

Homogeneity of human vertebral properties

Citation for published version (APA):

Terlouw, M. A., Rietbergen, van, B., Lochmüller, E. M., Eckstein, F., & Huiskes, H. W. J. (2004). Homogeneity of human vertebral properties. In *14th European Society of Biomechanics Conference (ESB 2004) 4-7 July 2004, 's-Hertogenbosch, The Netherlands* European Society of Biomechanics (ESB).

Document status and date:

Published: 01/01/2004

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

HOMOGENEITY OF HUMAN VERTEBRAL PROPERTIES

Marlies A. Terlouw(1), Bert van Rietbergen(1), Eva-Maria Lochmüller (2),
Felix Eckstein (3), Rik Huiskes(1)

1. BioMedical Engineering, Eindhoven University of Technology, The Netherlands
2. Gynecology Hospital, LMU München, Germany
3. Musculoskeletal Research Group, Institute of Anatomy, LMU München, Germany

INTRODUCTION

Osteoporosis is known to deteriorate mechanical and morphological properties of cancellous bone. The extent of this process is usually evaluated on small excised specimens. In such studies it usually is assumed that the results are not critically dependent on the actual sampling location. In particular in the elderly, cancellous bone inhomogeneities have been observed, and it should be questioned to what extent the results are affected by the inhomogeneity of the bone properties and variability of the sampling site.

The aim for this study was to answer this question by quantifying the variation in cancellous bone morphological and mechanical properties within thoracic and lumbar vertebral bodies.

METHODS

A micro-CT system was used to create high-resolution (60-80 μm) 3-D reconstructions of 43 excised vertebrae taken from 28 donors (average age 79 years) from two sites (thoracic vertebra 10 and lumbar vertebra 4). Within the core of each vertebral body eight volumes of interest (VOI's) with sides of 6 mm were identified, one for each octant (Figure 1). For each VOI morphological and mechanical parameters were calculated. Morphological parameters included volume fraction (BV/TV), trabecular thickness ($Tb.Th$), architectural anisotropy (DA) and connectivity density ($Conn.D$). Mechanical parameters included Young's moduli (E_i), shear moduli (G_i) and Poisson's ratios (ν_{ij}).

The intra-vertebral variation of each of these parameters was quantified with the coefficient of variation (CV) defined as the standard deviation over the 8 VOI's, normalized with the vertebral mean ($CV = (SD/mean)*100$). Non-parametric statistics were used to determinate if differences between the eight VOI-positions were significant.

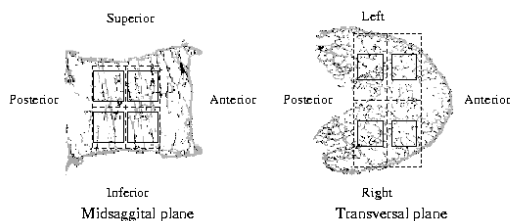


Figure 1. Positioning of the eight VOI

RESULTS

Figure 2 shows the means and standard deviations of the individual CV's over all individual vertebral bodies. The data are separated to show the differences between the two sites (T10 and L4).

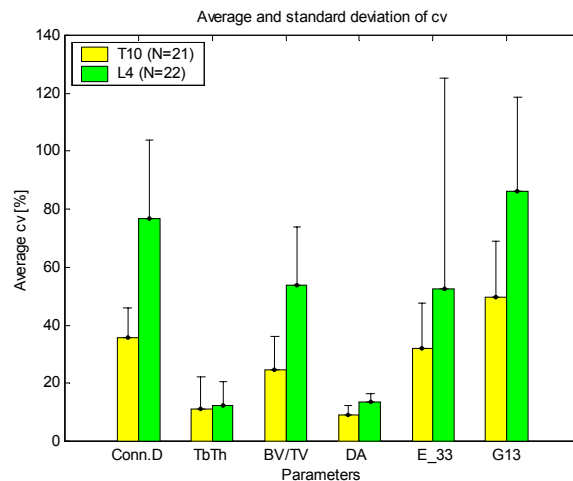


Figure 2: Mean and standard deviation of CV

Friedman analysis, followed by post-hoc pairwise comparisons using Tukey's method, demonstrated that the two posterior-inferior regions differed significantly from the other six positions with regard to most morphological and mechanical cancellous bone properties [exception: $Tb.Th$ and ν_{12}].

DISCUSSION

This study demonstrates that the variance in cancellous bone morphological and mechanical parameters of vertebrae from the elderly is considerable, with CV values on the order of 80%. $Tb.Th$ and DA show relatively little variance within the individual vertebral bodies, whereas $Conn.D$ and mechanical properties show a relative large variance within the vertebral bodies. CV values found for L4 were larger than those for T10, potentially due to the smaller size of the T 10 vertebrae.