Subregional bone mineral density and bone volume fraction in whole human vertebrae: concurrent analysis using DXA and micro-CT

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Aims
Vertebral fracture risk of patients is usually evaluated using dual-energy X-ray absorptiometry (DXA) of the lumbar spine, together with clinical factors. Posterior-Anterior (PA) projections are usually performed, with areal bone mineral density (BMD) measured within the whole vertebral body. However, bone distribution and thus bone strength vary within the vertebra¹,². Subregional BMD measurements using lateral-projection DXA scanning modality might be more informative about vertebral fragility. Nowadays, micro-computed tomography (micro-CT) allows three-dimensional structural characterization of entire bone segments, non-destructively and at high resolution³. To assess the capability of lateral-projection DXA to determine subregional variations in bone distribution, this study examined human vertebrae first by DXA and then by micro-CT.

Method
Eight human cadaver spines were examined (mean age at death 78±10 years). These were immersed in a water bath and scanned by DXA in PA and in lateral projections (densitometer Hologic QDR4500, Hologic, Waltham, MA, USA). Subregional BMD analysis was performed in lateral projection of the L2 vertebrae, with the examination area divided via software in three subregions of interest (superior, central, inferior). The L2 vertebrae were then dissected and entirely scanned by micro-CT (17.4 μm pixel size, Skyscan 1076, Skyscan Kontich, Belgium). The micro-CT volume of interest comprised the trabecular bone of the entire vertebral body³. It was divided via software into three analogous subregions with equal height (superior, central, inferior), from which bone volume fraction (BV/TV) was assessed (software CTAnalyser, Skyscan).

Results
For both DXA and micro-CT, the values of the whole vertebral body showed statistically significant differences compared to the subregions (p<0.01, one-way ANOVA for repeated measures, fig. 1 and 2). Statistically significant differences between the subregions were found for both BMD and BV/TV, with the inferior subregion having higher values than the superior subregion (p<0.05, paired t-test, fig.1 and 2).
The BMD measured by lateral-projection DXA over the whole vertebrae was significantly related to the total BV/TV measured by micro-CT ($R^2=0.59$, $p<0.05$, fig. 3), whereas BMD measured in PA-projection DXA was not ($R^2=0.16$, $p=0.33$, fig.3).
In the central subregion, the linear regression ‘BV/TV vs. BMD’ had the highest coefficient of determination \( R^2 = 0.80, p<0.01 \), compared to the inferior and superior subregion (figure 4).

The finding of BMD being lowest in the central subregion (fig. 1), whereas BV/TV being lowest in the superior subregion (fig. 2), can be explained by the inclusion of the vertebral endplates in DXA analysis. In the central subregion, which does not contain the endplates, the regression “BV/TV vs. BMD” shows the highest regression coefficient (figure 4, left).

**Conclusion**

Differences in the bone parameters between the whole vertebra and the subregions were found by both lateral-projection DXA and micro-CT, both techniques showing higher values in the inferior compared to the superior subregions. This study shows that, in contrast to BMD assessed using PA-projection DXA scanning, measurements using lateral-projection DXA in the L2 vertebra are significantly related to BV/TV assessed via micro-CT. In particular, subregional BMD measurements are highly related to trabecular bone volume fraction in the central part of the vertebral body. These findings support lateral-projection DXA examination as a valuable modality for improving the evaluation of vertebral fragility.

**References:**

2. Gong H, Zhang M, Yeung HY, Qin L, "Regional variations in microstructural properties of vertebral trabeculae with aging" J Bone Miner Metab, 23, 174-180, 2005