Determinants of Bone Quality as measured by HR-pQCT: Familial versus Lifestyle Factors

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Introduction:
Skeletal diseases such as osteoarthritis and osteoporosis are multifactorial diseases compromised of genetic, environmental and lifestyle influences. Studies suggest heritability of skeletal traits in parental-offspring pairs is apparent by adolescence or early adulthood. Approximately 40-62% of bone mineral density (BMD) may be determined by genetics [1], however environmental and lifestyle factors such as nutrition and physical activities are known to influence skeletal health. To date, the research on familial bone health has been based on dual x-ray absorptiometry (DXA). However, this two-dimensional measurement technique cannot account for the structural properties of bone and uses density measures as a surrogate measure of bone strength. Recently, high-resolution peripheral quantitative computed tomography (HR-pQCT), a three-dimensional measurement technique, has been used in conjunction with finite element analysis (FEA) to estimate the bone’s resistance to fracture. These techniques make it possible to explore the familial association of bone microarchitecture and bone strength. Therefore, the purpose of this study was to assess bone microarchitecture and lifestyle factors between mothers and daughters using DXA and HR-pQCT. We hypothesize mothers and daughters will have similar bone quality and lifestyle factors and that these similarities will be evident at different skeletal sites using different scanning techniques.

Methods:
This study comprised of 29 mature mother and daughter pairs (N = 62, mothers: 55 ± 4 SD years; daughters: 23 ± 4 SD years) from the Calgary area. HR-pQCT (Scanco Medical, Switzerland) scans at the non-dominant radius and tibia and DXA (Discovery W, Hologic) scans of the hip (femoral neck: FN, total hip: TH) and spine (lumbar spine: LS) were obtained for each participant, and analyzed to determine areal and volumetric BMD, as well as geometric and microstructural indices. FEA was performed to estimate apparent bone strength. Information on diet, exercise and health history was collected through questionnaires and a total body DXA scan assessed body composition. Following checks for normality, paired T-tests, Chi square and age and weight adjusted ANCOVAs were performed to compare group differences, and ICC was used to quality similarities between mothers and daughters. Linear regression assessed the variance between bone quality, heredity and lifestyle factors. Squared semi-partial correlations (from the regression model) assessed the proportion of variance accounted for by the predictor variables. Data were analyzed using SPSS and significance was set at p <0.05.

Results:
All mothers had at least one daughter, and four mothers had two daughters participate in the study. Our cohort was white (94%), no daughters had given birth and none of the mothers were osteoporotic, identified by a DXA T-score of < -2.5 SD at this hip. Furthermore, only 20% of mothers were menopausal. Mothers were 32 years older than daughters on average, but were not different from daughters for height, weight, BMI, lean or fat mass (p>0.05). DXA results showed no difference between mothers and daughters for areal BMD at the LS, FN or TH (p>0.05). Similar results were observed at the radius and tibia using HR-pQCT. Mothers were not different from daughters for volumetric BMD, or any bone geometric or microstructural parameters (p>0.05). Furthermore, lifestyle factors such as calcium intake, and physical activity were not different between mothers and daughters (p>0.05). These results remained following adjustment for age and weight. Time spent sitting per day was the only lifestyle variable that differed between mothers and daughters with daughters sitting an average of two hours longer than mothers (p<0.01). ICCs reveal low to moderate correlations between mothers and daughters with similar relationships observed by DXA (r = 0.38, p <0.05) and HR-pQCT (r = 0.36 to 0.38, p<0.05). ICCs were similar between the spine (r = 0.38), hip (r = 0.38), radius (r = 0.36 to 0.38) and tibia (r = 0.36 to 0.38), p<0.05. The strongest correlate between mothers and daughters was percent body fat (r = 0.44, p<0.05). Following regression models, heritability alone explained 14% of the variation in daughter’s trabecular thickness at the tibia. Heritability alone did not explain other microarchitectural parameters at the radius or tibia. When lifestyle factors were added to the models explained variance ranged from 12 to 51% (p<0.05). Fat mass, lean mass and total calcium intake predicted 51% of estimated bone strength at the radius (R² = 0.51, F(1, 31) = 10.01, p <0.001).

Discussion:
Within the limitations of a small sample size and retrospective questionnaires, lifestyle factors had more influence on daughter’s bone quality than familial association, according to our results. Significant differences between mothers’ and daughters’ bone quality was not evident. This may be due to daughters having reached peak bone mass, generally occurring in the second decade.
of life and mothers not yet undergoing the accelerated bone loss associated around the time of menopause, although bone quality has been shown to decrease prior to 50 years in women [2]. Perhaps there were no differences in bone quality between mothers and daughters due to daughters being less active (increased time per day sitting) than mothers. These findings lead us to speculate that perhaps as daughters age their bone quality will be worse than their mothers, potentially resulting in an increase in osteoporosis incidence.

Overall, ICCs showed low to moderate correlations between mothers and daughters for bone quality and body composition parameters. This indicates daughters bone quality and body compositions do resemble their mothers, to a certain extent. Although relationships existed between the bone quality of mothers and daughters, skeletal hereditability was not a strong predictor in our regression models. Maternal heritability explained up to 14% of daughter’s bone quality, which is lower than previous DXA studies 18 to 37% [3] and 22 to 42% [4]. It is possible that the percentage of bone traits directly determined by maternal descent differs based on imaging modality (DXA or HR-pQCT) and skeletal site (hip and spine versus radius and tibia). The strongest predictors of daughters bone quality were lean mass, fat mass, total calcium intake and physical activity, reflecting lifestyle factors more than hereditability, however the genetic association surrounding body composition also plays a role. In conclusion, mothers and daughters had similar bone quality and lifestyle factors. Furthermore, DXA and HR-pQCT gave comparable correlations in bone quality between mothers and daughters irrespective of skeletal site, and while heredity relationships existed between mothers and daughters, lifestyle factors appear to be stronger influences in bone quality. Moving forward, perhaps lifestyle factors could be an effective target to enhance bone quality in women.

Significance:
Further understanding on familial and lifestyle determinants of bone quality may help identify participants at risk of developing osteoporosis. If lifestyle factors rather than heritability have a larger influence on bone quality perhaps we should be educating and implementing lifestyle changes to ‘at risk’ individuals before menopause.

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References: