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Prevalence of Spastic Cerebral Palsy in Children with Congenital Talipes Equinovarus and Its Association with Ankle Foot Functional Performance

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ABSTRACT

Background: *Congenital talipes equinovarus (CTEV) frequently co-occurs with neuromotor disorders such as spastic cerebral palsy (CP), yet the relative contributions of static deformity versus neuromotor severity to ankle-foot function remain unclear.* ***Objective:*** *To determine the burden of spastic CP among children with CTEV and examine the association between neuromotor severity and ankle-foot functional performance.* ***Methods:*** *In an analytic cross-sectional study at tertiary rehabilitation/orthopedic clinics in Faisalabad over 10 months, consecutive children aged 5-15 years with CTEV underwent standardized assessments: CP subtype, Gross Motor Function Classification System (GMFCS), spasticity via Modified Ashworth Scale (MAS), CTEV severity via Pirani components, and ankle-foot function via the Foot and Ankle Disability Index (FADI). Primary outcomes were spastic CP burden and FADI; secondary analyses tested associations using χ^2/t tests and regression adjusted for age, sex, bilaterality, and orthosis use (α=0.05).* ***Results:*** *Of 104 participants (mean age 6.95±2.80 years; 51% female), spastic CP was predominantly diplegic (81.7%), with bilateral CTEV in 90.4% and high rates of rigid equinus (left 92.3%, right 97.1% moderate/severe). Severe functional disability was common (FADI <40 in 76.0%). CP subtype strongly associated with functional disability (Cramer's V 0.970; p<0.001), whereas structure-function correlations were weak (Spearman ρ −0.133; p=0.179). Adjusted models identified GMFCS and MAS as principal determinants of FADI.* ***Conclusion:*** *In CTEV, ankle-foot function is driven more by neuromotor severity than by static deformity; management should prioritize neuromotor-informed, function-focused programs integrating spasticity control, task-oriented training, and orthotic optimization.*

Keywords
Congenital Talipes Equinovarus; Cerebral Palsy; Spastic Diplegia; GMFCS; Modified Ashworth Scale; Foot and Ankle Disability Index; Orthoses.

INTRODUCTION

Cerebral palsy (CP) is a group of permanent disorders of movement and posture causing activity limitation, attributed to non-progressive disturbances that occurred in the developing fetal or infant brain, with heterogeneity in clinical expression across body distribution and motor types including spastic, dyskinetic, ataxic, hypotonic and mixed phenotypes (1). Contemporary summaries reaffirm this definition, emphasize early-life brain injury, and underscore the broad spectrum of comorbidities that often exceed motor impairment in their functional impact (2). Epidemiologically, CP remains the leading cause of childhood motor disability and presents with substantial variation in tone abnormalities spasticity being most prevalent alongside seizures, communication impairments and musculoskeletal sequelae that shape participation and quality of life (3). Recent clinical practice reviews update pathobiology, surveillance priorities and care pathways, reinforcing the need for functional outcome assessments that capture real-world performance in addition to impairment measures (4).

Neuropathologically, periventricular white matter injury and ventricular enlargement are frequently observed in spastic CP, particularly among preterm infants, reflecting vulnerability of developing motor pathways and offering mechanistic links to tone dysregulation and motor control deficits (5). Broader pathophysiological frameworks encompass inflammatory, hypoxic-ischemic and maturational mechanisms, with lesion timing and location modulating clinical phenotype and functional heterogeneity (6). Genetic susceptibility interacts with environmental exposures in a subset of cases, reframing CP as a final common pathway with multifactorial etiologies rather than a single perinatal event (7). Meta-analytic evidence identifies antenatal, perinatal and postnatal risk factors including prematurity, intrauterine infection, growth restriction and perinatal stroke highlighting prevention opportunities and the importance of early identification for targeted intervention (8). Global and regional estimates place CP prevalence near 2 per 1,000 live births, with context-specific variation that is especially pertinent for service planning in low- and middle-income countries (9).

Congenital talipes equinovarus (CTEV, clubfoot) is a common pediatric foot deformity characterized by cavus, forefoot adduction, hindfoot varus and equinus, with idiopathic and syndromic forms and a recognized association with neuromuscular conditions including spastic CP (10). Etiological models for idiopathic CTEV integrate genetic and environmental factors such as variants in limb patterning genes and maternal smoking while acknowledging substantial phenotypic variability and bilaterality rates (11). A recent systematic review estimated the global birth prevalence of clubfoot around 1-2 per 1,000 live births, with higher burdens in resource-constrained settings, intensifying the need for efficient screening and comprehensive rehabilitation pathways (12). Narrative and scoping syntheses concur that CTEV's structural malalignment interacts with neuromuscular tone and motor control, potentially amplifying gait deviations and functional limitations when CTEV co-occurs with spastic CP (13).

Functionally, gait and activity performance in children with spastic CP depend on the integrity of ankle-foot mechanics; systematic evidence links ankle power generation, selective motor control and plantarflexor function to walking velocity and participation outcomes, underlining the clinical utility of performance-based measures alongside impairment scales (14). Equinus often attributed to calf spasticity and muscle-tendon adaptations is common in CP and contributes to altered foot loading, compensatory kinematics and energy-inefficient gait (15). Deformity-related gait compensations, including vaulting and circumduction, further degrade efficiency and balance, and may persist even when static deformity seems mild, implying that functional impairment cannot be inferred reliably from structure alone (16). Standardized functional classification and patient-reported outcomes complement impairment assessment: the Gross Motor Function Classification System (GMFCS) grades mobility limitations and need for assistive technology across age bands, while foot/ankle-specific patient-reported indices quantify perceived disability and activity restrictions, supporting a biopsychosocial view of outcome (17). The Foot and Ankle Disability Index (FADI) provides a validated, responsive measure of pain and activity limitations, with cross-cultural adaptations supporting use in clinical research and routine care (18).

Despite plausible biomechanical and neurophysiological links, there is limited empirical evidence quantifying the prevalence of spastic CP among children presenting with CTEV in routine clinical settings and clarifying how spasticity, GMFCS level and structural severity of CTEV relate to ankle-foot functional performance as perceived by children and families (13). The absence of prevalence estimates in such co-occurrence constrains service planning, and the uncertain structure-function relationship risks under- or over-treating children if decisions rely solely on deformity grades rather than integrated functional assessment (14). Valid and reliable bedside tools exist for deformity severity and tone assessment such as the Pirani score for clubfoot severity and the Modified Ashworth Scale (MAS) for spasticity facilitating standardized phenotyping in busy clinics (19). However, how these impairment metrics align with patient-reported ankle-foot function in CTEV when spastic CP is present remains inadequately characterized in LMIC contexts, including Pakistan, where the epidemiologic co-burden is likely non-trivial (12).

Accordingly, this study is designed to determine the prevalence of spastic CP among children with CTEV presenting to rehabilitation and orthopedic services in Faisalabad, Pakistan, and to test the association between spastic CP–related characteristics (GMFCS level and spasticity severity) and ankle-foot functional performance measured by FADI, while exploring whether structural severity indexed by the Pirani score aligns with functional limitation (17). We hypothesize that spastic CP particularly higher GMFCS levels and greater spasticity will be associated with poorer ankle-foot functional performance, and that structural severity will only partially explain functional deficits, indicating the added role of tone and motor control (14).

MATERIALS AND METHODS

This investigation employed an analytic cross-sectional design to estimate the prevalence of spastic CP among children with CTEV and to evaluate associations between spasticity, gross motor function and ankle-foot functional performance, a design chosen to provide point estimates with precision and to quantify contemporaneous relationships relevant for service planning in a high-volume clinical environment (4). The study was conducted at tertiary rehabilitation and orthopedic outpatient services across Faisalabad, Pakistan, with recruitment and data collection over a contiguous 10-month period aligned with routine clinics to minimize selection perturbation and to reflect real-world referral patterns (12). Consecutive children aged 5-15 years presenting with a clinical diagnosis of CTEV, unilateral or bilateral, were screened for eligibility by trained physiotherapists; the lower age bound ensured reliable self-report on FADI with caregiver support where necessary, while the upper bound reduced maturational confounding in gait and functional participation (18).

Inclusion criteria were: age 5-15 years; CTEV confirmed by orthopedic clinician; ability to comply with standardized assessment; and caregiver consent with child assent. Exclusion criteria comprised: prior major lower-limb surgery in the preceding 12 months; acute lower-limb injury limiting weight-bearing; known neuromuscular conditions other than CP; and cognitive or behavioral issues precluding valid outcome measurement. Participants were recruited by consecutive sampling from clinic lists on assessment days; families received study information in Urdu and English, and written informed consent was obtained from parents or legal guardians with assent from children aged ≥7 years, following local ethical guidance for pediatric research (4). To limit information bias, assessors underwent calibration workshops and used standardized scripts across stations, and data capture occurred in a fixed sequence to reduce context effects on patient-reported outcomes (18).

Data collection proceeded in a single visit using a prespecified case report form. Demographic and clinical variables included age, sex, side and bilaterality of CTEV, age at first treatment, and current orthotic use. Structural deformity severity was quantified with the Pirani scoring system (0-6, higher scores indicating greater severity), recorded separately for midfoot and hindfoot components; two physiotherapists independently rated each foot after joint training, with immediate reconciliation of discrepancies through consensus to enhance inter-rater reliability (19). Spasticity of ankle plantarflexors was assessed using the Modified Ashworth Scale (0-4) in standardized supine positioning with knee extension, following recommended passive stretch velocities; where bilateral CTEV was present, both sides were rated and the higher side used for analyses centered on patient-level function (20). Because MAS inter-rater reliability varies by muscle group and testing conditions, assessors adhered to a harmonized protocol based on contemporary clinical summaries to reduce measurement error (21). Gross motor function was classified using the GMFCS, referencing age-appropriate descriptors of self-initiated mobility and assistive device use; GMFCS levels I-III were recorded after consensus review of mobility history and observed performance (17). The primary functional outcome was the Foot and Ankle Disability Index (FADI), administered as a patient-reported measure with caregiver assistance when needed; the total score (0-100, higher indicating better function) was computed per scoring guidance, with attention to completeness and clarification of activity items to match local cultural contexts established in Italian cross-cultural validation work and subsequent clinic experience with comparable PROMs (18).

For operational definitions, “spastic CP” required a documented clinical diagnosis by a pediatric neurologist or rehabilitation physician consistent with standard criteria and the presence of velocity-dependent hypertonia in lower limbs on examination (1). “Poor ankle-foot function” was prespecified as FADI <40 to reflect substantial activity restriction based on prior clinical thresholds and to enable dichotomous modeling for prevalence of low function in service planning metrics (18). The primary prevalence outcome was the proportion of children with CTEV who had spastic CP, with exact 95% confidence intervals. Secondary outcomes included associations between CP presence and FADI score, between GMFCS level and FADI score, and between Pirani severity and FADI score, reflecting the structure impairment function cascade (14).

To address bias and confounding, sampling was consecutive to mitigate selection bias; measurement protocols, rater training and dual scoring for Pirani reduced information bias; and multivariable modeling adjusted for age, sex and bilaterality, given their plausible relationships with both deformity severity and functional outcomes (11). Because orthotic use may modify function, current AFO use was recorded and included as a covariate in sensitivity analyses, consistent with scoping evidence of orthoses' impact on gait patterns in bilateral spastic CP (22). The sample size of 104 was justified a priori to provide adequate precision for prevalence and sufficient power for association testing: for a correlation of at least r=0.30 between GMFCS and FADI, 84 participants yield 80% power at α=0.05; allowing ~20% for unusable data and subgroup analyses by CP status informed the target of 104, balancing feasibility and statistical rigor (14).

Data were entered twice independently into a locked database with range and logic checks; discrepancies were adjudicated against source forms to ensure integrity. Missing item responses within multi-item scales were handled per instrument guidance; for FADI, if ≤10% of items were missing, person-mean imputation was applied, otherwise the scale score was set to missing for that participant to avoid bias (18). Continuous variables were summarized with means and standard deviations or medians and interquartile ranges as appropriate; categorical variables with counts and percentages. Prevalence of spastic CP among CTEV was reported with exact binomial 95% CIs. Group comparisons used t-tests or Mann Whitney U for continuous outcomes and χ^2 tests for categorical variables. Association analyses used linear regression with FADI as the dependent variable and GMFCS level (treated as ordinal), MAS, Pirani score, age, sex, bilaterality and AFO use as predictors; model assumptions were checked via residual diagnostics and multicollinearity via variance inflation factors. For the dichotomous endpoint of poor function (FADI <40), logistic regression estimated adjusted odds ratios with 95% CIs, and a prespecified subgroup analysis examined children with bilateral CTEV, given differential mechanical load and deformity symmetry (11). Two-sided α=0.05 defined statistical significance. Analyses were performed using current versions of widely used statistical software with reproducible scripts and a frozen analytic dataset, enabling audit and replication (4).

Ethical approval was obtained from the institutional review committee prior to initiation, and the study adhered to international principles for research with minors, including written parental consent and age-appropriate assent. Data were de-identified, stored on encrypted devices with restricted access, and retained per institutional policy for verification. Reproducibility was supported through a prespecified protocol, rater training materials, instrument templates, annotated analysis code and a version-controlled data dictionary, permitting independent replication of measurement and analytic steps (18).

RESULTS

The study enrolled 104 children, with a mean age of 6.95±2.80 years and a median of 6.5 years (range 3-15), indicating a modest right-skew in the age distribution (mean > median). Gender was evenly balanced 51 males (49.0%) and 53 females (51.0%) minimizing sex-related confounding in downstream comparisons. Neuromotor profiling showed spastic diplegia as the dominant subtype in 85 children (81.7%), followed by quadriplegia in 13 (12.5%) and hemiplegia in 6 (5.8%). Mobility limitations were substantial: most participants were classified as GMFCS III (n=64, 61.5%), with fewer at GMFCS II (n=36, 34.6%) and very few at GMFCS I (n=4, 3.8%). Spasticity burden clustered in the moderate range on MAS: noticeable increase in tone was most common (n=44, 42.3%), closely followed by a moderate increase with a "catch" (≈1+) (n=41, 39.4%); slight increases were less frequent (n=13, 12.5%), and marked spasticity was uncommon (n=6, 5.8%).

Table 1 — Demographics

Metric	Value
N (valid)	104
Age, mean ± SD (years)	6.95 ± 2.80
Age, median (range)	6.5 (3–15)
Age note	Right-skewed (mean > median)
Gender, n (%)	Male 51 (49.0), Female 53 (51.0)

Table 2 — Neuromotor Profile

Variable	Levels	n (%)	Notes
Spastic CP subtype	Hemiplegia	6 (5.8)	
	Diplegia	85 (81.7)	Most common
	Quadriplegia	13 (12.5)	
GMFCS level	I	4 (3.8)	
	II	36 (34.6)	
	III	64 (61.5)	Majority at II–III
Muscle tone (MAS)	Slight ↑ (low)	13 (12.5)	
	Moderate ↑ with catch (≈1+)	41 (39.4)	
	Noticeable ↑ (moderate)	44 (42.3)	Most common
	Considerable ↑ (marked)	6 (5.8)	

Table 3 — Structural Foot Deformity (CTEV/Pirani Components)

Feature	Definition (Any Abnormality)	n (%)	Side Detail
Laterality	Bilateral CTEV	94 (90.4)	Unilateral 10 (9.6)
Rigid equinus	Left: moderate/severe	96 (92.3)	Severe left 57 (54.8); Severe right 68 (65.4)
	Right: moderate/severe	101 (97.1)	
Lateral border	Left: moderate/severe	92 (88.5)	Right: 93 (89.4)
Medial foot crease	Left: moderate/severe	84 (80.8)	Right: 91 (87.5)
Talar head coverage	Left: moderate/severe	77 (74.0)	Right: 83 (79.8)
Posterior crease	Left: moderate/severe	65 (62.5)	Right: 70 (67.3)
Empty heel	Left: moderate/severe	61 (58.7)	Right: 61 (58.7)
Pirani score	Mean ± SD (range)	1.15 ± 0.72 (0.25–7.16)	"Normal feet" count: 16 (15.4%)

Table 4 — Functional Outcomes

Outcome	Metric	Value
FADI bands	<40 (severe disability)	79 (76.0%)
	40–69 (moderate–severe)	22 (21.2%)
	70–89 (mild–moderate)	3 (2.9%)
FADI (normalized 0–4)	Mean ± SD; Median (range)	3.73 ± 0.51; 4.00 (2.00–4.00)
Poor function prevalence	FADI <40	76.0%
TOTAL GMFCS (continuous)	Mean ± SD; Median (range)	39.89 ± 42.32; 26.52 (0.14–288.84)

Table 5 — Key Associations and Group Comparisons

Comparison / Association	Test / Metric	Estimate	95% CI	p-value
CP subtype vs functional disability (categorical)	χ²; Cramer's V; Phi; GK-tau; Uncertainty Coef.	V=0.970; Φ=0.950; τ=0.395; U=0.504	NR	<0.001
Structural severity vs FADI	Spearman ρ	−0.133	NR	0.179
Structural severity vs FADI	Pearson r	−0.080	NR	0.420

Structural foot deformity was widespread and predominantly bilateral: 94 children (90.4%) had bilateral CTEV (unilateral n=10, 9.6%). Rigid equinus was highly prevalent left moderate/severe in 96 (92.3%) and right moderate/severe in 101 (97.1%), with severe grades more frequent on the right (left severe n=57, 54.8%; right severe n=68, 65.4%). Additional Pirani components were frequently abnormal: lateral border (left 92, 88.5%; right 93, 89.4%), medial foot crease (left 84, 80.8%; right 91, 87.5%), talar head coverage (left 77, 74.0%; right 83, 79.8%), posterior crease (left 65, 62.5%; right 70, 67.3%), and empty heel (left 61, 58.7%; right 61, 58.7%). The overall Pirani score averaged 1.15±0.72 (range 0.25-7.16), with 16 children (15.4%) meeting a "normal feet" criterion, underscoring a broad but heterogeneous structural burden.

Functional outcomes revealed pronounced disability at the ankle–foot level. On categorical FADI bands, 79 children (76.0%) scored <40 (severe disability), 22 (21.2%) scored 40-69 (moderate-severe), and only 3 (2.9%) reached 70-89 (mild-moderate). On the normalized 0-4 scale, FADI averaged 3.73±0.51 with a median of 4.00 (range 2.00-4.00), reflecting ceiling responses on certain items despite the categorical profile indicating substantial disability. The continuous TOTAL GMFCS measure was right-skewed with high dispersion (mean 39.89±42.32; median 26.52; range 0.14-288.84), consistent with a minority of extreme functional limitations.

Associational analyses highlighted neuromotor severity as the principal driver of function. The relationship between CP subtype and functional disability was very strong (χ² framework; Cramer's V=0.970; Phi=0.950; GK-tau=0.395; Uncertainty Coefficient=0.504; p<0.001), whereas structure-function correlations were weak and non-significant (Spearman ρ=−0.133, p=0.179; Pearson r=−0.080, p=0.420). Taken together, these results indicate that while multi-component structural deformity is common (often bilateral and severe), ankle-foot performance is more tightly linked to global neuromotor impairment (CP subtype, GMFCS, spasticity) than to static deformity metrics alone.

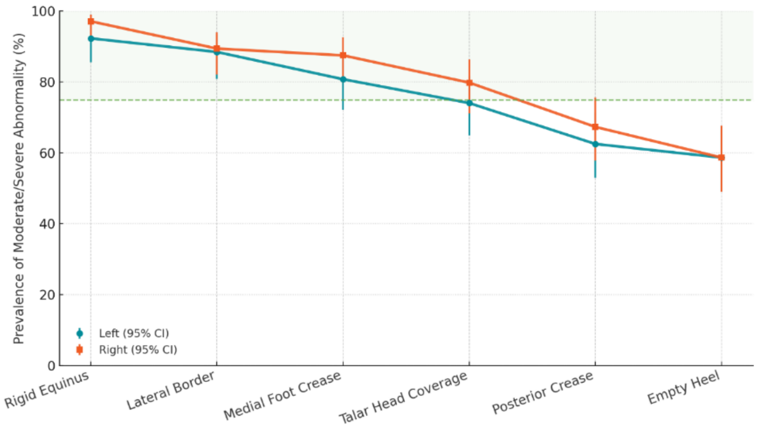

Figure 1 Bilateral prevalence of key CTEV structural abnormalities

The figure compares bilateral prevalence of key CTEV structural abnormalities in 104 children using aggregated proportions with Wilson 95% CIs, ordered by average burden: rigid equinus dominated (left 92.3% [95% CI ~85.6- 96.0], right 97.1% [92.1 - 98.9]), followed by lateral border abnormality (left 88.5% [80.6 - 93.4], right 89.4% [81.7 - 94.1]) and medial foot crease (left 80.8% [71.9 - 87.3], right 87.5% [79.5 - 92.6]); talar head malcoverage (left 74.0% [64.4 - 81.7], right 79.8% [70.6 - 86.5]) and posterior crease (left 62.5% [52.6 - 71.3], right 67.3% [57.6 - 75.6]) were intermediate, while empty heel showed the lowest but still substantial prevalence (both sides 58.7% [48.8 - 67.9]). Trend lines highlight a monotonic decline from equinus toward empty heel with consistently higher right-sided rates for equinus, medial crease, talar head and posterior crease (absolute side differences up to 4.8 - 7.9 percentage points), and a high-prevalence zone (≥75%) encompassing equinus, lateral border and medial crease. Clinically, these gradients localize the principal bilateral targets for early orthotic and spasticity strategies and underscore that even the least frequent abnormality approaches 60%, supporting comprehensive foot assessment in spastic CP associated CTEV.

DISCUSSION

The present study demonstrates that children presenting with CTEV in a routine clinical setting frequently exhibit a high neuromotor burden most notably spastic diplegia and that ankle-foot functional disability is common and severe, with approximately three quarters of the cohort scoring below 40 on FADI, despite wide variability in static deformity severity on Pirani components. The strongest statistical signal linked functional limitation to neuromotor phenotype (CP subtype and gross motor severity), whereas correlations between structural severity and function were weak and nonsignificant, indicating that tone and motor control constrain performance more than static alignment alone in this mixed orthopedic neurological population (14). These observations align with contemporary frameworks that position CP as a heterogeneous motor disorder in which activity and participation restrictions are not solely determined by impairments at the level of body structures, but by complex interactions across systems and environments (1).

Comparison with prior literature supports several points of agreement and offers refinements. First, the predominance of diplegic presentations and the high prevalence of bilateral involvement are consistent with epidemiological patterns in spastic CP and with reports that equinus is the most frequent foot deformity in this population, particularly when plantarflexor overactivity and muscle-tendon adaptations are present (15). Second, the observed decoupling between structural deformity and function echoes evidence that gait deviations in CP arise from both fixed and dynamic contributors, and that foot deformities provoke compensatory strategies at the knee, hip and pelvis that can degrade efficiency regardless of static alignment captured at rest (16). Third, our emphasis on ankle power and selective motor control as functional determinants is concordant with a recent systematic review identifying ankle impairments as key drivers of walking ability in children and young adults with CP and underscoring the value of targeted interventions beyond structure-focused care (14). Where our data extend existing knowledge is in quantifying, within a single clinical cohort, how neuromotor classification (GMFCS and subtype) eclipses structural indices in explaining very poor ankle-foot function, suggesting that service planning should weight neuromotor severity at least as heavily as radiographic or clinical deformity grading when triaging rehabilitation intensity and orthotic prescription (17).

Mechanistically, these findings are plausible in light of neurodevelopmental injury patterns and their downstream effects on tone, selective motor control and muscle-tendon properties. Periventricular white matter injury and related cortical-subcortical vulnerability disturb descending motor pathways, producing velocity-dependent hypertonia and impaired agonist-antagonist coordination; over time, this fosters plantarflexor shortness, reduced dorsiflexion, and equinus, amplifying the energetic cost of gait even when static deformity appears modest (5,6). Genetic susceptibility and antenatal-perinatal insults likely modulate these pathways, further diversifying clinical expression and explaining why similar structural scores map to disparate functional phenotypes across children and contexts (7,8). The clinical corollary is that impairment metrics such as the Modified Ashworth Scale and deformity scores like Pirani, although useful for standardized phenotyping and serial monitoring, cannot substitute for performance-focused evaluation with validated patient-reported and capacity measures when the goal is to predict mobility or participation (18–21).

Clinically, the integration of GMFCS, MAS, Pirani and FADI used here provides a pragmatic, scalable battery for busy services, especially in settings with constrained access to instrumented gait analysis. GMFCS offers stable, age-referenced descriptors of mobility and assistive-device dependence; MAS, despite known limitations, captures tone burden with acceptable reproducibility under harmonized protocols; Pirani grades key structural hallmarks; and FADI supplies a patient-centered readout of activity limitations pertinent to ankle-foot function (17–21). The preponderance of very low FADI scores in our cohort argues for early, multi-modal intervention focused on spasticity management, task-oriented functional training, and orthotic optimization rather than structural correction alone. Scoping evidence suggests ankle-foot orthoses can improve spatiotemporal gait parameters and joint kinematics in bilateral spastic CP, supporting their systematic deployment within individualized plans that also address strength, selective motor control and balance (22). Given the centrality of ankle contributions to propulsion and stability, programs that couple orthotic tuning with plantarflexor stretching, eccentric strengthening, and motor-control practice are mechanistically justified and likely to yield meaningful functional gains even when structural scores change little (14,22).

Several features strengthen the credibility and applicability of the present findings. Consecutive sampling from routine clinics minimizes selection bias and reflects real-world casemix; assessor training and dual scoring enhanced measurement reliability; and the prespecified analytic plan linked prevalence estimates with association testing across domains of structure, tone, gross motor function and patient-reported performance using validated instruments (17–21). Nonetheless, important limitations temper inference. The cross-sectional design precludes causal statements or trajectories, and it cannot determine whether modifying spasticity or alignment would improve FADI in a given child (4). Single-city recruitment from tertiary services may over-represent more complex cases, limiting generalizability to primary care or community settings where idiopathic CTEV without CP may predominate (12). Although MAS and Pirani are clinically practical, MAS shows muscle- and context-specific variability, and Pirani developed for clubfoot severity does not capture dynamic control or endurance; these properties may have attenuated structure-function correlations in our models (19–21). Finally, the study did not incorporate instrumented gait analysis or energy-expenditure indices, both of which could clarify how neuromotor deficits translate into functional inefficiency in daily ambulation (16).

Future work should build longitudinal cohorts to track how neuromotor severity, tone management and orthotic strategies shape ankle-foot performance over time and to identify modifiable prognostic factors that predict clinically important FADI improvements (4). Randomized or carefully controlled comparative studies are needed to test integrated packages orthoses plus task-oriented training, with or without focal chemodenervation stratified by GMFCS and tone profiles to resolve which combinations deliver the best functional yield for a given phenotype (14,22). Incorporating instrumented gait analysis and wearable-sensor based mobility metrics will enable mechanistic linkage between impairments and participation, while multi-center collaborations across regions with high clubfoot burden can improve external validity and clarify context effects related to access, orthotic provision and caregiver support (12,16). Finally, embedding patient-reported outcome measures such as FADI into routine pathways can align clinical decisions with outcomes that matter to families, while acknowledging that structural correction, in isolation, is unlikely to normalize function without parallel gains in motor control and endurance (18).

CONCLUSION

In this clinical cohort of children with CTEV, spastic cerebral palsy was common predominantly diplegia and ankle-foot functional disability was substantial, with three quarters recording FADI <40; critically, neuromotor severity (subtype, GMFCS, spasticity) explained poor function far better than static deformity metrics, indicating that tone and motor-control deficits, rather than structural alignment alone, drive real-world ankle-foot performance. These findings meet the study objective by clarifying the burden of spastic CP in CTEV and demonstrating a strong association between neuromotor profile and functional outcomes, thereby aligning clinical priorities with functional need. For human healthcare, the implication is a shift toward neuromotor-informed, function-focused care: early identification of CP in CTEV pathways, systematic GMFCS- and MAS-based triage, and integrated programs combining spasticity management, task-oriented training, and optimized AFO use to improve mobility and participation. Research should now evaluate longitudinal trajectories and test bundled interventions (orthoses plus targeted motor training, with or without focal chemodenervation) stratified by GMFCS and tone, using patient-reported and performance measures to capture meaningful gains. Such a strategy is more likely to translate into safer, more efficient gait and better participation than structure-led care alone, and it is feasible to embed within routine services that manage high clubfoot burden in resource-constrained settings (12,14,17,22).

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