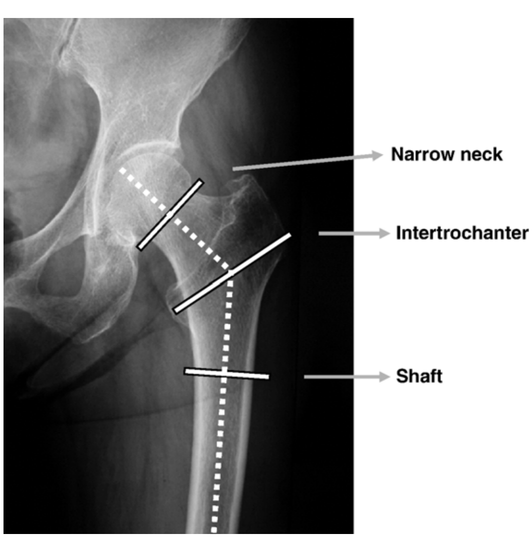

Fig. 1. Hip image from DXA scanner positions of narrow neck, intertrochanter, and shaft (not a Dxa image, DXA subtracts out soft tissues).

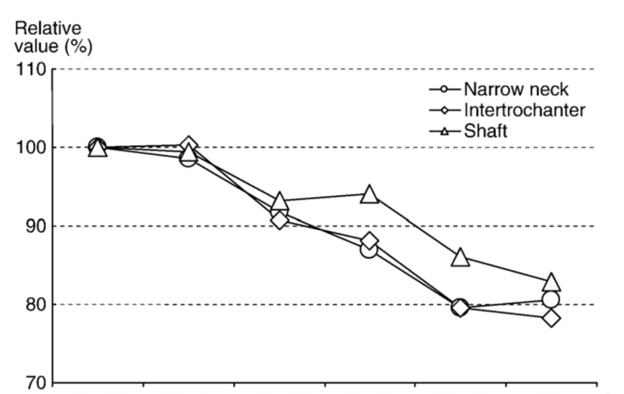

Fig. 2. Relative age trends in BMD at narrow neck, intertrochanter, and shaft. Values are expressed relative to those of the standard reference (50–59 years of age).

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