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Citation for published version (APA):

Homminga, J. J., Lochmüller, E. M., Weinans, H., Eckstein, F., & Huiskes, H. W. J. (2004). Osteoporotic vertebral structure is well adapted to the loads of daily life, but not to infrequent 'error' loads. 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.
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OSTEOPOROTIC VERTEBRAL STRUCTURE IS WELL ADAPTED TO THE LOADS OF DAILY LIFE, BUT NOT TO INFREQUENT 'ERROR' LOADS

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INTRODUCTION

As typical osteoporotic vertebral fractures have a gradual onset and remain clinically undetected, they seem to result from normal daily loads rather than trauma. Osteoporotic vertebrae could then be hypothesized to experience higher stresses for normal daily loads than healthy vertebrae. This hypothesis was tested using a method that could potentially be used as an *in vivo* diagnostic tool for fracture risk.

METHODS

One osteoporotic (T-score: -4.4) and one healthy (T-score: +2.5) vertebra were scanned in a μ CT80 and converted to μ FEA-models. Bone properties: $E=18$ GPa (Rho, 1997) and $\nu=0.3$. A load of 1.2 x bodyweight (walking, Wilke 1999) was applied physiologically (Adams 1996). The strain distributions throughout the structures were determined using μ FEA (van Rietbergen 1995). A cancellous bone cube (10mm) were extracted from the center of both to determine morphological parameters and behavior under an 'error' load. Both were loaded with the same relative load that decreased linearly from anterior to posterior.

RESULTS

Although all architectural parameters differed between the osteoporotic and healthy bone, largest differences were found for the volume fraction and the degree of architectural anisotropy (Table1). For the daily load the percentage of tissue with strains between -400 and +400 μ strain was 91% for the healthy and 92% for the osteoporotic vertebra. For the 'error' load these percentages were 96% for the healthy and 87% for the osteoporotic vertebra. (Figure.1).

DISCUSSION

The number of highly loaded trabeculae was surprisingly similar for the osteoporotic and healthy vertebra; both seemed equally well adapted to normal daily loads. The osteoporotic cancellous bone had accomplished this (in spite of its lower volume fraction) by an increased trabecular orientation in the longitudinal direction at the cost of the transverse directions. While this reestablishes adequate stiffness

for normal daily loads, it does increase the vulnerability to buckling and loads in other directions ('error' loads). Which was confirmed by our 'error' load analysis.

As the computational expenses for these studies on whole bones presently defy inclusion of whole series, we used only two vertebrae. As these represent extremes with regard to T-score we expect them to be exemplary of the general effects of osteoporosis.

In conclusion, our analyses indicated that the osteoporotic vertebra is equally well adapted to normal daily loads as the healthy one. However, the osteoporotic vertebra runs a much higher risk of failure under 'error' loads than the healthy one.

	BV/TV [%]	TbTh [μ m]	TbSp [μ m]	ML _{AP} [-]	ML _{ML} [-]	ML _{SI} [-]	DA [-]
healthy	14	268	957	0.31	0.33	0.36	1.15
osteop.	10	238	1111	0.30	0.29	0.41	1.43
change [%]	-31	-11	+16	-3	-12	+14	+30

Table 1: Architectural parameters of the bone cubes.

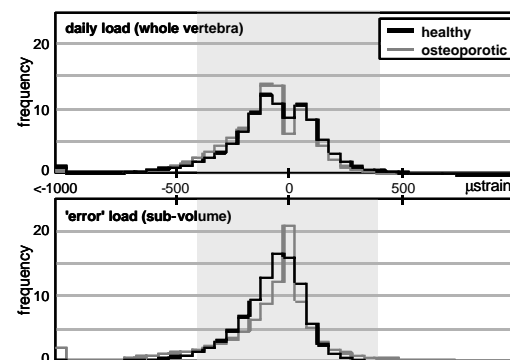


Figure 1: Frequency plots for the tissue principal strain for the daily (above) and 'error' load (below).

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