Opposing effects of childhood obesity on radial and tibial bone microstructure

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Introduction
The over-representation of overweight and obese children in fracture studies suggests that excess fat in children may alter skeletal microarchitecture or the biomechanical properties of bone. High resolution peripheral quantitative computed tomography (HR-pQCT, isotropic voxel size 82μm) provides the resolution required to accurately determine 3-dimensional in-vivo bone microstructure at partially loaded (distal radius) and loaded (distal tibia) skeletal sites at a low radiation dose (<3μSv per scan). Microfinite element analysis (mFE) of HR-pQCT images provides insight into the biomechanical properties of these skeletal sites.

Aim
To determine whether differences in cortical and trabecular bone microarchitecture and the biomechanical properties of the distal radius and tibia exist between obese and lean children matched for pubertal age and gender.

Methods
We recruited 18 lean children (BMI <91st percentile) and 18 obese children (BMI ≥98th percentile) matched for pubertal stage, gender and ethnicity. Height, weight and BMI SD score was calculated using the UK reference values. HR-pQCT image acquisition and analysis of the non-dominant distal radius and tibia were performed using the standard built-in software (XtremeCT, version 6.0, Scanco Medical AG, Brüttisellen, Switzerland – figure 1).

HR-pQCT measurements included total density (D_vot, mg/cm³), trabecular density (D_trab, mg/cm³), cortical density (D_cort, mg/cm³) and microstructural properties including trabecular number (Tb.N, 1/mm), trabecular thickness (Tb.Th, mm), trabecular separation (Tb.Sp, mm), bone volume fraction (BV/TV, %), cortical thickness (Ct.Th, mm) cortical porosity (Ct.Po, %) and mean cortical pore diameter (Ct.Po.dm, mm).

Microfinite element analysis
Measures of bone strength, for the distal radius and tibia, were determined by micro finite element analysis - bone stiffness (kilonewtons per millimeter), estimated ultimate failure load (kilonewtons), the ratio of the load taken by the trabecular bone in relation to the total load at the distal end (percent) and proximal end (percent); average von Mises stresses in the trabecular (megapascals) and the cortical (megapascals) bone. Bone strength index (BSI) was calculated using total density (D_vot) and total area (Area_vot): [BSI(mg²/mm⁴) = D_vot × Area_vot]

Results
There was a 1.27 (95% CI: 0.49 to 2.06, p=0.003) standard deviation difference in cortical porosity between groups at the distal radius and cortical pore diameter was 1.05 (95% CI: 0.27 to 1.84, p=0.011) and 0.62 (95% CI 0.16 to 1.08, p=0.012) standard deviations lower at the distal radius and tibia respectively in the obese group. In contrast, mean tibial trabecular thickness and tibial trabecular separation was 1.01 (95% CI: 0.41 to 1.61, p=0.003) standard deviations lower and tibial trabecular number was 0.74 (95% CI: 0.27 to 1.22, p=0.004) standard deviations higher in the obese group (figure 2). There was no difference in the radial and tibial mFE measurements between the groups.

Correlation with subtotal body and truncal fat (%) and lean mass was determined for cortical and trabecular microstructure that were previously identified as being significantly different between lean and obese groups (table 1). Subtotal and truncal fat mass had the strongest association with cortical porosity and mean cortical pore diameter at the radius and trabecular thickness at the distal tibia.

Discussion
Fat mass rather than lean mass appears to have a greater influence on the alterations in radial and tibial microstructure in obese children. Despite these changes, there was no difference in the biomechanical properties of the distal radius and tibia between the groups. Bone stiffness refers to the extent to which bone resists deformation in response to an applied force; ultimate failure load relates directly to material failure. As the force imparted from body weight during a fall or twisting injury will be greater in obese children, fracture is more likely to occur due to the lack of biomechanical adaption of the radius and tibia in relation to excessive fat mass. This may in part explain why the incidence of fracture in obese children is greater.