RELATIONSHIPS BETWEEN DIAPHYSIAL GEOMETRY AND CORTICAL MINERAL DENSITY AS ASSESSED BY PQCT IN THE HUMAN Tibia. A PQCT STUDY.

1. Center of P-Ca Metabolism Studies (CEMFoC), Natl Univ of Rosario, Argentina,
2. Manchester Metropolitan University, Manchester, UK.

GENERAL BACKGROUND AND AIM OF THE STUDY

The Bone Mecchanostat Theory proposes that the mineralized bone tissue is permanently re-distributed in every site of the skeleton as a function of the history of strains induced by mechanical usage. This re-distribution would control bone deformability in every vertebrate skeleton.

It can be assumed that the mineralized bone tissue is redistributed also as a function of its intrinsic stiffness (a variable that varies linearly with the degree of mineralization within physiological limits (Fig.1)). This paper tests this hypothesis by comparing tomographic indicators of bone material’s mass (cortical BMC, CIC), intrinsic stiffness (rBMD) of cortical bone adjusted for the partial-volume error according to Rittweger et al. (JMW 2002, Rhe-vCID) and distribution (tibial cross-sectional moments of inertia for bending or torsion, CSMs); (Fig.2) determined in call scars of normal men, and pre- and post-MP women (n = 60, 60, 120) aged 25-85 yr.

RESULTS

The CSMs (y) and Rhe-vCID (x) values correlated negatively as described by hyperbolic equations (distribution/quality) or (y) curves, typical of the relationships between variables regulated by feedback systems (Figs 1, 3). The (y) curves showed relatively high-CSM/low-Rhe-vCID values for men; low-CSM/low-Rhe-vCID values for pre-MP women, and low-CSM/low-Rhe-vCID values for post-MP women (Fig 3). Parallel, linear correlations between the CSMs and the CIC’s of the same scans from every group (distribution/mass) or (y) curve) were observed, with a common slope b = 11,796 mm³/g/cm^2, p<0.001 (Fig 4).

Statistical adjustment of all CSM values (Adj-CSMs) to a common CIC value (3.5 region; Fig 5) according to the slope was assumed to express the mechanical ability of the diaphyseal design (Adj-CSMs) achieved as a function of the available mineralized mass (CIC) in every individual in the study.

Re-built (y) graphs after substituting Adj-CSMs for the raw CSM values showed a substantially reduced but still significant difference between the slopes of the curves for men and pre-MP women, and similar curves for pre- and post-MP women (Fig 6).

INTERPRETATION

Confirming the working hypothesis of the study, results suggest that cortical density (as an expression of cortical material’s stiffness) has an effect upon the geometrical design of the tibia diaphysis (as assessed by the CSMs).

As far as the reduced density may reflect a reduced Young’s modulus of the tissue, the (y) curves can be regarded as expressing the bone ability to self-distribute the available cortical tissue (as assessed by the CSMs) as a function of its intrinsic stiffness, according to the Mechanostat Theory.

The gender-related differences between curves can be attributed to sex-hormone influences on the mechanical system. The anthropometric adjustment of CSM values to CIC values showed a trend of the data for all the groups studied to reflect a common relationship between the intrinsic stiffness and the efficiency of the architectural distribution of cortical mineralized tissue. This would indicate that the mechanostat system would show a similar pattern of control of cortical design as a function of the mechanical quality of the available cortical tissue as determined by mechanical usage of the skeleton, regardless of the gender and hormonal status of the individuals.

If so, then the much larger (unadjusted) CSM values shown by men compared by women would largely reflect allometric associations.

DIAGNOSTIC APPLICATIONS

Z-scored charts of the relationships between crude or adjusted CSM and Rhe-vBMd values of the studied individuals (Fig 6) can provide a suitable reference for comparative diagnosis.

Low Z-score values of these relationships obtained for a given individual might indicate a reduced ability of the mechanostat system to distributed the available cortical tissue concerning bending or torsion stress.

Figure 7 shows the data obtained for post-MP women in this study plotted on the Z-scored reference charts for the studied pre-MP women as an example of the proposed application.