Familial Determinants of Bone Health Parameters- A Dual X-ray Absorptiometry (DXA) and Peripheral Quantitative Computed Tomography (pQCT) -based parent and offspring study in Rural Indian Children.

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Abstract

Background:

Skeletal health relationships in children and parents have been investigated over the years with contradictory results and often without accounting for the influence of modifiable factors. Limited data exist on sex specific relationships using advanced techniques like peripheral quantitative computed tomography (pQCT), especially in populations with generationally insufficient calcium intake, where nutritional insufficiency, gender differences and environmental constraints may override and influence heritability trends. We examined the effect of parental phenotype and shared environment on bone density and geometry parameters of rural children aged 8-10.

Methods:

Healthy children aged 8-10 and their parents joined a multigenerational cohort. Bone health parameters were assessed for 689 and 428 triads using dual-energy x-ray absorptiometry (DXA) and pQCT (at the 4% and 66% radial site), respectively. Modifiable factors were recorded using standardized questionnaires. Hierarchical linear regression assessed parent-offspring relationships after accounting for these factors.

Results:

The cohort had significant calcium inadequacy, with only 6.5% having adequate dietary calcium intake. Even after accounting for modifiable factors, both parents' bone health parameters significantly ($p<0.05$) influenced children's parameters, with a stronger effect in female children. The maternal-offspring relationship was stronger than the paternal-offspring relationship for total body bone mineral density (TBLHBMD) ($\beta=0.19$ vs $\beta=0.12$), anteroposterior lumbar spine BMD ($\beta=0.22$ vs $\beta=0.16$), cortical density ($\beta=0.39$ vs $\beta=0.32$), cortical thickness ($\beta=0.23$ vs $\beta=0.17$), periosteal ($\beta=0.23$ vs $\beta=0.17$), and endosteal circumference ($\beta=0.27$ vs $\beta=0.23$). Whereas, trabecular density showed a slightly higher influence from male parents ($\beta=0.17$ vs $\beta=0.16$). (all $p<0.01$)

Conclusion:

Maternal-paternal influence on bone health was significant for all parameters and stronger in female children, asserting the importance of sex-specific growth promotion interventions. Parental influence persisted after accounting for modifiable factors in a nutritionally inadequate population, suggesting a strong heritability component.

Keywords: DXA, PQCT, phenotypic bone health, parent-offspring bone health relationship, calcium inadequacy, osteoporosis risk, bone geometry.

1. Introduction:

Bone is a metabolically active organ that can regulate its own physiology while influencing the systemic metabolism of the body.[1] Neglecting bone health can cause osteoporosis, which leads to low-impact fractures that significantly affect quality of life.[2] Osteoporosis, often referred to as a silent disease, is a major public health problem worldwide, affecting over 18% of the global population.[3]Although detected in later adulthood, preventive care for osteoporosis is believed to start from early childhood. Optimal bone mineral density achieved during the accrual of peak bone mass around puberty is associated with a lower risk of fractures in later life.[4]

Bone health in apparently healthy populations is known to be influenced by multiple factors, including non-modifiable factors like genetics, sex, ethnicity, and modifiable factors such as nutrition, physical activity, body composition and hormonal status.[2] Hereditary factors are thought to influence 50-90% of the differences in bone health between people.[5] Nongenetic factors such as a shared environment and lifestyle also contribute towards these associations, and need to be accounted for when studying influences on children's bone health. Parental influence on bone density has been previously studied, with a majority of the studies investigating maternal influence as the primary objective.[6,8] Maternal influence on multiple health parameters of the offspring is suspected to be higher because of the in-utero relationship.[9] Paternal influence on foetal-neonatal growth parameters has been established, but scarce data are available on parameters of bone density and geometry.[10] Investigating the paternal-offspring relationship is of significant importance to clarify relative genetic contribution to aid early identification of children who are at a higher risk of poor bone health.

Although a few previous studies have investigated this relationship, disproportionate sex representation among children and parents for dual x-ray absorptiometry (DXA) and peripheral

quantitative computed tomography (pQCT) derived parameters has limited the ability to examine differences due to sex in these relationships.[9,11,12] Further, some parent-offspring bone health studies using the pQCT have examined the tibial site, which may be more strongly influenced by confounding effects of mechanical loading and physical activity.

To the best of our knowledge, no prior study has investigated the heritability of DXA and pQCT-derived bone health parameters after accounting for modifiable factors that may be correlated in parents and offspring, like diet, physical activity, 25(OH) vitamin D concentrations, sunlight exposure and socioeconomic class to observe changes in heritability estimates. Accounting for these post-natal factors reduces the confounding created by shared environment so as to reveal the true relationship between parental-offspring bone health. Thus, we aimed to examine the effect of parental phenotype and shared environment on bone density and geometry parameters of rural children aged 8-10. Furthermore, this paper also attempts to give a comprehensive overview of bone health in a rural low and middle-income country (LMIC) population, where nutritional insufficiency and environmental constraints may influence long-term bone health outcomes, significantly overriding the influence of genetic predisposition.

2. Methods:

2.1 Study design and Participants-

This study is a part of a multigenerational prospective YUAAN (Young Adolescents Behaviour, Musculoskeletal Health, Growth and Nutrition) cohort. Healthy children aged 8-10 and their parents were enrolled from 12 villages and settlements around Pune city, Maharashtra, India. Recruitment details are outlined in a previously published paper [13]. Ethics approval was obtained from the Institutional Ethics Committee (EC registration no.: JCDC/BHR/23/034). All the health assessments were conducted at the rural bone health unit

of our centre. Consent from parents for themselves and their children was obtained, along with the assent from children. Participants first underwent anthropometric measurements and were then alternated among bone health assessments, medical checkups, and interview-based questionnaires. Participants with medical conditions likely to affect bone health or having implants were excluded after an assessment by a clinician. At baseline, 768 families were enrolled (total 2304 participants, including complete triads of male parent, female parent, and children). DXA and pQCT-based parameters were available for 689 and 428 triads, respectively (total 1889 participants, 689 children, 600 fathers and 600 mothers). Siblings were also included if they were eligible. Incomplete triads (total 23) and insufficient forearm length (total 317) for adequate positioning in pQCT were the reasons for the decrease in sample size in the pQCT-based measurements.

2.2 Measuring anthropometry, diet, physical activity, sunlight exposure and 25(OH) vitamin D

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A government-issued biometric document was used to confirm the reported birth date and calculate age. Height and weight were measured using a SECA 213 – portable mechanical stadiometer and Tanita Body composition analyzer (Model BC-420MA), respectively. Dietary data was recorded using 24-hour dietary recall (2 days- weekday and weekend).

Participant-specific physical activity data was collected using a validated questionnaire (occupational activities for adults and play-related activities for children). Time spent in an activity was classified into sleep, screen, light, moderate and vigorous categories based on the metabolic equivalent of task (MET).[14–16] Validated questionnaires were also used to collect data on sunlight exposure and socio-economic class.[17,18] For 25(OH) Vitamin D estimations, a standardized Beckman Coulter Access 2 immunoassay system was used (intra-assay coefficient of variation, CV <10%).

2.3 Measuring DXA and pQCT bone health parameters –

All DXA and pQCT-derived scans were conducted by trained technicians. The Lunar iDXA system (GE Healthcare, Encore version 18) was utilized to measure bone mineral density (BMD in g/cm^2). DXA parameters were analysed for total body less head and anteroposterior lumbar spine (TBLHBMD, AP spine BMD) in both parents and children. Weekly quality assurance (QA) was performed using an aluminium spine phantom provided by the manufacturer, and the coefficient of variance (CV) was 0.5% throughout enrolments. Likewise, CVs for TBLHBMD and AP spine BMD were 0.7% and 1%. All scans, including the manual setting of the region of interest (ROI) and analysis, were performed by the same technician. pQCT measurements were performed using a Stratec device (model XCT 2000, Stratec, Pforzheim, Germany) on the radius of the non-dominant hand and Stratec 2000 software, version 6.0. Parameters were analysed at 4% and 66% distal-proximal length for all the participants. Daily QA was done using a standard phantom (20mm-0.590mm). Trabecular density was assessed at 4% with a threshold of 180 mg/cm^3 (contour mode 2). Furthermore, cortical density, cortical thickness, periosteal circumference, and endosteal circumference were measured at 66% with a threshold of 711 mg/cm^3 (contour mode 3). A stretchable SECA 210 measuring tape was used to measure the distance between the ulnar styloid process and the olecranon, referred to as the ulnar length. A scout view was used to establish a reference line at the midpoint of the ulnar border of the articular cartilage. The coefficients of variation for total, trabecular and cortical density were 0.7, 0.3 and 0.8, respectively. These CVs were measured at 0.7, 0.3 and 0.8% for cortical thickness, periosteal circumference and endosteal circumference, correspondingly. Any movement artefacts were evaluated, and scans of suboptimal quality were repeated based on the researchers' inspection during data collection.

2.4 Statistical Analysis-

Statistical analysis and data visualization were performed using the Statistical Package for Social Sciences version 27 (SPSS, Chicago, IL, USA) and Python 3.12.2 (Matplotlib 3.9.2), respectively.

Data distribution for all variables was assessed using the Kolmogorov-Smirnov test for normality to determine whether parametric or non-parametric tests should be used for further analysis. All continuous variables were presented as means, standard deviations, medians, and interquartile ranges (IQR), whereas categorical variables were presented as percentages. To assess if the differences in means between the two groups (female parent vs. male parent and female child vs. male child) were significant, T-tests and Mann-Whitney U tests were conducted based on the parametric or non-parametric nature of the variables.

To examine the strength and direction of the association between parent-child bone health parameters, Pearson/Spearman correlation test was used. Since multiple comparisons were made during correlation tests, the likelihood of false positives was high; therefore, the Benjamini-Hochberg false discovery rate (FDR) was used to adjust for multiple correlations.

To explore a potential causal relationship between parent and offspring bone health parameters, hierarchical (block-wise) linear regression analysis was conducted. It indicated how changes in parental parameters affected the child's parameters. Two distinct models were provided for all bone health parameters. In the first model, the dependent variable was the children's bone health parameters, while the independent variables were parental bone health parameters.

In the second model, independent variables encompassed both parental bone health parameters and the children's modifiable factors as covariates. Since, Modifiable factors may act as confounders in examining the true parent-offspring relationship. All models were stratified by

sex and adjusted for both parent and child age, height, and ulnar length. Adjusted and unadjusted correlation and regression models yielded similar results.

Additionally, interaction analysis was performed to investigate whether the differences observed between male and female children in regression analysis were statistically significant, thus allowing for formal testing of whether a child's sex modifies the relationship with prenatal bone health. (details of analysis flow in Supplementary Table S3).

3. Results:

Table 1 summarizes the characteristics of the study population. Means of height (Z-score -0.3±0.9, -0.5±0.9), weight (Z-score -0.7±0.9, -0.80±1.0) and BMI Z-scores (Z-score -0.8±1.0, -0.9±1.0) indicated that male and female children were slightly below but within the normal reference range. Dietary assessment indicated substantially lower calcium and protein intake in the parents as per the estimated average requirement (EAR).[19] Only 39% males and 0.5% females consume adequate dietary calcium. Whereas, 61.7% and 64.2% of male and female parents had sufficient dietary protein, respectively. Female children had significantly lower intakes of both macronutrients and micronutrients (p<0.05) as compared to male children. Merely 11.1% male and 6.8% female children consumed acceptable dietary calcium. Despite engaging in higher levels of physical activity than male children, female children demonstrated reduced sunlight exposure, indicative of a greater propensity for indoor activities (p<0.05). More than 50% households belonged to the lower-class category of socio-economic status[18]

Figures 1a and b summarise the associations between bone health parameters in children and their parents. Strong positive correlations were observed between all bone density and geometry parameters between parent and offspring (p<0.001). Additionally, Figure 1c demonstrated that BMI Z-scores, ulnar length, dietary protein intake, dietary calcium intake, moderate physical activity, serum 25 (OH) vitamin D concentrations and socioeconomic status

were significantly positively associated with several bone health parameters (p<0.05). Indicating the need to consider these modifiable factors as covariates while testing the parent-offspring causal relationship, to account for their influence.

After accounting for Benjamini-Hochberg FDR correction for multiple comparisons in correlation, all parental bone health parameters remained significant. Out of 21 significant modifiable factors in correlation analysis, 16 retained their significance (p≤0.007).

Hierarchical linear regression analysis determined that parental characteristics were significant determinants of various bone health parameters in children, with a particularly pronounced influence observed in female children (Figure 2). Full regression coefficients for DXA and pQCT parameters are presented in the supplementary materials as tables S1 and S2, respectively. These models included all 21 modifiable factors as they were part of our initial hypothesis. Moreover, the regression direction and significance remained unchanged after including just 16 factors that passed Benjamini-Hochberg FDR.

After accounting for modifiable factors as covariates in all children, most of the bone density and geometry parameters exhibited a markedly stronger maternal-offspring relationship (p<0.001). In contrast, trabecular density demonstrated an enhanced relationship with paternal characteristics (β=0.17, p<0.001). The maternal-paternal influence retained its statistical significance even after stratification by children's sex. Male children displayed a significant paternal influence on cortical density (β=0.27), whereas for female children, it was periosteal circumference (β=0.23) (both p<0.001). Both maternal-paternal influence on male children's trabecular density were equivalent (β=0.18 p<0.001). Indicating the significance of paternal bone health in determining children’s.

Hierarchical linear regression analysis revealed differences in influence as per the child's sex after stratification. Further interaction analysis confirmed that these differences were

statistically significant (p<0.05). The influence of female parents' TBLHBMD and cortical density, as well as male parents' AP spine BMD, differed by child's sex, with stronger effects observed in female children. Indicating parental influence on bone health parameters varied according to the child's sex.

Higher dietary protein intake in children was indicative of higher TBLHBMD (β=0.002, p=0.001) and trabecular density (β=0.75, p=0.03). Highlighting the importance of protein as the primary source of collagen, a key structural component of bone matrix. Body Mass Index (BMI) Z-scores exhibited a substantial impact on all parameters (p≤0.001), except for cortical density and cortical thickness. Ulnar length affected cortical density (β=0.58, p=0.001) and all bone geometry parameters (p<0.001). R^2 values were low for all parameters (range 0.8 to 0.43), given how multifactorial and complex skeletal health is.

4. Discussion:

To the best of our knowledge, this is the first study from the South Asian subcontinent to explore the heritability of bone density and geometry among parents and children. In addition, ours is the only study that considered children's modifiable factors to observe changes in heritability estimates. We found a significantly strong parental influence (both maternal and paternal) on bone health parameters in prepubertal children, which persisted even after accounting for modifiable factors. The stability of regression coefficients across bone traits suggests a uniform pattern of familial resemblance. This supported the hypothesis that shared genetic or early-life environmental factors contribute broadly to skeletal development. Moreover, findings highlight that intergenerational transmission of skeletal characteristics remains prominent for bone geometry and density even after generational calcium insufficiency. Female children in our study exhibited slightly enhanced parental influence. Although anthropometric parameters in prepubertal children are similar, estradiol, IGF1, and leptin concentrations in prepubertal female children have been reported to be slightly higher

and are known to affect bone health parameters.[20] This may explain the increased parental influence due to prepubertal sexual dimorphism. Apart from heritability, we observed that modifiable factors such as dietary protein intake and body mass index (BMI) also played a role in children's bone health. Our findings also indicate that a greater number of modifiable factors in children were significantly related to bone density parameters as compared to geometry. Density is directly affected by minerals packed into bone structure, hence having a more direct and measurable effect from modifiable factors that influence mineral absorption and deposition.

We observed a statistically significant relationship between children's bone health parameters and those of both parents. In agreement with our findings, previous studies that have investigated the heritability of phenotypic bone health parameters consistently revealed a stronger maternal influence.[8,9,11,12] However, the strength of these associations that have been reported previously has varying degrees of contradictions. These discrepancies in the findings may be attributed to a range of factors, including variations in protocols, different anatomical sites of assessment, ethnic diversity, dietary habits, socioeconomic status, environmental influences, and epigenetic interactions. [20]

A DXA-based population study (KNHANES-2008–2011) in Korean children reported a strong whole-body BMD association with parents.[12] These findings were consistent with our observations, including low dietary calcium intakes in both populations. A study from the United Kingdom (UK) as part of the Southampton Women (SWS) cohort attributed their observations of stronger maternal-offspring influence to inherited genotype, environment and early life in utero.[9] A decreasing trend was noted in parental influence after adjustment, unlike in our study, where parental influence was retained after accounting for modifiable factors. These differences may have arisen from the inclusion of maternal late pregnancy walking speed and maternal pre-pregnancy education level that were included in the subsiding

models in the SWS cohort study. Also, stratification as per children's sex for pQCT was not reported due to insufficient sample size. Similarly, the Longitudinal Study of Australian Children (LSAC) also reported a higher maternal influence.[11] Although these findings aligned with ours, a detailed comparison was not possible due to the lack of stratification by children's sex in the LSAC. Also, maternal representation was 86% of all parents in the LSAC cohort, which could have influenced the documented trend. A familial resemblance HRpQCT study reported a stronger connection between female parent-son pairs regarding geometry parameters and female parent-daughter pairs for volumetric parameters.[8] However, unlike in our study, this effect was independent of paternal influences and modifiable factors, which may have contributed to the observed trend. Interventional studies planned on such findings may focus more on optimizing maternal bone health, completely overlooking paternal contribution. Therefore, paucity of studies exploring paternal bone density and geometry along with modifiable factors highlights a significant gap in the literature, thereby enhancing the relevance of our study.

Our study attempts a holistic view of the interactions between phenotypic traits and lifestyle influences. Dietary protein intake and BMI were the modifiable factors that were significantly associated with bone health parameters in our cohort. Other studies also report that BMI, as a growth parameter, positively associates with good nutrition, mechanical loading, and possibly slight estrogen dominance.[21,22,23]A Korean heritability study, KNHANES-2008–2011, reported that lifestyle factors such as calcium intake and serum vitamin D concentrations were positively associated with DXA-measured whole body BMD and lumbar spine BMD in 10-18-year-old female children.[12] The variations observed compared to our cohort may have arisen from differences in age group. Children in our cohort were aged 8 – 10 and are still growing and undergoing active remodelling of the bone matrix.

Modifiable factors as determinants for bone health have been investigated previously in isolation by some studies. Dietary calcium intake, physical activity, 25(OH)D levels, sun index, and some DXA-measured body composition parameters were reported to have a positive relationship with DXA-measured BMD in children.[24,25] An Australian study investigated the relationship between physical activity and pQCT-measured bone health parameters and found that moderate-vigorous physical activity showed a positive association with bone density parameters and larger bone size.[26] We investigated some of the above parameters, but they did not achieve statistical significance in predicting bone health. In a randomised control trial of a low glycaemic index diet in pregnancy to prevent macrosomia (ROLO) kids study, five-year-old children showed no association between diet, physical activity and DXA parameters, which aligned with our findings. [27]As outlined above, modifiable factors show high variance as per geographical location, ethnicity, age, and sex. Therefore, accounting for them enhances the rigour and focus of the study. [28,21,22,23,29]

The strengths of our study include that a large segment of the rural population was studied using gold standard approaches of measuring bone health. This rural LMIC population is unique in terms of having large bone geometry and lower bone density because of high physical activity and a compromised calcium diet. This enabled us to study bone health in a population not often represented in genetic epidemiology studies. Moreover, we were able to account for modifiable factors such as dietary intake, physical activity, sunlight exposures, serum 25 (OH) vit D and socioeconomic class. This added to the knowledge about the influence of modifiable factors on bone health parameters and further enhanced the heritability estimates. Additionally, stratification analysis as per children and parents' sex allowed for sex-specific genetic and environmental interaction, enabling profound conclusions. Furthermore, a high participation rate and inclusion of triads led to direct assessment of familial resemblance, inheritance pattern and enhanced internal validity of the study.

Although utmost care was taken while planning and assessing, our study is not without limitations. First, there is potential for self-reported bias while assessing modifiable factors. Additionally, we were unable to assess 25(OH) vitamin D concentrations in parents. Further, the study's cross-sectional design also limited the assessment of the long-term impact of heredity on pre-pubertal bone health, which could have accounted for increased exposure to lifestyle factors. Alongside these, maternal factors during pregnancy could significantly affect bone parameters in offspring, which we could not account for. Finally, while our findings are robust in terms of methodology and substantial sample size, the generalizability of our findings may be limited to similar rural LMIC populations and may not extend to urban or high-income settings with different lifestyle and environmental exposures. However, our results are important for refining global models of skeletal health that reflect diverse nutritional and environmental contexts.

5. Conclusion:

To conclude, both parents' influence on skeletal characteristics remains measurable and consistent across structural and densitometric traits even under nutrient-insufficient conditions and after considering modifiable factors. Both female parent-offspring and male parent-offspring relationships exhibit a proportional share, hinting at the importance of paternal inclusion in heritability studies. Our study thus highlights the crucial role of parents in skeletal health imprinting. Further, modifiable factors in children were significantly related to bone density parameters, underlining the importance of nutrition, specifically higher protein intake, in optimising bone density. Various sustainable nutritional interventions planned on such findings should be of priority to help attain maximum skeletal health potential. Given the higher maternal influence and enhanced parental influence on female children, attention to bone health and nutrition in girls and women in LMICs is critical. Studying these relationships longitudinally is important to further estimate the effect of long-term shared environments on

the heritability of skeletal health. Studies assessing the effect of long-term behavioural change interventions and sex-specific growth promotion interventions will also help to explore and add to our current findings.

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7. CRediT authorship contribution statement:

Sharvani Patil: Conceptualization, Methodology, Data collection, Formal analysis, Visualization, Writing original draft. **Nikhil Shah:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Alex Ireland:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Vivek Patwardhan:** Conceptualization, Data curation, Supervision, Visualization, Writing – review & editing. **Neha Sanwalka:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Neha Kajale:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Chidvilas more:** Project administration, Writing – review & editing. **Ketan Gondhalekar:** Formal analysis, Methodology, Writing - review & editing. **Anuradha Khadilkar:** Conceptualization, Methodology, Supervision, Resources, Funding acquisition, Writing – review & editing.

8. Conflict of interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Anthropometry, DXA, pQCT-derived bone parameters and modifiable factors of the study population.

Parameters	Male parent	Female parent	Male children	Female children
Demography and Anthropometry				
Age (yrs)*a	37.2±4.0	31.2±3.6	9.0±1.6	9.0±1.0
Height (cm)*a	167.7±6.1	153.9±5.7	132.2±7.5	131.2±8.0
Weight (kg)*a	70.9±13.3	55.5±10.9	26.0±6.3	25.3±6.6
BMI (kg/m^2) *a	25.1±4.2	23.4±4.5	14.7±2.6	14.5±2.5
Bone density parameters DXA				
TBLH aBMD (g/cm^2) *a	1.191±0.106	1.101±0.088	0.623±0.068	0.600±0.073
Z-scores*ab	0.1±0.9	0.4±0.8	-0.9±0.7	-1.5±08
T-scores*a	-0.0±1.0	0.2±0.8	NA	NA
AP spine aBMD (g/cm^2)	1.087±0.132	1.086±0.118	0.625±0.073	0.626±0.092
Z-scores*a	-1.1±1.0	-0.7±0.9	-1.0±0.7	-1.1±0.8
T-scores	-0.8±1.0	-0.8±0.9	NA	NA
Bone Density Parameters pQCT (radial)				
Trabecular density 4% (mg/cm^3) *ab	200.4±46.5	154.4±38.2	180.3±31.5	170.9±34.1
Cortical density 66% (mg/cm^3) *ab	1146.1±31.7	1156.5±32.3	998.9±45.1	987.3±50.6
Bone Geometry Parameters pQCT (radial)				
Cortical thickness 66% (mm)*ab	2.3±0.2	2.0±0.3	1.2±0.2	1.2±0.2

Periosteal Circumference 66%(mm)*ab	43.1±3.6	37.5±3.0	34.8±2.8	33.3±3.2
Endosteal circumference 66% (mm)*ab	28.1±4.0	24.5±3.6	26.7±3.4	25.7±4.0
Lifestyle factors and biochemical assessment				
Dietary protein (g/1000kcal) *ab	27.7±4.4	26.2 (5.4)	25.7 (5.9)	25.5 (5.5)
Dietary calcium (mg/1000kcal) *ab	201.1 (106.8)	223.8 (93.9)	220.7 (110.2)	210.7 (101.4)
Moderate physical activity (minutes/day) *a	107.7±118	129.1±69.9	75.5±54.6	78.6±57.3
Sunlight exposure per day (in minutes/day) *ab	134.4 (173.1)	222.9 (195.0)	52.8 (46.4)	45.9 (34.5)
25(OH) Vitamin D (ng/ml) *b	NA	NA	25.9±7.3	23.9±8.9
Household Socioeconomic Categories (%)				
Upper Class Middle Class Lower Class	0.3% 44.8% 54.9%			

All values represented as Mean±S.D, median (IQR) or n (%)

BMI- Body Mass Index, TBLH – Total body less head, AP- Anteroposterior, aBMD- Areal Bone Mineral Density, aBMC- Areal Bone Mineral Content.

*a – $p < 0.05$ for significant differences in the means when compared between male parents vs female parents.*b – $p < 0.05$ for significant differences in the means when comparing male children and female children.

Figure 1: A] B] and C] the correlogram of child bone health parameters with male parent and female parent bone health parameters

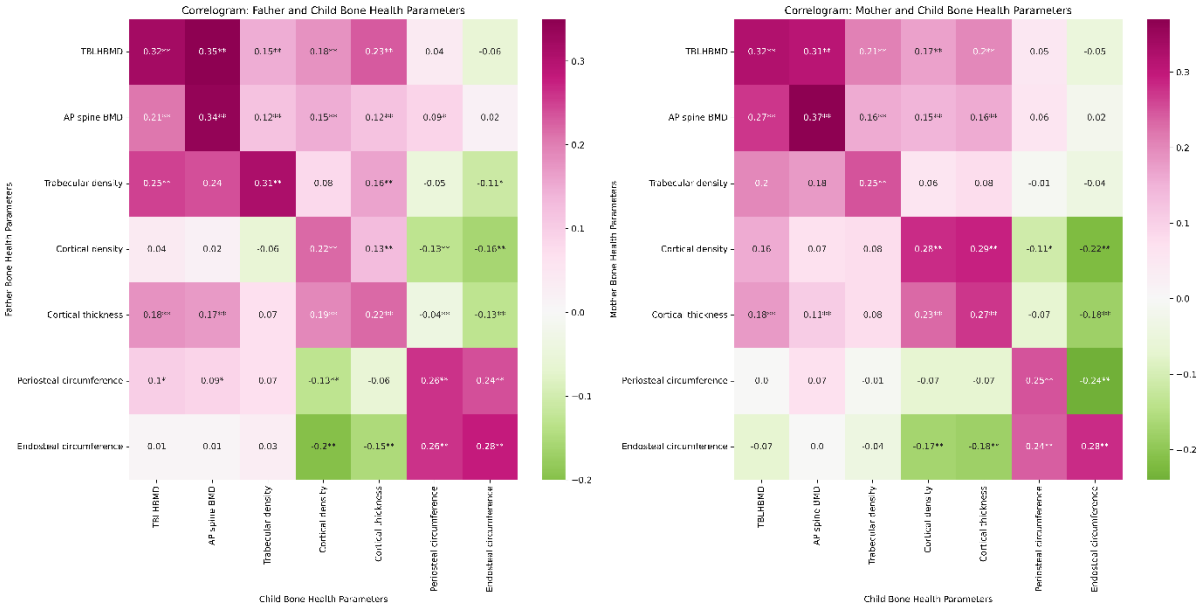
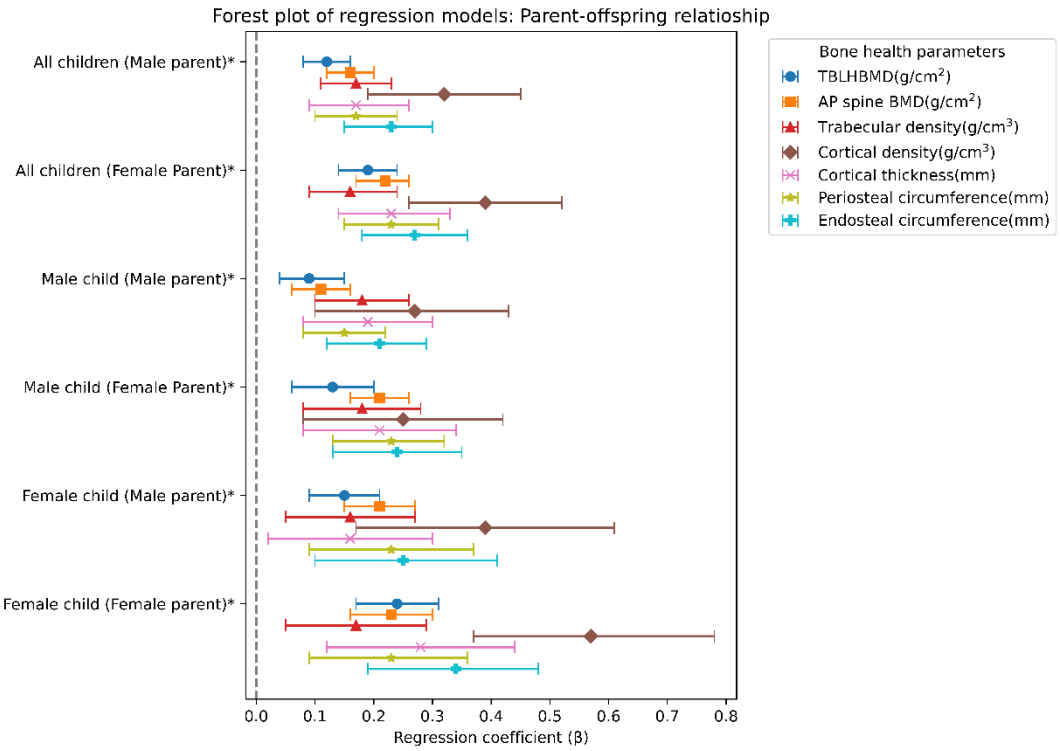


Figure 1: A] and B] represent the correlogram of child bone health parameters with male parent and female parent bone health parameters, respectively. C] Correlation heat map of non-

modifiable factors such as ulnar length and modifiable factors such as BMI, moderate physical activity, dietary intake, sunlight exposure, 25-hydroxyvitamin D (25(OH)D) with child bone health parameters. Positive correlations are shown in pink and negative correlations in green. Significant correlations (p<0.*05*) * (*p*<0.01) **are indicated with an asterisk.

Figure 2: Forest Plot of Regression Coefficient showing relationship between parents and children DXA - PQCT derived bone density and geometry parameters (Model 2 presented for all parameters).



Results represented from model 2 (accounted for modifiable factors) for all parameters. P-values significant (<0.05) are represented by (*). Beta coefficients (95% Confidence Intervals) are derived from a hierarchical linear regression model adjusted for child's BMI, object length, diet, physical activity, serum Vitamin D, sunlight exposure and socioeconomic status, that showed a significant correlation with child bone health parameter.