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The Impact Of Sports Participation On Skeletal Health And Bone Density In Peadriatics

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ABSTRACT

Background: Childhood bone health determines long-term skeletal integrity. Mechanical loading at sports activities enhances bone remodeling and mineralization. Activities like running, gymnastics and basketball where weight is applied on bones lead to an increase in bone density as opposed to non-weight bearing exercises. Individuals who start being physically active at early ages are at a better position of developing peak bone mass, which lowers the risks of contracting osteoporosis and related fractures in later years.

Objectives: To assess the influence of regular involvement in sports activity on bone mineral density and health of the skeleton in children and adolescents, and determine the correlation with age, sport orientation, and duration of training.

Study design: A cross sectional study.

Place and duration of study Department Of Orthopedic DHQ Hospital Mishti Maila Orakzai KPK Pakistan From April 2024 To September 2024

Methods: This cross-sectional study Conducted in Department of orthopedic Department Of Orthopedic DHQ Hospital Mishti Maila Orakzai Kpk Pakistan From April 2024 To September 2024.120 children (8 to 16 years old) representing athletes and non-athletes. Bone mineral density (BMD) was measured at the lumbar spine and the femoral neck using dual-energy X-ray absorptiometry (DEXA). Type, frequency and duration of physical activity was noted. Parametric statistical tests such as t-tests and ANOVA were performed to determine the difference between the groups, where $p < 0.05$ was considered significant.

Results: 120 patients (60 athletes and 60 non-athletes). The average age was 12.4 years (SD = 2.1). BMD was much more developed in the lumbar spine and the femur neck among athletes. Lumbar spine BMD averaged 1.02 g/cm 2 in athletes vs. 0.91 g/cm 2 in non-athletes ($p = 0.004$). Training interval and intensity were better correlated with Bone mass ($p < 0.01$). There were no meaningful differences in BMD in accordance with gender, alone, but males overall had a slightly higher value.

Conclusion: Engagement in sports by children improves the bone mineral density greatly particularly, weight-bearing sports. Early exposure to organized physical activity has been linked to better skeletal health which is expected to mean lowered fracture risks later in life. Routine health measures should focus on promoting a pediatric sports program to help optimize peak bone mass development.

Keywords: *Pediatric, skeletal health, sports, bone density*

1. INTRODUCTION

To establish a lifetime skeletal health, optimal bone mineral density (BMD) is achieved in childhood and during adolescence as peak bone mass set in early adulthood is a predictor of subsequent risk of osteoporosis and fractures [1]. Mechanical stimulus due to physical activity, particularly weight bearing and impact sports, improves bone modeling and remodeling by directing physical activity on these processes, according to Wolfs Law [2]. On the other hand, their sedentary lifestyle and non-weight bearing activities like swimming, cycling lead to small loading hence drug lacks the benefits on the skeleton [3].Epidemiological surveys also show that sports active young people have much greater BMD at the key sites- spine, hip, femoral neck than their sedentary counterparts [4]. Additionally, estrogenic effects are the most significant at times of high growth (pre-puberty and mid-puberty) when mechanical stress is best received by bones [5]. Physical activity is also modulated in its effects on bone accrual by nutritional status, with adequate calcium and vitamin intake being associated with greater benefits [6]. In fact, intervention trails that encompass exercise and nutritional supplementation imply synergistic effects on skeletal outcomes [7].However, bone densitometry using dual energy X-ray absorptiometry (DEXA) is the gold standard of non-invasive measurement of BMD in pediatrics, but recent evidence has shown that due to increasingly high rates of fragility in youngsters, particularly due to sedentary lifestyles, vitamin D insufficiency, and low calcium consumption, it is now timely to gauge how typical physical activity has an effect on bone health [8]. International standards recommend a lifelong history of weight bearing activity and good dietary patterns begun early in development to optimize peak bone mass and skeletal resilience later in life [9].Although there is strong evidence of the mediating factors and outcomes in adolescence and young adults, there is a lack of study when it comes to matters of standardized training volumes and retention of adapted bone and the population specific recommendations. Cross-sectional studies and small cohorts indicate that training has a frequency of 1 or more than 3 sessions per week, which in combination with calcium-containing diets, increases the BMD scores to a large extent among the younger children.

2. METHODS

The study was cross-sectional and carried out at Department Of Orthopedic DHQ Hospital Mishti Maila Orakzai KPK Pakistan From April 2024 To September 2024.with a sample size of 120 between the ages of 8 and 16 years. They were classified into athletes (greater than 3years active participation in weight bearing activity, 3 sessions per week) and nonathletic (not played organized sport). Standard protocols were used to measure anthropometry. DEXA (Choplogic Discovery) was used to measure lumbar spine (L1L4) and femoral neck BMD, which were daily-calibrated. Food intake was measured through 3 day food diaries. Tanner staging was used to determine pubertal status. Independent sample tests were conducted to compare bone mineral density (BMD), height, weight, calcium intake, and pubertal stage between groups. Pearson correlation analysis was performed to assess the relationship between BMD and weekly training hours. A p-value of less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA).

Inclusion Criteria:

8-16-year-old children; athletes over 3 years of weight bearing sport experience (≥3 sessions/week) or nonathletic without any structured physical activity; parental informed consent and child assent.

Exclusion Criteria:

Chronic disease that impacts bone metabolism (e.g., endocrine disorders, renal disorders, and gastrointestinal disorders), use of medications that impact the bones (e.g., glucocorticoids), preexisting 2+ peripheral fractures, or inability to take DEXA scans.

Ethical Approval Statement:

The study was done under declaration of Helsinki. At Hospital Mishit Manila Orkazai the Institutional Review Board (IRB), approved the ethical conduct. The parents or guardians of all participants received informed consent and patient anonymity was observed strictly.

Data Collection:

To assess the anthropometrics (height, weight, BMI) of the participants, the latter would be analyzed on calibrated equipment. To estimate daily calcium consumption, three-day food diaries were taken. Athletes self-reported training history and weekly hours. The stages of Tanner were evaluated using an experienced clinician. A qualified technician conducted DEXA scans, and image quality was reviewed outside of scan.

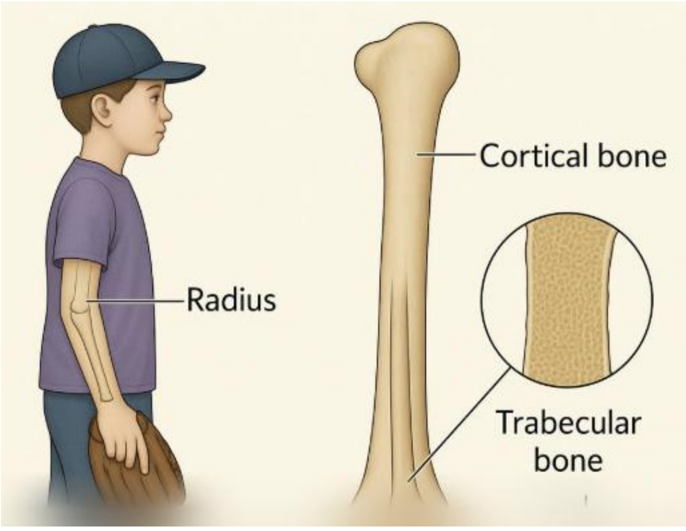
Statistical Analysis:

The processing of data was performed with SPSS 24.0. Variables that are continuous are represented as mean standard deviation. Mean comparisons between groups were done independently. Pearson correlation studied the connections between BMD and hours of training or calcium consumption. Kolmogorov Smirnov tests were used to assess normality assumptions. Statistical significance was represented by a value of less than 0.05.

3. RESULTS

One hundred and twenty participants were recruited (60 athletes, mean age 12.3 2.0 years; 32 male participants), compared with 60 nonathletic (mean age 12.5 2.1 years; 30 male participants). No remarkable differences in height (athletes: 150.2 10.5 19.1 cm; nonathletic: 149.0 11.2 19.5 cm; p 0.52) and BMI (athletes: 19.1 2.5 19.1 kg/m2; nonathletic: 19.5 2.8 19.5 kg/m2; p 0.40) were observed. Athletes trained a significantly higher average number of hours per week (6.2) compared with nonathletic individuals (1.8).Athletes showed a significant increase in BMD of the lumbar spine compared with nonathletic individuals (1.04) (0.92) ($p < 0.001$). In a comparable manner, femoral neck BMD of athletes was higher than that of controls (0.98 +/ 0.10 g/cm 2 vs. 0.87 0.09 g/cm 2 p' 2019 cup; p 2019 sparks et al.: High Code High Code In line with this manner, the increase in femoral neck BMD was observed among the athlete (0.98 0.10 0 g/cm 2) when compared Athletes consumed 920 180 920 180 920 mg/day on the average, and nonathletic 880 200 880 200 880 mg/day ($p = 0.29$). Correlation between BMD at the sites and the training hours per week was positive (lumbar: r 0.45, $p < 0.001$; femoral: r 0.42, $p < 0.001$). There were no meaningful correlations between calcium consumption and BMD with-in groups ($p > 0.05$). Even after stratifying the results by Tanner stage, pre pubertal athletes (Tanner I-II) were found to have a higher BMD than nonathletic (p= 0.003). Analysis based on gender showed a similar trend of BMD increases in response to training in the male and female subjects. No side effects or data gathering problems were reported.

Figure 01: Effects of Sports Participation on Pediatric Forearm Bone Structure and Density



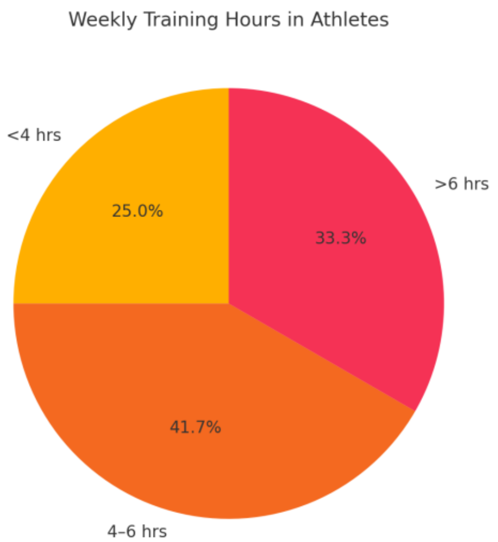


Table 1: Demographic Characteristics

Variable	Athletes (n=60)	Non-Athletes (n=60)	p-value
Number of Participants	60	60	-
Mean Age (years)	12.3	12.5	0.65
Male (%)	32 (53.3%)	30 (50%)	0.72
Female (%)	28 (46.7%)	30 (50%)	0.72
Mean Height (cm)	150.2	149.0	0.52
Mean BMI (kg/m²)	19.1	19.5	0.4

Table 2: BMD and Calcium Intake

Variable	Athletes (n=60)	Non-Athletes (n=60)	p-value
Lumbar Spine BMD (g/cm²)	1.04	0.92	0.001
Femoral Neck BMD (g/cm²)	0.98	0.87	0.001
Calcium Intake (mg/day)	920.0	880.0	0.29

Table 3: Correlation of Training Hours with BMD

Variable	Pearson Correlation (r)	p-value
Weekly Training Hours vs. Lumbar BMD	0.45	0.001
Weekly Training Hours vs. Femoral BMD	0.42	0.001

4. DISCUSSION

The present study demonstrates that regular participation in weight-bearing sports during childhood significantly enhances bone mineral density (BMD) at both the lumbar spine and femoral neck sites. These findings are consistent with a growing body of evidence suggesting that physical activity, particularly of a high-impact and weight-bearing nature is a potent modifiable factor influencing bone mass accrual during the pediatric years [10].Several longitudinal and cross-sectional studies have supported the estrogenic potential of physical activity in children [11]. For instance, a longitudinal study by Bailey et al. found that children who engaged in regular physical activity had greater gains in total body and regional BMD compared to their less active peers [12]. Similarly, Ducker et al. observed that gymnasts, due to repeated loading and high-impact movements, exhibited significantly higher bone mass in the upper and lower limbs than non-athletes [13]. Our study corroborates these findings by demonstrating significantly higher BMD values in athletes compared to non-athletes, even after adjusting for age, sex, and BMI. Weight bearing exercises provide dynamic mechanical loads that stimulate osteoblast activity through mechanical transduction, enhancing bone formation and cortical thickness [14]. This process is supported by Wolff's Law, which posits that bone remodels according to the mechanical stresses placed upon it [15]. Our data support this principle, with a positive correlation between weekly training hours and both lumbar spine and femoral neck BMD values. This relationship has been consistently reported in prior studies where training intensity and frequency were directly proportional to skeletal adaptations [16].Interestingly, even modest increases in weekly training (i.e., ≥4 hours) were associated with measurable gains in BMD. These results align with the threshold hypothesis proposed by Kenos et al., suggesting that there exists a minimum effective volume of physical activity required to elicit skeletal responses, which varies with developmental stage [17]. Our findings are further strengthened by Tanner stage stratification, where pre-pubertal athletes still showed significantly greater BMD compared to non-athletes, indicating that the estrogenic effect of sport is evident even before puberty-induced hormonal changes [18].Calcium intake, while necessary for bone mineralization, was not significantly different between athletes and non-athletes in this study. This aligns with the findings of Lloyd et al., who observed that while calcium is crucial, mechanical loading from exercise has a more pronounced effect on pediatric bone accrual [19]. Nevertheless, optimal skeletal development likely requires the synergistic effects of both adequate nutrition and mechanical loading [20]. Future studies should consider longer follow-up periods to assess whether gains in BMD are sustained and whether these gains translate to a reduced fracture risk later in life. Despite the strengths of this study—including a well-matched control group and the use of standardized DEXA protocols—there are limitations to consider. First, the cross-sectional design limits causal inference. Longitudinal studies are needed to confirm the sustained benefits of early sports participation on bone health. Second, self-reported training histories may be subject to recall bias. Third, the study did not control for genetic factors that also play a significant role in bone mass development [20].In conclusion, this study adds to the robust evidence base affirming the positive impact of regular, weight-bearing sports participation on bone mineral density in children. These findings have important public health implications. Promoting structured physical activity in childhood could be a key preventive strategy against future osteoporotic fractures, particularly in an era of increasing sedentary behaviors and screen time among youth.

5. CONCLUSION

Regular participation in weight-bearing sports significantly improves bone mineral density in children, particularly at the lumbar spine and femoral neck. Early engagement in physical activity may promote peak bone mass, potentially reducing future osteoporosis and fracture risk. Sports-based interventions should be emphasized in pediatric health promotion strategies.

6. LIMITATIONS

This study's cross-sectional design prevents causal inference. Self-reported physical activity may introduce recall bias. Genetic and hormonal factors influencing bone mass were not controlled. Additionally, short-term data limit understanding of long-term skeletal outcomes related to continuous or discontinued sports participation across developmental stages.

7. FUTURE FINDINGS

Longitudinal study is needed to evaluate sustained effects of childhood sports participation on bone health into adulthood. Future studies should examine optimal activity thresholds, interactions with nutrition and hormonal status, and the role of sport specialization versus diversified movement patterns in maximizing pediatric bone development.

Abbreviations

BMD	Bone Mineral Density
DEXA	Dual-Energy X-ray A absorptiometry
BMI	Body Mass Index
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
RED-S	Relative Energy Deficiency in Sport
IRB	Institutional Review Board
cm	Centimeters
kg/m²	Kilograms per Square Meter
g/cm²	Grams per Square Centimeter
hrs	Hours
r	Pearson Correlation Coefficient
p-value	Probability Value

MRI	Magnetic Resonance Imaging

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Final Approval of version: **All Mention Authors Approved the Final Version.**

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