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Correspondence
Rubab Rehman,
rubabrehman17@gmail.com

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The Association of Pes Planus and Calf Muscle Tightness Among School-Age Children

Rubab Rehman[1], Faryal Arshad[1], Karan Parkash[1], Asma Malik[1], Warda Eman[1], Maria Farooq[1]

1 PSRD Hospital Lahore and PSRD High School Lahore, Lahore, Pakistan

ABSTRACT

Background: *Pes planus is a common pediatric foot posture variant characterized by medial longitudinal arch collapse during weight bearing and has been linked to altered lower-limb biomechanics, including restricted ankle dorsiflexion leading to compensatory pronation.* ***Objective:*** *To determine the association of pes planus and calf muscle tightness (gastrocnemius and soleus) among school-age children.* ***Methods***: *A cross-sectional observational study was conducted over six months at PSRD Hospital Lahore and PSRD High School Lahore using convenience sampling. Children aged 6–12 years were classified as pes planus or normal foot posture using Jack's test. Ankle dorsiflexion was measured bilaterally with a goniometer in knee extension (gastrocnemius) and knee flexion (soleus) and categorized into severity bands. Associations were tested using Pearson's chi-square with effect sizes (Cramér's V).* ***Results***: *Among 142 children (mean age 9.16 ± 2.04 years; 54.2% male), 86 (60.6%) had pes planus. Pes planus was strongly associated with gastrocnemius tightness bilaterally (χ^2=118.52, df=2, $p<0.001$; Cramér's V=0.65), with severe tightness present in ~65% of the pes planus group versus ~11% without pes planus. Soleus tightness was also associated with pes planus (right: χ^2=62.01, df=2, $p<0.001$; V=0.47; left: χ^2=44.31, df=1, $p<0.001$; V=0.40).* ***Conclusion***: *School-age children with pes planus demonstrate significantly higher prevalence of calf muscle tightness, particularly gastrocnemius restriction, supporting routine dorsiflexion assessment in pediatric flatfoot evaluation.*

Keywords
Pes planus; flatfoot; calf muscle tightness; gastrocnemius; soleus; ankle dorsiflexion; children.

INTRODUCTION

Pes planus, commonly referred to as flatfoot, is characterized by the partial or complete collapse of the medial longitudinal arch of the foot during weight-bearing and represents one of the most frequently encountered pediatric musculoskeletal conditions (1). Although the medial arch is physiologically underdeveloped in early childhood, it typically forms between the ages of three and five years and persists into adolescence, with only a small proportion of children continuing to exhibit flatfoot beyond the age of ten (2). From a biomechanical perspective, pes planus is not solely defined by arch flattening but also by a constellation of structural and functional alterations, including hindfoot hyperpronation, calcaneal eversion, and relative forefoot supination during stance (3). These alterations can disrupt normal lower limb kinematics and load distribution, particularly during gait and other functional activities.

Pes planus may be classified as flexible or rigid, with flexible pes planus being the most prevalent form in children. In flexible pes planus, the medial longitudinal arch is present during non–weight-bearing but collapses under load, reflecting functional instability rather than fixed structural deformity (4). This form is frequently considered benign; however, growing evidence suggests that persistent flexible flatfoot may be associated with pain, altered gait mechanics, and secondary musculoskeletal dysfunctions affecting the ankle, knee, hip, and even the lumbar spine (5). Epidemiological studies have demonstrated considerable variability in prevalence across populations, with recent data from school-aged children in Lahore reporting a prevalence exceeding 40%, highlighting the clinical and public health relevance of this condition in pediatric populations

The integrity of the medial longitudinal arch depends on the coordinated interaction between osseous alignment, ligamentous support, and dynamic muscular control. In addition to intrinsic foot musculature and key static stabilizers such as the plantar fascia and spring ligament, extrinsic muscles crossing the ankle joint play a critical role in maintaining normal foot posture (6).

Among these, the gastrocnemius–soleus complex is of particular interest because it spans one or two joints and directly influences ankle dorsiflexion range of motion. Tightness within this muscle–tendon unit can restrict dorsiflexion at the talocrural joint, forcing compensatory pronation at the subtalar and midtarsal joints during stance and gait (7). This compensatory mechanism has been proposed as a contributing factor to excessive foot pronation and functional collapse of the medial arch.

Several studies have reported an association between limited ankle dorsiflexion and altered foot mechanics. Gastrocnemius tightness, in particular, has been implicated in the pathomechanics of flatfoot deformity, with evidence suggesting that isolated gastrocnemius or combined Achilles contracture may exacerbate pronatory forces acting on the foot (8). Cross-sectional investigations in pediatric and adult populations have demonstrated reduced ankle dorsiflexion in individuals with flatfoot compared to those with normal foot posture, supporting the biomechanical plausibility of this relationship (9). Moreover, developmental studies indicate that ankle dorsiflexion range naturally decreases with age during childhood, potentially increasing susceptibility to calf muscle tightness during critical periods of musculoskeletal growth (10).

Despite this growing body of literature, important gaps remain. Many existing studies focus on adult populations or symptomatic individuals, limiting generalizability to school-age children. Others emphasize intervention outcomes, such as orthotic management or surgical lengthening procedures, without clearly establishing the baseline association between pes planus and calf muscle tightness in pediatric cohorts (11,12). Furthermore, few studies distinguish between gastrocnemius and soleus contributions to dorsiflexion limitation using standardized knee-position testing, an approach that is essential for precise clinical interpretation and targeted intervention planning. Given the high prevalence of pes planus

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in school-age children, its potential progression to symptomatic or functionally limiting conditions, and the modifiable nature of calf muscle tightness through conservative physiotherapy interventions, clarifying this association is of substantial clinical importance. Establishing whether children with pes planus demonstrate a higher prevalence of gastrocnemius or soleus tightness compared to their peers without pes planus may inform early screening strategies and preventative management approaches.

Therefore, the objective of the present study was to investigate the association between pes planus and calf muscle tightness—specifically gastrocnemius and soleus tightness assessed via ankle dorsiflexion in knee-extended and knee-flexed positions—among school-age children. It was hypothesized that children with pes planus would demonstrate a significantly higher prevalence of calf muscle tightness compared to children without pes planus.

MATERIALS AND METHODS

This cross-sectional observational study was designed to examine the association between pes planus and calf muscle tightness among school-age children, with a specific focus on differentiating gastrocnemius and soleus muscle involvement through standardized ankle dorsiflexion assessment. The study was conducted over a six-month period at the Pakistan Society for the Rehabilitation of the Disabled (PSRD) Hospital Lahore and PSRD High School Lahore, institutions that provide access to both clinical and community-based pediatric populations, thereby supporting the external validity of the findings.

Children aged 6 to 12 years of either sex were eligible to participate. This age range was selected to capture the period during which the medial longitudinal arch is expected to be structurally developed while musculoskeletal growth-related changes in muscle flexibility remain active (13). Participants were included if they were identified as having pes planus or normal foot posture based on clinical assessment using Jack's test, a widely accepted method for distinguishing flexible pes planus through observation of medial arch reconstitution during hallux dorsiflexion (14). Children with a negative Jack's test served as the comparison group without pes planus. Exclusion criteria were defined to minimize confounding from conditions known to independently affect lower limb biomechanics or muscle tone, including neurological disorders such as cerebral palsy, spina bifida, or muscular dystrophies; congenital or acquired musculoskeletal deformities of the lower limb; a history of lower extremity fracture or surgical intervention; and participation in structured calf strengthening or flexibility programs within the preceding six months.

Participants were recruited using a non-probability convenience sampling approach. At the school setting, information sheets were distributed to parents or guardians, while at the hospital setting, potentially eligible children were identified during routine outpatient visits. Written informed consent was obtained from parents or legal guardians prior to participation, and verbal assent was obtained from the children in accordance with ethical standards for pediatric research (15). All assessments were conducted on-site in a controlled environment by a trained physiotherapist to ensure consistency of measurement procedures.

Data collection involved a standardized physical examination protocol. Pes planus status was determined first using Jack's test, performed in a weight-bearing position. Following foot posture classification, ankle dorsiflexion range of motion was assessed using a universal goniometer, an instrument shown to have high validity and test–retest reliability for measuring ankle joint angles in pediatric populations (16). Measurements were performed bilaterally. To assess gastrocnemius tightness, ankle dorsiflexion was measured with the participant seated and the knee fully extended, ensuring isolation of the gastrocnemius muscle. Soleus tightness was assessed with the participant positioned prone and the knee flexed to approximately 90 degrees, thereby minimizing gastrocnemius contribution. The subtalar joint was maintained in a neutral position during all measurements to reduce measurement bias related to foot pronation or supination. Each measurement was performed twice, and the mean value was recorded for analysis to improve measurement precision.

Calf muscle tightness was operationally defined based on ankle dorsiflexion range of motion thresholds derived from established pediatric normative data. For the knee-extended position, dorsiflexion angles of 0–4 degrees were categorized as severe gastrocnemius tightness, 5–9 degrees as mild tightness, and 10–20 degrees as normal. For the knee-flexed position, dorsiflexion angles of 0–14 degrees indicated severe soleus tightness, 15–19 degrees mild tightness, and 20–30 degrees normal flexibility (17). Pes planus was treated as a categorical independent variable, while calf muscle tightness categories served as the primary dependent variables.

Several measures were incorporated to limit bias and improve internal validity. All assessments were conducted by the same examiner, who followed a standardized measurement protocol to minimize inter-examiner variability. Age and sex were recorded for all participants and examined descriptively to assess group comparability. Bilateral measurements were analyzed with awareness of within-subject correlation, and analytical decisions were made to avoid artificial inflation of statistical significance due to non-independence of observations. The sample size of 142 participants was calculated a priori using Epitool software based on expected prevalence estimates of pes planus in school-age children and an assumed moderate association with calf muscle tightness, providing adequate power to detect statistically significant associations at a 95% confidence level (18).

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS), version 25. Continuous variables were summarized using means and standard deviations, while categorical variables were presented as frequencies and percentages. The association between pes planus status and calf muscle tightness categories was examined using the Pearson chi-square test. Where contingency table assumptions were challenged by low expected cell counts, appropriate category collapsing was applied to maintain statistical validity. Statistical significance was set at $p < 0.05$. Missing data were minimal and handled using complete-case analysis. Subgroup analyses were performed for gastrocnemius and soleus tightness separately, with laterality considered descriptively.

Ethical approval for the study was obtained from the institutional Research Ethics Committee prior to commencement. All procedures were conducted in accordance with the principles outlined in the Declaration of Helsinki for research involving human participants (19). Participant confidentiality was maintained by assigning anonymized identification codes, and all data were securely stored with access restricted to the research team. Standardized data collection forms and predefined variable definitions were used throughout the study to ensure reproducibility and data integrity, enabling independent replication by future researchers.

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RESULTS

Table 1 summarizes the sample profile for the 142 included children. The cohort had a mean age of 9.16 ± 2.04 years, with males representing 54.2% (77/142) and females 45.8% (65/142). Based on Jack's test classification, pes planus was identified in 60.6% of participants (86/142), while 39.4% (56/142) demonstrated normal foot posture, establishing a majority pes planus group for subsequent association analyses.

Table 2 presents the association between pes planus and gastrocnemius tightness assessed in the knee-extended position (0–20° dorsiflexion reference range), reported separately for the right and left sides. On the right side, severe gastrocnemius tightness (0–4°) was observed in 65.1% (56/86) of children with pes planus compared with 10.7% (6/56) of children without pes planus. Mild tightness (5–9°) occurred in 19.8% (17/86) of the pes planus group and 0.0% (0/56) of the non–pes planus group, whereas normal dorsiflexion (10–20°) was present in only 15.1% (13/86) of those with pes planus but in 89.3% (50/56) of those without pes planus.

This distributional contrast yielded a highly significant association ($\chi^2 = 118.52$, df = 2, $p < 0.001$) with a large effect size (Cramér's V = 0.65). The left side showed a closely comparable pattern: severe tightness was present in 64.0% (55/86) of children with pes planus versus 10.7% (6/56) without pes planus; mild tightness in 20.9% (18/86) versus 0.0% (0/56); and normal dorsiflexion in 15.1% (13/86) versus 89.3% (50/56), again demonstrating a strong association ($\chi^2 = 118.52$, df = 2, $p < 0.001$; Cramér's V = 0.65). Taken together, Table 2 indicates that children without pes planus were predominantly categorized as normal dorsiflexion, whereas children with pes planus clustered in the severe tightness category bilaterally.

Table 3 reports the association between pes planus and soleus tightness assessed in the knee-flexed position (0–30° dorsiflexion reference range), again stratified by side. For the right side, severe soleus tightness (0–14°) was present in 33.7% (29/86) of the pes planus group and in 0.0% (0/56) of the non–pes planus group. Mild tightness (15–19°) was observed in 12.8% (11/86) with pes planus and 0.0% (0/56) without pes planus. Normal dorsiflexion (20–30°) was observed in 53.5% (46/86) among children with pes planus compared with 100.0% (56/56) among children without pes planus.

This yielded a statistically significant association ($\chi^2 = 62.01$, df = 2, $p < 0.001$) with a moderate-to-large effect size (Cramér's V = 0.47). On the left side, the observed distribution differed in that no severe soleus tightness cases (0–14°) were recorded in either group (0/86 and 0/56). Instead, the pes planus group demonstrated substantial mild tightness (15–19°) at 53.5% (46/86), with the remaining 46.5% (40/86) classified as normal (20–30°), whereas the non–pes planus group remained entirely normal (100.0%, 56/56).

This left-side pattern also showed a statistically significant association ($\chi^2 = 44.31$, df = 1, $p < 0.001$) with a moderate effect size (Cramér's V = 0.40). Overall, Table 3 indicates that soleus-related dorsiflexion limitation was more frequently observed in children with pes planus, while children without pes planus consistently demonstrated normal dorsiflexion, particularly evident on both sides for the "normal" category (100% in the non–pes planus group).

Across Tables 2 and 3, the magnitude and consistency of effects indicate that the association is strongest for gastrocnemius tightness (Cramér's V = 0.65 bilaterally), while the association for soleus tightness is comparatively smaller but still meaningful (Cramér's V = 0.47 right; 0.40 left), with all tests demonstrating high statistical significance ($p < 0.001$). These distributions collectively show that children with pes planus were disproportionately represented in restricted dorsiflexion categories—particularly severe gastrocnemius tightness—whereas children without pes planus were predominantly classified as normal dorsiflexion across both knee positions.

Table 1. Baseline characteristics of the study participants (N = 142)

Variable	Total (N = 142)
Age, mean ± SD (years)	9.16 ± 2.04
Sex, n (%)	
Male	77 (54.2)
Female	65 (45.8)
Foot posture, n (%)	
Pes planus	86 (60.6)
Normal foot posture	56 (39.4)

Table 2. Association of pes planus and gastrocnemius tightness (knee extended position)

Side	Gastrocnemius tightness	Pes planus n (%) (n = 86)	No pes planus n (%) (n = 56)	χ² (df)	p-value	Cramér's V
Right	Severe (0–4°)	56 (65.1)	6 (10.7)	118.52 (2)	<0.001	0.65
	Mild (5–9°)	17 (19.8)	0 (0.0)			
	Normal (10–20°)	13 (15.1)	50 (89.3)			
Left	Severe (0–4°)	55 (64.0)	6 (10.7)	118.52 (2)	<0.001	0.65
	Mild (5–9°)	18 (20.9)	0 (0.0)			
	Normal (10–20°)	13 (15.1)	50 (89.3)			

Table 3. Association of pes planus and soleus tightness (knee flexed position)

Side	Soleus tightness	Pes planus n (%) (n = 86)	No pes planus n (%) (n = 56)	χ² (df)	p-value	Cramér's V
Right	Severe (0–14°)	29 (33.7)	0 (0.0)	62.01 (2)	<0.001	0.47
	Mild (15–19°)	11 (12.8)	0 (0.0)			
	Normal (20–30°)	46 (53.5)	56 (100.0)			
Left	Severe (0–14°)	0 (0.0)	0 (0.0)	44.31 (1)	<0.001	0.40
	Mild (15–19°)	46 (53.5)	0 (0.0)			
	Normal (20–30°)	40 (46.5)	56 (100.0)			

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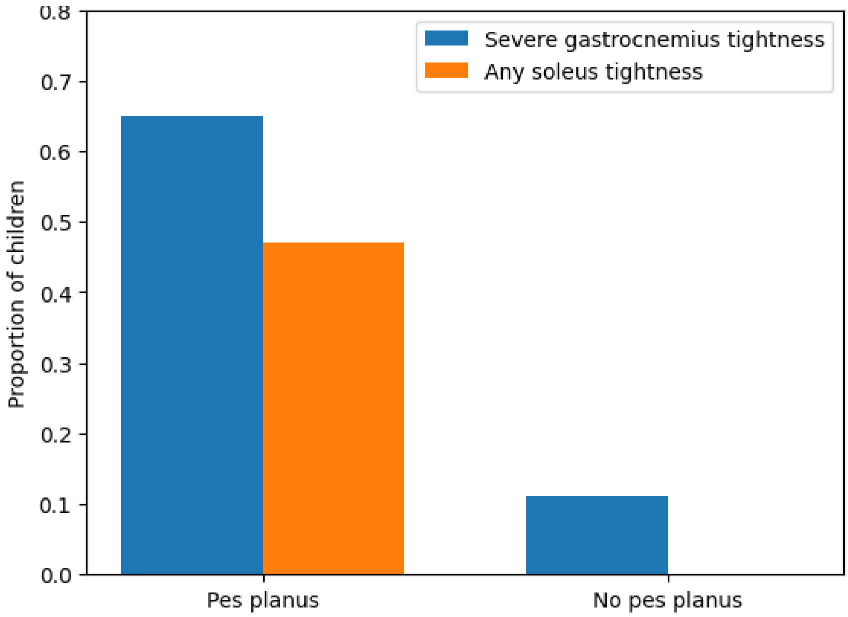

Figure 1 Differential burden of calf muscle tightness by foot posture

The figure illustrates a comparative distribution of calf muscle tightness patterns between children with pes planus and those with normal foot posture, integrating severity and muscle-specific involvement into a single visual summary. Among children with pes planus, severe gastrocnemius tightness was present in approximately 65% of cases, markedly exceeding the prevalence observed in children without pes planus (about 11%). In contrast, any degree of soleus tightness (combined mild and severe categories) affected nearly 47% of children with pes planus, while no soleus tightness was observed in the non–pes planus group. This divergence highlights a pronounced gradient in muscle-specific tightness, with gastrocnemius involvement demonstrating the largest absolute difference between groups (≈54 percentage points), followed by soleus involvement (≈47 percentage points). Clinically, the figure underscores that gastrocnemius tightness represents the dominant restriction pattern associated with pes planus, whereas soleus tightness appears as a secondary but still substantial contributor, reinforcing the importance of differentiating calf muscle components when assessing ankle dorsiflexion limitations in children with flatfoot.

DISCUSSION

The present study investigated the association between pes planus and calf muscle tightness in school-age children and demonstrated a clear, statistically significant relationship between flatfoot posture and reduced ankle dorsiflexion attributable to gastrocnemius and, to a lesser extent, soleus tightness. The findings indicate that children with pes planus were substantially more likely to exhibit severe gastrocnemius tightness and mild-to-moderate soleus tightness compared with their peers without pes planus, with large effect sizes observed particularly for gastrocnemius involvement. These results support the study hypothesis and provide clinically meaningful evidence that altered calf muscle flexibility is closely linked to foot posture during a critical period of musculoskeletal development.

The strong association between pes planus and gastrocnemius tightness observed in this study is consistent with prior cross-sectional research that identified limited ankle dorsiflexion as a common finding in individuals with flatfoot posture. Mohamed et al. reported a higher prevalence of calf muscle tightness among asymptomatic individuals with flat feet, suggesting that muscle tightness may exist even in the absence of overt pain or disability (20). Similarly, DiGiovanni and Langer described the contributory role of isolated gastrocnemius and combined Achilles contractures in the development and persistence of flatfoot deformity, emphasizing the biomechanical impact of dorsiflexion restriction on subtalar joint compensation and midfoot collapse (21). The large effect sizes demonstrated in the present study further strengthen this association in a pediatric population, where early identification may have preventive implications.

Biomechanically, restricted ankle dorsiflexion due to gastrocnemius tightness increases compensatory pronation at the subtalar and midtarsal joints during stance and gait, thereby amplifying stress on the medial longitudinal arch. This compensatory mechanism may explain why gastrocnemius tightness showed a stronger association with pes planus than soleus tightness in the present findings. Sung's kinematic analysis similarly demonstrated increased ankle stiffness during dorsiflexion in individuals with flat feet, independent of demographic variables, underscoring the role of restricted ankle motion in flatfoot biomechanics (22). The present study extends these findings by differentiating gastrocnemius and soleus contributions using knee-position–specific testing, thereby offering greater clinical specificity.

Although soleus tightness was less pronounced than gastrocnemius tightness, the presence of mild-to-moderate soleus restriction in nearly half of the children with pes planus suggests that deeper calf musculature may also contribute to functional limitations in ankle mobility. This aligns with developmental observations reported by Liyanarachi et al., who found that ankle dorsiflexion range tends to decrease with age in children, potentially increasing susceptibility to calf muscle tightness as growth progresses (23). The absence of soleus tightness in children without pes planus in the present study further highlights the specificity of this association and suggests that soleus involvement may represent a secondary adaptation rather than a primary driver of flatfoot posture.

The clinical implications of these findings are noteworthy. Previous interventional studies have demonstrated that addressing calf muscle tightness through stretching, orthotic management, or surgical lengthening can improve functional outcomes in individuals with flatfoot. Gurudut and Kumar reported improved foot posture and function following combined gastrocnemius–soleus stretching and anti-pronation taping in individuals with flexible flatfoot (24), while Rong et al. demonstrated that targeted intramuscular lengthening procedures effectively corrected equinus deformity associated with flatfoot without significant long-term complications (25). By establishing a robust association between pes planus and calf muscle

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tightness in school-age children, the present study provides a rationale for early screening and conservative intervention strategies aimed at improving ankle dorsiflexion and potentially mitigating progression to symptomatic or rigid deformities.

Despite its strengths, including a clearly defined pediatric population, standardized assessment procedures, and separation of gastrocnemius and soleus contributions, this study has limitations that warrant consideration. The cross-sectional design precludes causal inference, and the observed associations cannot determine whether calf muscle tightness precedes or results from pes planus. Additionally, the use of convenience sampling may limit generalizability, and potential confounders such as body mass index, physical activity level, footwear habits, and generalized ligamentous laxity were not formally adjusted for. Future longitudinal studies incorporating these variables and employing multivariable analytical models would be valuable in clarifying temporal relationships and underlying mechanisms.

CONCLUSION

This study demonstrated a strong and statistically significant association between pes planus and calf muscle tightness in school-age children, with gastrocnemius tightness showing the greatest magnitude of association and soleus tightness contributing to a lesser but still meaningful extent. Children with pes planus were disproportionately affected by restricted ankle dorsiflexion compared with children without pes planus, highlighting the importance of comprehensive calf muscle assessment in pediatric flatfoot evaluation. These findings support early identification and targeted management of calf muscle tightness as a potentially modifiable factor in children with pes planus, while underscoring the need for prospective research to clarify causal pathways and optimize preventive and therapeutic strategies.

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