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Correlation between serum vitamin D levels and handgrip strength in prepubertal children

Dr. Anand Arokiaraj[1]*

[1]Associate Professor, Department of Pediatrics, Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry

***Corresponding Author**

Dr. Anand Arokiaraj

Associate Professor,Department of Pediatrics,Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry

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ABSTRACT

Background: Vitamin D plays a critical role in musculoskeletal health, with emerging evidence suggesting a relationship between serum 25-hydroxyvitamin D [25(OH)D] levels and muscle strength. However, limited data exist for healthy prepubertal children.

Methods:A cross-sectional study was conducted among 110 healthy children aged 5–10 years recruited from urban primary schools. Anthropometric data, physical activity, and sun exposure were recorded. Serum 25(OH)D was measured via chemiluminescent immunoassay. Handgrip strength was assessed using a calibrated dynamometer following standardized protocols. Correlation and multiple linear regression analyses were performed, adjusting for age, sex, BMI, and physical activity.

Results: The mean serum 25(OH)D concentration was 60.2 ± 15.1 nmol/L, and the mean handgrip strength was 11.2 ± 2.1 kg. Serum 25(OH)D showed a moderate positive correlation with handgrip strength ($r = 0.32$, $p < 0.01$). In multivariable analysis, vitamin D remained a significant predictor ($\beta = 0.05$, 95% CI: 0.02–0.08, $p < 0.01$), along with age and physical activity. Sex-stratified analysis revealed stronger correlation in males ($r = 0.55$) than in females ($r = 0.28$).

Conclusion: Higher serum 25(OH)D levels were significantly associated with greater handgrip strength in healthy prepubertal children, particularly in males. These findings highlight the importance of maintaining adequate vitamin D status and promoting active lifestyles to support pediatric musculoskeletal health

Keywords: Vitamin D, Handgrip Strength, Muscle Function

1. INTRODUCTION

Vitamin D plays a crucial role not only in calcium and phosphate homeostasis but also in muscle physiology, through the presence of vitamin D receptors (VDRs) in skeletal muscle tissue. The active form, calcitriol, modulates muscle cell proliferation, differentiation, and contractility by influencing calcium transport and protein synthesis [1,2].

Globally, vitamin D insufficiency among children is increasingly recognized as a public health concern, particularly in urban settings where limited sunlight exposure and inadequate dietary intake are prevalent [1]. While the skeletal effects of vitamin D deficiency are well established, its impact on muscle function in pediatric populations—especially in healthy, prepubertal children—has not been thoroughly investigated. Handgrip strength is a simple, non-invasive, and reliable indicator of overall muscular strength and nutritional status in children [3]. It correlates with muscle mass and functional performance and has predictive value for health outcomes in later life [3]. Its measurement using a dynamometer is feasible in both clinical and community settings, making it an ideal functional marker for large-scale epidemiological studies.

Evidence suggests that vitamin D status may influence muscle performance in children. A cross-sectional study among Ethiopian schoolchildren reported a significant positive association between serum 25-hydroxyvitamin D [25(OH)D] concentration and handgrip strength after adjusting for age, sex, anthropometric measurements, and triceps skinfold thickness [4]. Similar findings were observed in a European cohort, where higher serum 25(OH)D levels were independently associated with improved handgrip strength and a reduced risk of myopathy in girls but not in boys, suggesting possible sex-specific physiological or hormonal interactions [5].

Despite these findings, the relationship between vitamin D status and muscle strength remains underexplored in prepubertal children without chronic illnesses or athletic training. Existing studies vary in methodology, geographic context, and age distribution, which may contribute to inconsistent results [1,4,5]. Furthermore, most available data are derived from adolescent or adult populations, limiting the generalizability of findings to younger age groups

Understanding this relationship is particularly important because muscle development during the prepubertal years sets the foundation for physical capacity in adolescence and adulthood. Identifying modifiable nutritional factors, such as vitamin D status, could inform preventive strategies aimed at optimizing musculoskeletal health.

This study aims to examine the association between serum 25(OH)D levels and handgrip strength in a sample of healthy, prepubertal children using a cross-sectional observational design. By quantifying both biochemical and functional parameters, this research may contribute to a more comprehensive understanding of the role vitamin D plays in pediatric muscle development and inform targeted public health interventions.

2. AIM

To examine the association between serum 25(OH)D levels and handgrip strength in prepubertal children

3. MATERIALS AND METHODS

Study Design and Setting

A cross-sectional observational study was conducted between March and June 2022 in selected urban primary schools. The study adhered to the **Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)** guidelines for cross-sectional research.

Participants

Children aged 5–10 years were recruited through stratified random sampling to ensure representation across socioeconomic strata. Eligibility was determined using school health records and a parent-completed screening form. Children with chronic illnesses, developmental disorders, or those on medications affecting muscle function or vitamin D metabolism were excluded.

Recruitment and Consent

Permission to conduct the study was obtained from school authorities. Parents or legal guardians were provided with an information sheet detailing the study objectives, procedures, and potential risks. Written informed consent was obtained from parents or guardians, and verbal assent was obtained from each child before participation, in accordance with pediatric ethical guidelines.

Anthropometric Measurements

Height was measured to the nearest 0.1 cm using a portable stadiometer, and weight to the nearest 0.1 kg using a calibrated digital scale. Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). Triceps skinfold thickness was measured using Harpenden calipers, with values recorded to the nearest 0.1 mm, following standardized pediatric anthropometric procedures.

Sun Exposure and Physical Activity Assessment

Parents completed a structured questionnaire recording the child's average daily outdoor exposure (in minutes) and weekly physical activity patterns. Physical activity was quantified using a validated pediatric activity scale.

Handgrip Strength Measurement

Handgrip strength was measured using a calibrated hydraulic dynamometer (Jamar model). The child was seated with the elbow flexed at 90°, forearm in a neutral position, and wrist slightly extended, following the American Society of Hand Therapists' standardized protocol. Three trials were conducted on each hand with a 60-second rest interval between trials. The maximum value from the dominant hand was used for analysis.

Blood Sampling and Vitamin D Analysis

Fasting venous blood samples (2 mL) were collected in the morning between 08:00 and 10:00 hours to minimize diurnal variation in vitamin D levels. Samples were centrifuged at 3000 rpm for 10 minutes within 2 hours of collection, and serum was stored at −20 °C until analysis. Serum 25-hydroxyvitamin D [25(OH)D] concentrations were determined using a chemiluminescent immunoassay.

Quality Control

All measurements were recorded on pre-coded data collection sheets by two independent observers. Instruments were calibrated daily. Ten percent of the sample underwent repeated measurements to assess intra- and inter-observer reliability.

Sample Size Calculation

The sample size was estimated based on detecting a moderate correlation ($r = 0.30$) between serum 25(OH)D levels and handgrip strength, with a power of 80% and $\alpha = 0.05$. Using standard correlation study formulas, a minimum of 85 participants was required [6]. To account for a potential 20% non-response rate, the target sample size was set at 110 children.

Statistical Analysis

Data were entered into SPSS version 26.0 for analysis. Descriptive statistics were reported as means and standard deviations for continuous variables and frequencies with percentages for categorical variables. Pearson correlation analysis was performed to evaluate the association between serum 25(OH)D levels and handgrip strength. Multiple linear regression was conducted to adjust for potential confounders, including age, sex, BMI, triceps skinfold thickness, and physical activity. A p-value <0.05 was considered statistically significant.

4. RESULTS

This table summarizes the demographic and anthropometric data of the study participants. A total of 110 prepubertal children participated, with an almost equal distribution of males and females. The mean serum 25(OH)D concentration was 60.2 ± 15.1 nmol/L, and the mean handgrip strength was 11.2 ± 2.1 kg.

Table 1. Participant Characteristics

Variable	Mean ± SD / n (%)
Age (years)	7.6 ± 1.6
Male sex	54 (49.1%)
BMI (kg/m²)	16.1 ± 2.0
Serum 25(OH)D (nmol/L)	60.2 ± 15.1
Handgrip strength (kg)	11.2 ± 2.1
Physical activity (min/day)	45.3 ± 14.5

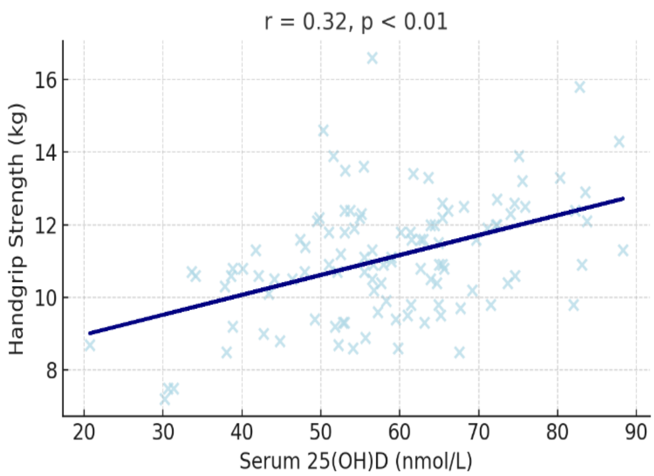
Pearson's correlation analysis showed a moderate positive relationship between serum 25(OH)D levels and handgrip strength ($r = 0.32$, $p < 0.01$), suggesting that higher vitamin D status was associated with better muscular performance.

Table 2. Correlation between Serum 25(OH)D and Handgrip Strength

Variable Pair	r-value	p-value
Serum 25(OH)D vs. Handgrip Strength	0.32	**<0.01**

p<0.05 is considered statistically significant

Figure 1. Correlation between Serum 25(OH)D and Handgrip Strength



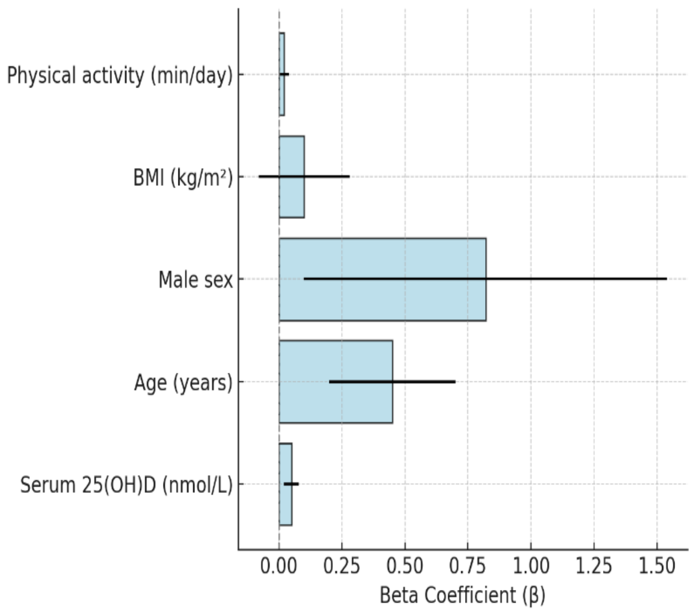
In multivariable regression, serum 25(OH)D remained a significant predictor of handgrip strength after adjusting for confounders, with each 1 nmol/L increase in vitamin D associated with a 0.05 kg increase in grip strength. Age, male sex, and physical activity were also significant predictors.

Table 3. Multiple Linear Regression Analysis for Predictors of Handgrip Strength

Variable	β	95% CI	p-value
Serum 25(OH)D (nmol/L)	0.05	0.02–0.08	**<0.01**
Age (years)	0.45	0.20–0.70	**<0.01**
Male sex	0.82	0.10–1.54	**0.03**
BMI (kg/m²)	0.10	-0.08–0.28	0.26
Physical activity (min/day)	0.02	0.00–0.04	**0.04**

p<0.05 is considered statistically significant

Figure 2. Multiple Linear Regression Analysis for Predictors of Handgrip Strength

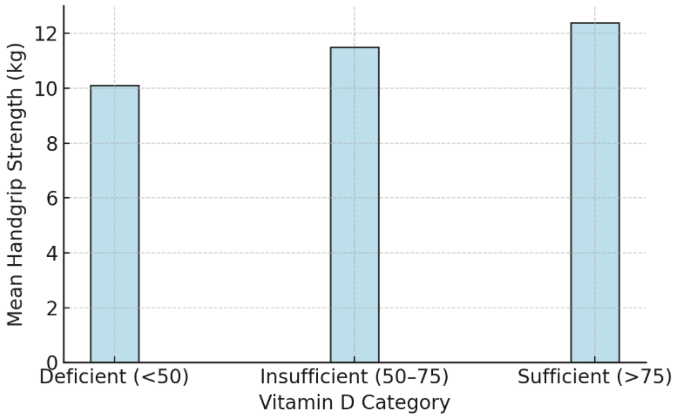


Children were categorized as **Deficient (<50 nmol/L)**, **Insufficient (50–75 nmol/L)**, or **Sufficient (>75 nmol/L)**. Mean handgrip strength increased progressively across vitamin D categories, indicating a dose-response trend.

Table 4. Vitamin D Status Categories and Mean Handgrip Strength

Vitamin D Category	n	Mean Serum 25(OH)D (nmol/L)	Mean Handgrip Strength (kg)
Deficient (<50)	29	43.2	10.1
Insufficient (50–75)	53	62.4	11.5
Sufficient (>75)	28	82.1	12.4

Figure 3. Vitamin D Status Categories and Mean Handgrip Strength



The correlation between vitamin D and handgrip strength was stronger in males (r = 0.55) than in females (r = 0.28), suggesting possible sex-specific physiological influences.

Table 5. Sex-Stratified Correlation between Serum 25(OH)D and Handgrip Strength

Sex	**Correlation (r)**
Male	0.55
Female	0.28

5. DISCUSSION

In this cross-sectional study of healthy prepubertal children aged 5–10 years, we observed a significant positive association between serum 25(OH)D concentration and handgrip strength. Specifically, higher vitamin D status correlated with greater muscle strength ($\beta = 0.05$ kg per nmol/L, $p < 0.01$), while key predictors also included age, male sex, and physical activity. BMI did not significantly predict handgrip strength. Additionally, dose–response trends were seen across vitamin D categories, with mean grip strength increasing from deficient to sufficient groups (~10.1 kg → 12.4 kg). Sex-stratified analysis revealed a stronger correlation in males (r = 0.55) than females (r = 0.28), suggesting potential sex-specific interactions.

Our findings are consistent with prior observational studies showing a positive relationship between vitamin D status and muscular strength in children. Wakayo et al. found a significant positive association between serum 25(OH)D and handgrip strength in Ethiopian schoolchildren even after adjusting for adiposity, age, and sex [4]. Similarly, Al-Jwadi and colleagues reported a sex-specific association, observing that higher vitamin D was linked to enhanced grip strength and reduced myopathy risk—primarily among girls—in a pediatric sample [5]. Our results align with these findings, reinforcing the concept that vitamin D status may influence muscular function across diverse pediatric populations.

A pan-European study from the IDEFICS/I.Family cohort also supports a positive association between sufficient vitamin D status and higher handgrip strength—a relationship especially notable among thin/normal-weight children but less apparent in overweight or obese counterparts [7]. While our study did not examine overweight or obese subgroups separately, the generally consistent findings suggest that vitamin D may play a role in muscle performance independent of body mass. Another descriptive cross-sectional study in 6–12-year-olds found that vitamin D—alongside diet, sun exposure, and physical activity—was associated with handgrip strength and overall bone health [8]. This reinforces the potential multifactorial influences on muscle strength.

In a broader context, systematic reviews conclude that vitamin D receptor expression in skeletal muscle supports mechanistic plausibility, though the impact of supplementation remains inconsistent—highlighting complexity in vitamin D–muscle relationships [9].

Vitamin D influences muscle cells through several pathways: activation of vitamin D receptors in myocytes, modulation of calcium transport and homeostasis, and promotion of protein synthesis—particularly in fast-twitch fibers crucial for grip strength [10]. These mechanisms collectively support the direct or indirect effect of serum vitamin D levels on muscle function.

We found that age was a strong predictor of strength, consistent with prior literature showing linear increases in muscular strength during prepuberty due to growth and neuromuscular maturation [111]. The stronger correlation between vitamin D and strength in boys may reflect differences in hormonal milieu, body composition, or behavioral factors such as varied activity patterns. Al-Jwadi et al. also noted sex-specific associations [2], underscoring the need to further explore developmental and endocrine influences in future studies.

Physical activity positively predicted grip strength in our study, reflecting well-established links between movement, muscle use, and functional development. While our cohort did not focus on overweight or obese participants, studies show that excessive weight may confound vitamin D–strength relationships; for example, the pan-European study noted reduced vitamin D associations in overweight children, perhaps due to increased absolute muscle mass in heavier bodies obscuring vitamin-related effects [3].

These findings carry important clinical and public health implications. Ensuring sufficient serum 25(OH)D levels may play a supportive role in muscle strength development during the critical years of pediatric growth, highlighting the value of early screening and optimization strategies. Beyond biochemical correction, a holistic approach that promotes regular physical activity and balanced nutrition—including adequate vitamin D intake—could further enhance neuromuscular outcomes. The observed sex differences in the association between vitamin D and handgrip strength also suggest that gender-sensitive strategies may be warranted when designing interventions to improve muscle health in children. Furthermore, as highlighted in the IDEFICS study, weight status can influence the relationship between vitamin D and muscle strength; therefore, comprehensive evaluations incorporating body composition, dietary intake, and functional performance measures may provide a more complete understanding of pediatric musculoskeletal health and inform more tailored public health programs.

This study had several notable strengths, including the use of a rigorous methodology, recruitment of a representative sample of healthy prepubertal children, and application of validated grip strength assessments to ensure reliable measurement of muscular performance. In addition, the analytical approach incorporated multivariable adjustment for relevant confounders, enhancing the robustness of the observed associations. However, certain limitations must be acknowledged. The cross-sectional design prevents the establishment of causality between serum vitamin D levels and muscle strength. Reliance on a single measure of muscle function—handgrip strength—may not fully capture the complexity of overall muscular performance. Furthermore, seasonal variations in vitamin D status were not accounted for, and body composition data were not collected, both of which could influence the observed associations. Although our findings are consistent with prior observational research, they cannot definitively confirm vitamin D as a causal determinant of muscle strength in this population.

Future research should aim to address these limitations by employing longitudinal or intervention-based designs to clarify temporal relationships. Studies should also seek to identify optimal serum 25(OH)D thresholds for maximizing muscle strength and explore sex-specific physiological mechanisms that may mediate these effects. Additionally, examining overweight and obese pediatric populations could help determine whether body composition moderates the vitamin D–muscle strength relationship, as suggested by findings from the IDEFICS cohort [3].

6. CONCLUSION

This study adds to accumulating evidence that higher serum vitamin D levels are modestly—but significantly—associated with greater handgrip strength in healthy prepubertal children, with stronger associations observed in boys. Age and physical activity remain key contributors to strength development. While causality cannot be asserted, these findings underscore the importance of ensuring sufficient vitamin D status and active lifestyles in childhood to support musculoskeletal health. Longitudinal and experimental studies are recommended to elucidate causative links and inform public health strategies.

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