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Design Agency
United Kingdom

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User Design, Illustration and Typesetting offer a range of services: book design, book cover design, illustration (freehand, technical, redrawing) and production (corrections, scanning, typesetting) for academic, children's, educational and general trade book publishers. We also do highly accessible and usable graphic communication design. Please visit https://www.userdesignillustrationandtypesetting.com for more information.

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• Book cover design services UK webpage.
• Journal design services UK webpage.
• Graphic design services UK webpage.
• Information design services UK webpage.
• Publication design services UK webpage.
• Typographic design services UK webpage.
• Website design services UK webpage.

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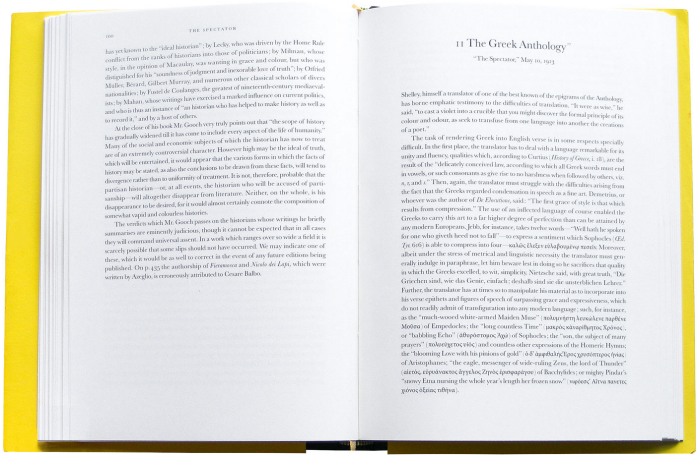

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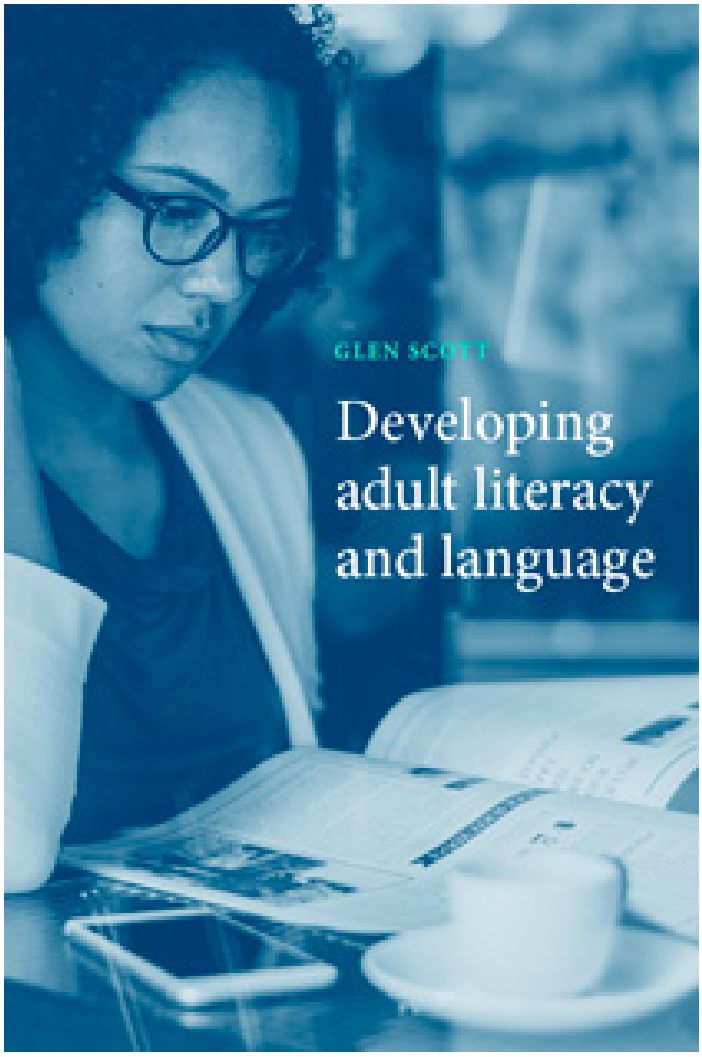

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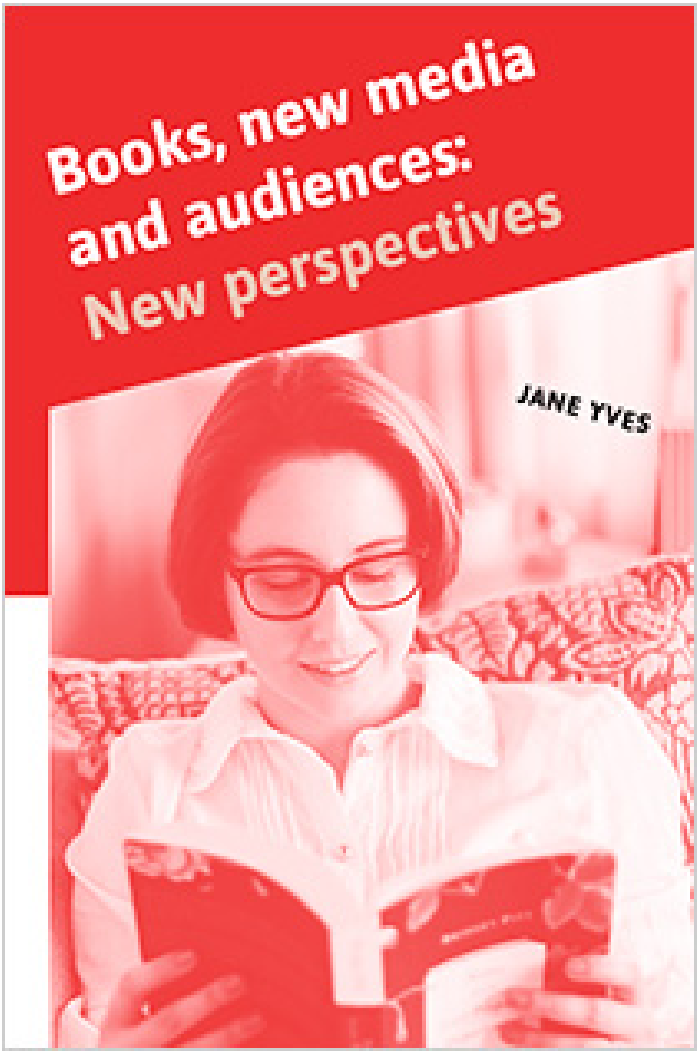

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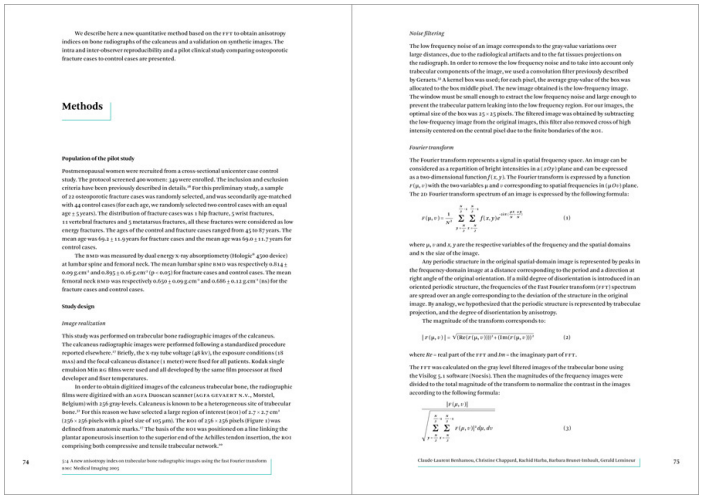


We describe here a new quantitative method based on the FFT to obtain anisotropy indices on bone radiographs of the calcaneus and a validation on synthetic images. The intra and inter-observer reproducibility and a pilot clinical study comparing osteoporotic fracture cases to control cases are presented.

Methods

Population of the pilot study

Postmenopausal women were recruited from a cross-sectional unicenter case control study. The protocol screened 400 women: 349 were enrolled. The inclusion and exclusion criteria have been previously described in details.[9] For this preliminary study, a sample of 22 osteoporotic fracture cases was randomly selected, and was secondarily age-matched with 44 control cases (for each age, we randomly selected two control cases with an equal age ± 5 years). The distribution of fracture cases was 1 hip fracture, 3 wrist fractures, 11 vertebral fractures and 5 metatarsus fractures, all these fractures were considered as low energy fractures. The ages of the control and fracture cases ranged from 45 to 87 years. The mean age was 69.2 ± 11.9 years for fracture cases and the mean age was 69.0 ± 11.7 years for control cases.

The BMD was measured by dual energy X-ray absorptiometry (Hologic® 4500 device) at lumbar spine and femoral neck. The mean lumbar spine BMD was respectively 0.814 ± 0.095 g.cm^{-2} and 0.895 ± 0.16 g.cm^{-2} ($p < 0.05$) for fracture cases and control cases. The mean femoral neck BMD was respectively 0.650 ± 0.095 g.cm^{-2} and 0.688 ± 0.12 g.cm^{-2} (ns) for the fracture cases and control cases.

Study design

Image realization

This study was performed on trabecular bone radiographic images of the calcaneus. The calcaneus radiographic images were performed following a standardized procedure reported elsewhere.[9] Briefly, the X-ray tube voltage (48 kV), the exposure conditions (58 mAs) and the focal-calcaneus distance (1 meter) were fixed for all patients. Kodak single emulsion Min R2 films were used and all developed by the same film processor at fixed developer and fixer temperatures.

In order to obtain digitized images of the calcaneus trabecular bone, the radiographic films were digitized with an AGFA DUOSCAN SCANNER (AGFA GEVAERT N. V., Mortsel, Belgium) with 256 gray-levels. Calcaneus is known to be a heterogeneous site of trabecular bone.[9] For this reason we have selected a large region of interest (ROI) of 2.7 × 2.7 cm^2 (256 × 256 pixels with a pixel size of 105 µm). The ROI of 256 × 256 pixels (Figure 1) was defined from anatomic marks.[17] The basis of the ROI was positioned on a line linking the plantar apponeurosis insertion to the superior end of the Achilles tendon insertion, the ROI comprising both compressive and tensile trabecular network.[18]

74

Fig 4 Anew anisotropy index on trabecular bone radiographic images using the fast Fourier transform BMC Medical Imaging 2005

Noise filtering

The low frequency noise of an image corresponds to the gray-value variations over large distances, due to the radiological artifacts and to the fat tissues projections on the radiograph. In order to remove the low frequency noise and to take into account only trabecular components of the image, we used a convolution filter previously described by Geraets.[19] A kernel box was used; for each pixel, the average gray-value of the box was allocated to the box middle pixel. The new image obtained is the low-frequency image. The window must be small enough to extract the low frequency noise and large enough to prevent the trabecular pattern leaking into the low frequency region. For our images, the optimal size of the box was 25 × 25 pixels. The filtered image was obtained by subtracting the low-frequency image from the original images, this filter also removed cross of high intensity centered on the central pixel due to the finite bondaries of the ROI.

Fourier transform

The Fourier transform represents a signal in spatial frequency space. An image can be considered as a repartition of bright intensities in a (x;y) plane and can be expressed as a two-dimensional function $f(x, y)$. The Fourier transform is expressed by a function $F(\mu, \nu)$ with the two variables μ and ν corresponding to spatial frequencies in (μ;ν) plane. The 2D Fourier transform spectrum of an image is expressed by the following formula:

$$F(\mu,\nu) = \frac{1}{n^2} \sum_{x=-\frac{n}{2}}^{\frac{n}{2}-1} \sum_{y=-\frac{n}{2}}^{\frac{n}{2}-1} f(x,y) e^{-2i\pi \frac{xx}{n} \frac{yy}{n}} \quad (1)$$

where μ, ν and x, y are the respective variables of the frequency and the spatial domains and n the size of the image.

Any periodic structure in the original spatial-domain image is represented by peaks in the frequency-domain image at a distance corresponding to the period and a direction at right angle of the original orientation. If a mild degree of disorientation is introduced in an oriented periodic structure, the frequencies of the Fast Fourier transform (FFT) spectrum are spread over an angle corresponding to the deviation of the structure in the original image. By analogy, we hypothesized that the periodic structure is represented by trabeculae projection, and the degree of disorientation by anisotropy.

The magnitude of the transform corresponds to:

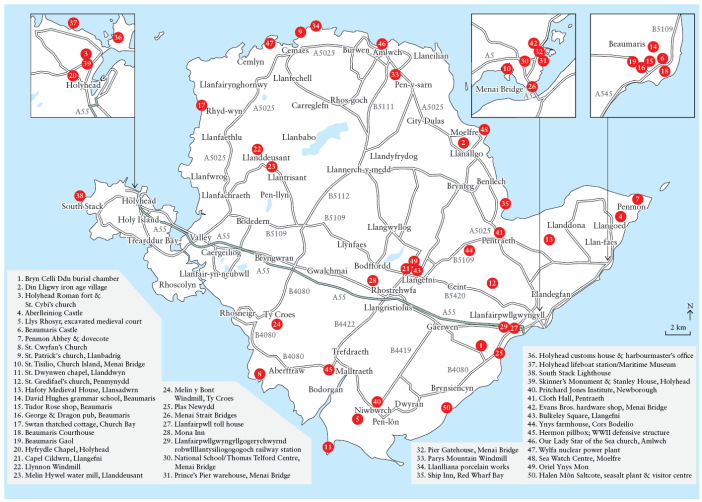
$$|F(\mu,\nu)| = \sqrt{[\mathrm{Re}(F(\mu,\nu))]^2 + [\mathrm{Im}(F(\mu,\nu))]^2} \quad (2)$$

where Re = real part of the FFT and Im = the imaginary part of FFT.

The FFT was calculated on the gray-level filtered images of the trabecular bone using the Visilog 5.1 software (Noesis). Then the magnitudes of the frequency images were divided to the total magnitude of the transform to normalize the contrast in the images according to the following formula:

$$\frac{|F(\mu,\nu)|}{\sqrt{\sum_{x=-\frac{n}{2}}^{\frac{n}{2}-1} \sum_{y=-\frac{n}{2}}^{\frac{n}{2}-1} F(\mu,\nu)^2 d\mu\, d\nu}} \quad (3)$$

Claude-Laurent Benhamou, Christine Chappard, Rachid Harba, Barbara Brunet-Imbault, Gerald Lemineur 75



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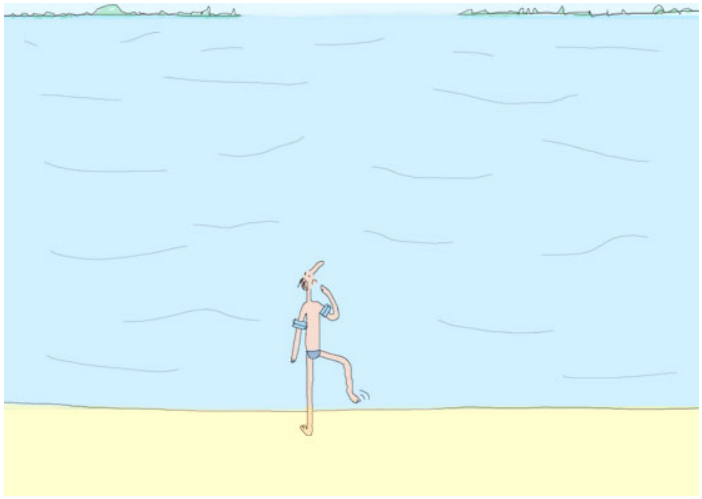

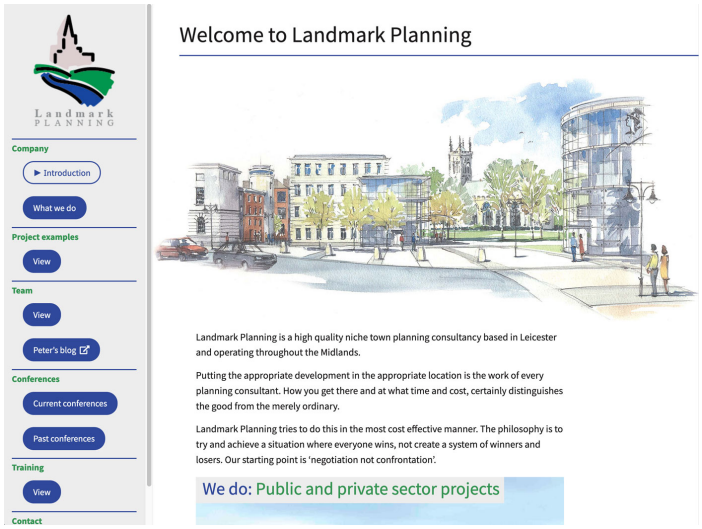

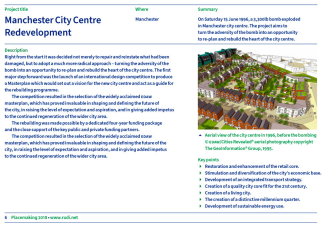

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