

The Effect of Clark's Angle and Body Weight on Dynamic Balance in School-Aged Children

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ABSTRACT

Background: Foot structure and body weight are considered important factors influencing dynamic balance in school-aged children. Dynamic balance in this study was assessed using the Functional Reach Test (FRT). This study aimed to analyze Effect of Clark's Angle and Body Weight on Dynamic Balance in School-Aged Children

Methods: This study employed an analytical observational cross-sectional design. A total of 58 children aged 9–12 years were recruited using purposive sampling. The independent variables included Clark's Angle of the left and right feet and body weight, while the dependent variable was dynamic balance measured using the FRT. Data analysis consisted of the Kolmogorov–Smirnov normality test and Pearson correlation analysis, with a significance level set at $p < 0.05$.

Results: The findings revealed a very strong positive correlation between Clark's Angle and FRT scores for both the right foot ($r = 0.808$) and the left foot ($r = 0.801$). In contrast, body weight demonstrated a significant negative correlation with FRT ($r = -0.569$). An almost perfect correlation between left and right Clark's Angle values ($r = 0.994$) indicated a high degree of bilateral foot morphology symmetry within the sample. Children with higher medial longitudinal arches exhibited better dynamic balance, whereas those with flat feet or higher body weight tended to show reduced dynamic balance performance.

Conclusion: Clark's Angle is a significant predictor of dynamic balance in school-aged children, while increased body weight may adversely affect postural stability. Assessment of foot structure and body weight status should be incorporated into routine child health screening to support early intervention strategies aimed at improving motor development and balance.

I. Introduction

Dynamic balance is defined as the capacity of the neuromusculoskeletal system to maintain postural stability during movement or in response to shifts in the body's center of gravity. In school-aged children, dynamic balance plays a critical role, as this developmental stage is characterized by rapid maturation of motor control and coordination. During this period, children progressively acquire the ability to regulate body movements during activities such as running, jumping, playing, and performing daily functional tasks that require integrated postural control. Adequate dynamic balance is also essential for fostering self-confidence and active participation in school-based physical education and sports activities, thereby supporting overall physical development and functional independence (Yanovich 2022). Beyond neuromuscular maturation, environmental and behavioral factors substantially influence the development of dynamic balance. Regular participation in physical activity has been associated with improved postural regulation in children. Evidence from a Spanish study indicates that children who engage in active lifestyles exhibit more effective postural control than their sedentary counterparts,

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highlighting the role of habitual movement in optimizing postural stabilization mechanisms (Garc and Leir 2020). In line with this perspective, evidence from motor development studies suggests that dynamic postural stability gradually advances as sensorimotor integration and interlimb coordination mature, yet remains incompletely developed until around the age of 10 years (Mani et al. 2021). Consistent with these findings, research on motor development indicates that dynamic postural stability improves progressively in parallel with sensorimotor maturation and interlimb coordination. However, this process is not fully consolidated until approximately the age of ten. This developmental trajectory highlights primary school age as a critical period for monitoring and supporting balance capabilities. Furthermore, accumulating evidence demonstrates a positive association between physical activity and motor competence, both of which contribute substantially to effective functional postural control (John et al. 2024).

Notably, dynamic balance extends its influence beyond physical function and has been associated with academic performance. Longitudinal evidence indicates that children with well-developed dynamic balance tend to achieve higher academic outcomes, particularly in language-related subjects and mathematics, suggesting an interaction between motor control and cognitive development (Lima et al. 2020). This relationship may be explained by the maturation of the sensorimotor system, which enables children to maintain an appropriate sitting posture, sustain attention, and produce efficient motor responses during learning activities. Consequently, balance can be considered a fundamental component of academic readiness, reflecting the close integration between postural control and cognitive performance (Wang 2025). Accordingly, dynamic balance may be regarded as a key component supporting school readiness, as a well-developed sensorimotor system enables children to maintain seated posture, sustain attention, and generate appropriate motor responses during learning activities (Gill et al. 2016).

Consequently, dynamic balance can be regarded as a fundamental component supporting learning readiness in school-aged children. As children grow, balance ability progressively develops through changes in body structure, improvements in coordination, and the accumulation of daily motor experiences (Lilik et al. 2025). Balance serves as a fundamental foundation for a wide range of motor skills; therefore, impairments in this ability may adversely affect both physical activities and the performance of simple motor tasks (Martín-díaz et al. 2024).

Body weight represents one of the key factors influencing balance performance. Previous studies have demonstrated that children with overweight or obesity tend to exhibit deficits in both static and dynamic balance, as reflected by increased postural sway, greater displacement of the center of pressure, and poorer performance on balance assessment tests compared with their normal-weight peers (Guzm et al. 2023). Excess adiposity alters the position of the body's center of mass and modifies postural biomechanics, thereby reducing the efficiency of neuromuscular responses to stability perturbations (Lestari et al. 2024).

Structural characteristics of the medial longitudinal arch influence plantar pressure distribution and biomechanical stability during dynamic activities. Foot type variations, including flatfoot with reduced arch height, have been shown to alter plantar load patterns and reduce postural balance in children (Ramadhani and Romadhoni 2024), while different foot arch types affect plantar pressure distribution under static and dynamic conditions, impacting mechanical stability (Ramos-frutos et al. 2025). Additionally, altered MLA status has been associated with poorer balance control and functional stability (Ghorbani and Yaali 2025), consistent with evidence that foot structural changes influence proprioceptive feedback relevant to balance control (Chinpeerasathian et al. 2024).

Recent pediatric research has reinforced the utility of the Functional Reach Test (FRT) as a reliable clinical measure of dynamic balance in children. A cross-sectional study involving 6–11-year-old Saudi children established normative FRT values and found significant correlations with age, height, and body mass, highlighting the influence of anthropometric characteristics on forward reach performance (Alotaibi et al. 2023). Additional normative data from school-aged children in India and Turkey corroborate average FRT values that vary with body weight alongside age and height, suggesting that anthropometric load influences dynamic balance measures in typically developing children (Hedel et al. 2025). Furthermore, a 2024 systematic review confirmed the strong psychometric properties of the Functional Reach Test (FRT) in children and adolescents, showing that reference values increase with growth and the development of body structure (Sharma and Kumar 2024). Collectively, this evidence underscores the relevance of FRT as a comprehensive and reliable tool for evaluating the relationship between body weight, anthropometric characteristics, and dynamic balance in school-aged children.

Therefore, the present study is warranted to address the existing gap by investigating the influence of body weight on dynamic balance using the FRT, providing further evidence to support clinical assessment and pediatric balance evaluation.

Given the fundamental role of the medial longitudinal arch and body weight in postural regulation, and recognizing the scarcity of studies addressing these factors in school-aged children, this study seeks to explore the impact of Clark's Angle and body weight on dynamic balance. The Functional Reach Test (FRT) was employed as a standardized measure to evaluate forward reach and postural control, providing insights into how structural and anthropometric characteristics contribute to balance performance in this population.

METHODS

This study employed a cross-sectional analytical observational design to explore how Clark's Angle and body weight influence dynamic balance in school-aged children. This design was chosen because it allows for the simultaneous assessment of multiple variables without introducing interventions, providing a clear snapshot of the relationships among the studied factors.

Participants were children aged 9–12 years, selected through purposive sampling based on the following inclusion criteria: no history of lower limb injury in the past three months, the ability to stand and walk independently, and willingness to participate in all study procedures. A total of 58 children met these criteria, and all data were complete, ensuring that every participant could be included in the analysis.

The independent variables were the left and right Clark's Angles and body weight. Clark's Angle was measured through standardized footprint analysis to assess the medial longitudinal arch. Body weight was recorded using a digital scale with 0.1 kg precision, and BMI was calculated as weight divided by height squared. Dynamic balance, the dependent variable, was assessed using the Functional Reach Test (FRT). Children were asked to stand upright and reach forward as far as possible without stepping or losing balance. Each participant performed three trials, and the highest value was recorded as their final score.

Data analysis was performed using SPSS version 25. Normality was tested with the Kolmogorov-Smirnov method, confirming that all variables were normally distributed ($p > 0.05$). Pearson's correlation was then applied to examine the relationships between Clark's Angle, body weight, and FRT scores, with statistical significance set at $p < 0.05$.

RESULTS

This section presents the research findings based on the analysis of data obtained from 58 participants. All variables were complete with no missing data, as summarized in Table 1.

Table 1. Summary of Data Processing

Variable	Valid (n, %)	Missing (n, %)	Total (n, %)
Clark's Angle Kiri	58 (100%)	0 (0%)	58 (100%)
Clark's Angle Kanan	58 (100%)	0 (0%)	58 (100%)
Functional Reach Test	58 (100%)	0 (0%)	58 (100%)
Body Mass Index (BMI)	58 (100%)	0 (0%)	58 (100%)
Body Weight	58 (100%)	0 (0%)	58 (100%)

Table 1 summarizes the data processing for all study variables. All 58 participants provided complete data, with no missing values recorded for Left and Right Clark's Angles, Functional Reach Test (FRT), Body Mass Index (BMI), or Body Weight. This completeness ensures that all participants could be included in subsequent statistical analyses, providing a robust dataset for examining the relationships between foot structure, body weight, and dynamic balance.

Descriptive statistics for all study variables are presented in Table 2. The left and right Clark's Angles exhibited similar mean values with relatively wide data dispersion ($SD > 14^\circ$). The Functional Reach Test (FRT) had a mean score of 33.07 cm with moderate variability. Body Mass Index (BMI) and body weight showed a right-skewed distribution, indicating the presence of several children with higher body weight.

DISCUSSION

The discussion should explore the significance of the results of the study. The following components should be covered in discussion: How do your results relate to the original question or objectives outlined in the background section (what)? Do you provide interpretation scientifically for each of your results or findings presented (why)? Are your results consistent with what other investigators have reported (what else)? Or are there any differences?

Table 2. Descriptive Statistics of Study Variables

Variabel	Mean	SD	Min	Maks	Skewness
Clark's Angle Left (°)	35.24	14.52	10	65	-0.098
Clark's Angle Right (°)	35.55	14.10	10	65	-0.140
Functional Reach Test (cm)	33.07	10.02	15	57	0.296
Body Mass Index	18.77	4.07	12	31	0.894
Weight (kg)	37.17	10.69	18.3	68.6	0.834

Table 2 The data indicate that the left and right Clark's Angles are distributed almost symmetrically, reflecting consistent foot structure among participants. In contrast, body weight and BMI show a tendency toward positive skewness, suggesting the presence of a few children with higher body weight within the sample.

The Kolmogorov–Smirnov test indicated that all variables were normally distributed ($p > 0.05$). Based on these results, Pearson's correlation was applied to examine the relationships between Clark's Angle, body weight, and Functional Reach Test (FRT) scores. The results are presented in **Table 3**.

Table 3. Pearson's Correlation between Clark's Angle, Body Weight, and FRT

Variabel	Right CA	Left CA	Weight	FRT
Right CA	1	0.994**	-0.643**	0.808**
Left CA	0.994**	1	-0.655**	0.801**
Weight	-0.643**	-0.655**	1	-0.569**
FRT	0.808**	0.801**	-0.569**	1

Note: $p < 0.01$ (significant)

The analysis revealed a very strong positive correlation between both the right and left Clark's Angles and FRT scores ($r = 0.808$ and $r = 0.801$, respectively), indicating that children with higher medial longitudinal arches tend to achieve greater forward reach distances. Conversely, body weight showed a strong negative correlation with FRT ($r = -0.569$), suggesting that higher body mass may limit dynamic balance performance.

Additionally, the left and right Clark's Angles were almost perfectly correlated ($r = 0.994$), highlighting the symmetrical nature of foot morphology in this sample. These findings collectively underscore the significant role of both foot structure and body weight in influencing dynamic postural control among school-aged children.

The present findings demonstrated a very strong positive correlation between both right and left Clark's Angles and Functional Reach Test (FRT) scores ($r = 0.808$ and $r = 0.801$, respectively). This indicates that children with a higher medial longitudinal arch (MLA) tend to achieve greater forward reach distances, reflecting superior dynamic balance performance. These results are consistent with previous studies reporting that adequate arch height contributes to improved postural stability by optimizing plantar pressure distribution and enhancing proprioceptive input from the foot sole. A well-formed MLA acts as a dynamic shock absorber and lever during movement, facilitating efficient force transmission and stability during forward-reaching tasks (Ghorbani & Yaali, 2025; Chinpeerasathian et al., 2024).

Several biomechanical studies have shown that children with flatfoot or reduced arch height exhibit altered foot mechanics, increased midfoot contact area, and diminished sensory feedback, all of which negatively affect balance control. Ramadhani and Romadhoni (2024) reported that children with flatfoot demonstrated poorer dynamic balance performance compared with those with normal arches, as evidenced by reduced reach distances and increased postural sway. Similarly, Ramos-Frutos et al. (2025) found that variations in foot arch structure significantly influenced plantar load patterns during dynamic tasks, thereby affecting postural control. These findings support the present results, suggesting that higher Clark's Angle values indicative of a more developed MLA—are associated with enhanced dynamic postural stability in school-aged children.

The nearly perfect correlation observed between left and right Clark's Angles ($r = 0.994$) highlights the symmetrical development of foot morphology in the study population. This symmetry aligns with

previous pediatric studies indicating that, in typically developing children, bilateral foot structures tend to mature in parallel unless influenced by pathological conditions or asymmetric loading patterns (Martin-Díaz et al., 2024). Symmetrical foot architecture is believed to promote balanced weight distribution and coordinated neuromuscular responses, both of which are essential for maintaining postural stability during functional movements such as forward reaching.

Conversely, body weight demonstrated a strong negative correlation with FRT scores ($r = -0.569$), suggesting that increased body mass adversely affects dynamic balance performance. This finding is in agreement with a growing body of literature indicating that overweight and obese children often exhibit poorer balance control than their normal-weight peers. Guzmán et al. (2023) reported that excess body weight is associated with increased postural sway and reduced reach capacity, particularly during dynamic balance assessments. Increased adiposity shifts the body's center of mass upward and anteriorly, thereby increasing the torque demands on the postural control system and reducing stability during forward-reaching tasks.

Furthermore, Lestari et al. (2024) demonstrated that higher body mass impairs neuromuscular efficiency and delays postural adjustment responses in children, leading to compromised balance performance. Excess body weight also increases mechanical load on the lower extremities, potentially limiting joint range of motion and muscular endurance, which are critical for maintaining balance during functional reach tasks. These biomechanical constraints may explain the reduced FRT performance observed in children with higher body weight in the present study.

Taken together, the findings emphasize the combined influence of structural and anthropometric factors on dynamic postural control in school-aged children. While a well-developed medial longitudinal arch appears to enhance balance performance by improving biomechanical efficiency and sensory feedback, excessive body weight poses a significant challenge to postural stability by altering center-of-mass dynamics and increasing neuromuscular demands. These results align with previous evidence highlighting the multifactorial nature of balance control, which depends on the interaction between musculoskeletal structure, body composition, and neuromotor coordination (John et al., 2024; Sharma & Kumar, 2024).

The present findings reinforce the importance of considering both foot morphology and body weight when assessing dynamic balance in children. The strong associations observed with the Functional Reach Test further support its utility as a sensitive clinical tool for identifying balance impairments related to structural and anthropometric characteristics. Early identification of children with reduced MLA height or excessive body weight may allow for timely interventions, such as targeted physical activity programs, weight management strategies, and foot-specific exercises, to promote optimal balance development and functional independence during this critical developmental period.

CONCLUSION

The findings of this study demonstrate a very strong relationship between Clark's Angle and dynamic balance in school-aged children. The correlations between right Clark's Angle and FRT ($r = 0.808$) and left Clark's Angle and FRT ($r = 0.801$) indicate that children with higher medial longitudinal arches tend to have better postural stability when reaching forward. In other words, an optimal foot arch facilitates postural control during movement, making dynamic balance tasks, such as the Functional Reach Test (FRT), easier to perform.

These results are consistent with previous research emphasizing the role of the foot arch in plantar pressure distribution and postural stability. For instance, a study on children aged 10–12 years reported that an optimal foot arch enhances walking balance by efficiently adjusting plantar pressure (Sharma et al., 2024). Additionally, research among middle school students indicated that children with flat feet exhibit lower static and dynamic balance, making postural control more challenging (Ramadhani and Kusumawati 2025).

Descriptive statistics from the current study showed that the left and right Clark's Angles had nearly identical mean values with wide variability, reflecting individual differences in arch height. Conversely, body weight and Body Mass Index (BMI) displayed a right-skewed distribution, suggesting that some children had higher body mass. Notably, children with higher body weight tended to have lower FRT scores, as additional mass can elevate the center of gravity, increase postural sway, and impose greater load on the feet and stabilizing muscles (Górna et al. 2022).

Furthermore, the near-perfect correlation between left and right Clark's Angles ($r = 0.994$) indicates that foot structure in this sample was relatively symmetrical. Therefore, variations in FRT scores are more

likely influenced by arch height and body weight rather than foot asymmetry. Children with flat feet or low arches typically exhibit increased pronation, instability during the stance phase, and greater activation of intrinsic foot muscles. These biomechanical changes reduce dynamic balance, particularly during challenging tasks such as the FRT. Previous studies have similarly supported these observations (Ramadhani and Romadhoni 2024).

Overall, this study underscores that medial longitudinal arch height is a critical factor in maintaining postural stability in children, while higher body weight can pose a risk for reduced balance. Accordingly, health screenings for school-aged children should extend beyond measuring body weight and BMI to include assessment of foot structure. Early interventions, whether through foot strengthening exercises or weight management programs, can then be implemented to support motor development and dynamic balance in children.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this research

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