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# Exploring the Relationship Between Lower Limb Spasticity and Postural Control Mechanisms in Children with Spastic Diplegic Cerebral Palsy: A Neurophysiological and Functional Balance Analysis

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**Abstract:**
**Introduction:** Spasticity is a common neuromuscular impairment in children with spastic diplegic cerebral palsy, often leading to functional limitations in balance and gross motor performance. Understanding the relationship between spasticity and these functional domains is crucial for guiding effective therapeutic interventions. This study aimed to evaluate the correlation between lower limb spasticity and both balance and gross motor function in children with spastic diplegic cerebral palsy.
**Methodology:** A total of 22 children with spastic diplegic cerebral palsy were selected from various cerebral palsy rehabilitation centers in Dehradun. Subjects who met the inclusion criteria were enrolled in this correlation study. Prior to participation, informed consent was obtained from the parents or legal guardians after explaining the purpose and procedures of the study.
All participants were assessed for:
Spasticity using the Modified Ashworth Scale (MAS)
Balance using the Pediatric Balance Scale (PBS)
Gross motor function using the Gross Motor Function Measure (GMFM)
The data collected were statistically analyzed to determine the relationship between spasticity and balance, as well as between spasticity and gross motor function.
**Results:** The results demonstrated that:
The mean spasticity of the knee flexors in both lower limbs had a fair negative correlation with the Pediatric Balance Scale ($r = -0.433$).
The mean spasticity of the plantar flexors showed a stronger negative correlation with the Pediatric Balance Scale ($r = -0.616$), indicating a greater influence on balance.
A moderate negative correlation was found between the average MAS scores of both limbs and the GMF

M scores, suggesting that higher spasticity is associated with poorer gross motor function.
**Discussion:** The findings indicate that increased spasticity, particularly in the plantar flexors, adversely affects balance more significantly than spasticity in the knee flexors. Moreover, the moderate correlation between overall lower limb spasticity and GMFM scores supports the notion that spasticity limits functional mobility. These results align with the hypothesis that neuromuscular impairments such as spasticity can influence postural control and motor performance in a biomechanically predictable manner.
**Conclusion:** This study concludes that lower limb spasticity, especially in the plantar flexors, has a negative impact on balance and gross motor function in children with spastic diplegic cerebral palsy. Early assessment and targeted management of spasticity are essential for improving functional outcomes in this population.

**Keywords:** Spasticity, Gross Motor Function, Pediatric Balance Scale, Cerebral Palsy, Functional Performance.

**Introduction**
Cerebral palsy is a non-progressive disorders resulting in an abnormal development of movement [1] . Cerebral palsy presents with various types of disorders such as spasticity, low muscle strength and improved motor control . One of the key problem in children with cerebral palsy is deficient postural control [3]. The impairment of balance in these children is due to the impairment of motor control, tone, vestibular system, visual and sensory system ,thus postural control requires a complex interaction between systems , such as musculoskeletal and neural system [5]. Research by Nasher et al have shown that a number of factors contribute to poor reactive balance control in this population ; these include spasticity , muscle weakness ,excessive co-contraction of agonist muscles at a joint and increased stiffness [6]. On the previous studies had also postulated that the main impairment in postural control is lack of descending inhibition of spinal reflexes due to damage in higher cortical center .This allows primitive reflexes to dominate postural control, resulting in spasticity [6]. Abnormal muscle tone is the most common motor abnormalities that occurs in cerebral palsy .Spasticity has been characterized in a variety of ways including muscles , hypertonia, hyper active deep reflexes and clonus[12-14] . Spasticity is considered to be main problem in cerebral palsy [14]. Spastic diplegia is the most common form of CP ,and it is characterized by greater involvement in lower limb than in upper limb[8]. In clinical practice spasticity is assessed as a velocity – dependent increased resistance to passive muscles stretch. The modified Ashworth scale , which grades resistance to passive stretch ,has gained widespread acceptance as a clinical tool [10], and is also frequently used to document the effect of medication and surgery on spasticity in children with CP[2,11] .
There are many functional effects of spasticity; in some children it causes major problems in ambulation . Spasticity causes typical spastic gait patterns . The presence of spasticity in the lower extremity musculature of children with spastic diplegia has been thought to be a contribution factors to there limitation in standing balance and walking function [4]. Balance requires a complex interaction of musculoskeletal and neural system [5]. A pilot study done on two subjects showed that creating a functional position reduces spaticity and enhances postural control [22]. Move over, children with cerebral palsy showed temporal reversals among the muscle responding to aloss of balance , in addition to high level of agonist and antagonist muscle co-activation [6].

Pediatric balance scale was developed as a balance measure for children with mild to moderate impairment. The PBS has been demonstrated to have good test –retest (ICC= 0.998] and Interrater reliability (ICC=O.997)[20M].
The Gross Motor Function Measures (GMFM) is a criterition-reference observational measure that was developed and validated to assess children with cerebral palsy (CP). The GMFM-66 provides a better understanding of motor development for the children with CP than the 88- items GMFM. Test-retest reliability was prove to be high i.e. interclass correlation coefficient is 0.99 [15].
Although various factors have been thought to be the contributing factors for balance impairment in this population but there is a little literature which suggest any relation between spasticity and balance in diplegic cerebral palsy population.

## Methodology

### Study Design

The present research employed a **correlational study design** to investigate the relationship between spasticity, balance, and gross motor function in children with spastic diplegic cerebral palsy. This design was chosen as it facilitates understanding the nature and strength of associations among the selected variables without manipulating the independent variables.

### Study Setting

The study was conducted across multiple **cerebral palsy rehabilitation centers located in Dehradun, Uttarakhand, India**. These centers provided access to children diagnosed with spastic diplegia, a common form of cerebral palsy characterized primarily by lower limb involvement, thereby ensuring an appropriate clinical population for the study.

### Participants and Sampling

A total of **22 children with spastic diplegic cerebral palsy** were recruited for the study. Participants were selected based on specific inclusion and exclusion criteria to ensure homogeneity of the study population and the reliability of the findings. A **purposive sampling** technique was utilized, targeting children who fit the inclusion criteria and were attending therapy at the selected centers.

### Inclusion Criteria

Participants were included in the study based on the following criteria:
Clinically diagnosed with **spastic diplegic cerebral palsy** by a medical professional.
Aged between **5 and 15 years**.
**Both male and female** participants were considered eligible.
Able to **stand independently for at least five minutes**, indicating a minimum functional balance and motor capability necessary for assessment.
Had the **cognitive ability to understand and follow simple instructions**, ensuring valid administration of functional assessments.

### Exclusion Criteria

Children meeting any of the following criteria were excluded from the study:
History of **lower limb orthopedic surgery**, which could significantly alter spasticity or motor patterns.

Administration of **botulinum toxin (Botox) injections** in the lower extremities within the past six months, which could temporarily reduce spasticity and skew results.

**Ethical Considerations**

Ethical clearance for the study was obtained from the relevant institutional ethics committee. Informed consent was obtained from the parents or legal guardians of all participants after explaining the **purpose, procedures, benefits, and potential risks** of the study in an understandable language. Assent was also obtained from children wherever possible. The confidentiality of participant data was maintained throughout the research.

**Instrumentation and Outcome Measures**

Three primary tools were used to assess spasticity, balance, and gross motor function:

**1. Modified Ashworth Scale (MAS)**

The **Modified Ashworth Scale** is a clinical measure used to assess **muscle tone and spasticity**. It is widely accepted in both research and clinical practice due to its simplicity and ease of administration. The interrater reliability of the MAS for knee flexors has been reported as **ICC = 0.76**, and for plantar flexors as **ICC = 0.64**. Intrarater reliability for knee flexors and plantar flexors is reported at **ICC = 0.64** and **ICC = 0.43**, respectively. In this study, MAS was employed to measure spasticity in **two major lower limb muscle groups**: the **knee flexors (hamstrings)** and the **plantar flexors (gastrocnemius-soleus complex)**, which are commonly spastic in children with diplegia.

**2. Pediatric Balance Scale (PBS)**

The **Pediatric Balance Scale** is a modified version of the Berg Balance Scale tailored to assess **functional balance in children**. It consists of 14 functional tasks that examine static and dynamic balance abilities. The PBS has demonstrated excellent **test-retest reliability (ICC = 0.998)** and **interrater reliability (ICC = 0.997)**. Equipment used included a **stopwatch**, **footstool or step**, and **two chairs** (one with armrests and one without), as per the requirements of the tasks.

**3. Gross Motor Function Measure-66 (GMFM-66)**

The **GMFM-66**, specifically designed for children with cerebral palsy, was used to assess **gross motor function**, focusing on **Dimension E**, which evaluates tasks such as **walking, running, and jumping**. The GMFM provides ordinal-level data and quantifies a child's functional capabilities. A score of zero was assigned to tasks that were not attempted or not successfully performed by the child. This dimension was selected as it best correlates with ambulatory function and is most influenced by lower limb spasticity.

**Protocol and Procedure**

Participant Recruitment and Initial Assessment

Participants were screened and selected according to the predefined inclusion and exclusion criteria. Following consent, the children were enrolled in the study. A detailed explanation of each test and procedure was provided to the parents and the children in an age-appropriate manner. All assessments were conducted in a safe, quiet room within the rehabilitation centers, ensuring comfort and minimizing distractions.

Spasticity Assessment Procedure

Spasticity of the **knee flexors** was assessed with the child lying in the **prone position**. The examiner stabilized the pelvis with one hand and grasped the ankle with the other to perform **rapid passive movements** of knee flexion and extension. Spasticity was then graded using the **Modified Ashworth Scale (MAS)**.

For **plantar flexor spasticity**, the child was positioned in **supine lying**. The examiner held the **proximal end of the ankle joint** with one hand and the **forefoot** with the other to rapidly dorsiflex the ankle. The resistance felt was recorded according to the MAS grading system. Both limbs were assessed, and the average scores for each muscle group were documented.

**Balance Assessment Procedure**

The **Pediatric Balance Scale** was administered to evaluate the child's ability to maintain balance in different static and dynamic situations. Tasks included reaching, turning, standing on one foot, and transferring from sitting to standing. **Instructions were explained clearly** to the children, and **demonstrations** were provided when needed. Precautions were taken to prevent falls, and rest periods were provided between tasks to avoid fatigue.

Gross Motor Function Assessment

Gross motor abilities were assessed using **Dimension E** of the **GMFM-66**, which includes walking, running, and jumping tasks. The child was given **clear verbal instructions** and **visual demonstrations** where necessary. Emphasis was placed on safety and correct technique rather than speed. If the child was unable to perform a task, it was marked as zero. The assessment was conducted in a safe space, and adequate rest was given between tasks to ensure optimal performance and minimize the risk of injury.

**Data Analysis**

The data obtained from all three assessments were compiled and analyzed using appropriate statistical software. Descriptive statistics were calculated to summarize the demographic data and mean scores of MAS, PBS, and GMFM-66. **Pearson's correlation coefficient (r)** was computed to determine the **strength and direction of the relationship** between:

Spasticity (knee and plantar flexors) and balance (PBS scores),

Spasticity and gross motor function (GMFM-66 scores).

A **p-value of less than 0.05** was considered statistically significant.

**<u>RESULT</u> :**

Mean age was analysed for 22 participants . Mean age of participants was 8.31 3.45 yr where maximum age is 15 yr and minimum age is 4 yr .

**Table- Descriptives of PBS AND spasticity (MAS)**

| | MEAN SD | Maximum | Minimum |
|---|---|---|---|
| PBS | 37±7.7 | 50 | 27 |
| RT knee flexor spasticity | 2.27±0.59 | 3 | 1+ |
| LT Knee flexor spasticity | 2.18±0.54 | 3 | 1+ |
| RT Ankle plantar flexor spasticity | 2.34±0.58 | 3 | 1+ |
| LT Ankle | 2.09±0.47 | 3 | 1+ |

| | | | |
|---|---|---|---|
| plantar flexor spasticity | | | |
| Mean knee flexor spaticity | 2.20±0.43 | 3 | 1.5 |
| Mean Ankle plantar flexor spaticity | 2.21 ±0.45 | 3 | 1.5 |
| Mean knee and plantar flexor spasticity | 2.21±,34 | 2.25 | 1.62 |

**Table- Relationship between spasticity and pediatric balance scale(PBS)**

| Relation between | Correlation coefficient(r) | P value |
|---|---|---|
| RT knee flexor spasticity and PBS | -0.38 | .040 |
| LT Knee flexor spasticity and PBS | -0.416 | .027 |
| RT Ankle plantar flexor spasticity and PBS | -0.431 | .023 |
| LT Ankle plantar flexor spasticity and PBS | -0.623 | .01 |
| Both knee flexor mean spasticity | -0.433 | -.022 |
| Both plantar flexor mean spaticity | -0.616 | -.01 |
| Mean of both knee and plantar flexor spasticity and PBS | -O.642 | -.001 |

**Table- Descriptives of spasticity (MAS) and GMFM(Dimension E)**

| | Maximum | Minimum | Mean± SD |
|---|---|---|---|
| MEAN OF BOTH ANKLE AND PLANTAR FLEXORS | 2.25 | 1.65 | 2.21±0.34 |
| GMFM(Item E) | 86.11 | 33.33 | 64.28±15.77 |
| | | | |

**Discussion**

The present study aimed to investigate the **relationship between spasticity, balance, and gross motor function** in children with spastic diplegic cerebral palsy. Based on the results obtained, there exists a

**statistically significant negative correlation** between spasticity and both balance and gross motor function. This suggests that increased spasticity is associated with impaired balance and motor abilities in this population.

**Relationship Between Spasticity and Balance**

The primary objective of this research was to determine the impact of **lower limb spasticity**—specifically of the **knee flexors and plantar flexors**—on balance in children with spastic diplegia. The data analysis revealed that the **mean spasticity of the knee flexors** in both lower limbs was **fairly negatively correlated** with balance scores obtained via the **Pediatric Balance Scale (PBS)** (r = -0.433). In contrast, the **mean spasticity of the plantar flexors** showed a **stronger negative correlation** with PBS scores (r = -0.616). This indicates that **plantar flexor spasticity has a greater adverse effect on balance** than knee flexor spasticity.

This finding is consistent with biomechanical and developmental observations. In typically developing children, **ankle strategies** are commonly used to maintain postural balance. However, in children with diplegic cerebral palsy, the use of ankle strategies is often impaired. It has been established in previous literature that the use of an **ankle strategy** to restore the center of mass (COM) to a position of stability requires **normal muscle tone and adequate range of motion**, particularly at the ankle joint. If spasticity is present in the plantar flexors, it restricts the range of motion and limits the ability to execute ankle strategies, which are essential for postural adjustments during quiet stance and perturbations [5].

This limitation may explain why **plantar flexor spasticity had a more pronounced impact on balance** than spasticity in the knee flexors. The impaired ability to dorsiflex due to plantar flexor tightness may result in compensatory postural strategies that are less efficient and more unstable, contributing to increased balance impairment.

Furthermore, when the average spasticity of **both knee flexors and plantar flexors** was analyzed in relation to balance, the study showed a **good negative correlation** (r = -0.642) with PBS scores. This reinforces the cumulative effect of lower limb spasticity on balance performance. Children with diplegic cerebral palsy typically present with **contractures and limited joint range** in multiple joints, including the hips, knees, and ankles. These musculoskeletal impairments contribute to **atypical postures** in both sitting and standing positions, leading to altered **alignment of body segments** and disruption in the body's ability to maintain a stable **center of mass over the base of support**.

According to existing literature, abnormal postural alignment due to joint contractures can shift the center of gravity outside the optimal range, which significantly hampers postural stability [5]. Additionally, **increased muscle tone** leads to **antagonist co-contractions**, which cause resistance to both passive and active movements. This restricts fluid movement and results in **abnormal movement patterns**, as described in several studies [6,17].

Further supporting the relationship between spasticity and balance is the study by **Yang (1996)**, which investigated the effect of **selective posterior rhizotomy (SPR)** on sitting balance. The results demonstrated a marked improvement in balance following the reduction in spasticity, offering strong evidence for the detrimental effect of excessive muscle tone on postural control [16].

Despite the statistically significant correlations found in our study, the **strength of correlation between spasticity and balance ranged from weak to good**, indicating that other factors may also contribute to impaired balance in children with diplegia. **Balance is a complex function**, requiring the integration of **musculoskeletal and neurological components**. Critical neural elements include **neuromuscular**

**coordination**, and the efficient processing of **visual, vestibular, and somatosensory inputs**. Disruption in any of these systems, which is commonly seen in children with cerebral palsy, may further contribute to balance impairments [5].

It is also worth noting that the **Pediatric Balance Scale**, although widely used and validated, does have limitations. It may not account for all aspects of balance and has been reported to exhibit **floor and ceiling effects**. Additionally, while the PBS evaluates tasks involving both **upper body and trunk control**, our study measured spasticity only in **knee and plantar flexor muscles**, and **not in the upper body or trunk muscles**, which may also significantly influence balance.

**Relationship Between Spasticity and Gross Motor Function**

Our study also found a **moderate negative correlation** between **spasticity (mean MAS scores)** of both limbs and **gross motor function (GMFM-66 scores)**. This indicates that increased spasticity limits the performance of gross motor tasks such as **walking, running, and jumping**, which are evaluated in Dimension E of the GMFM-66.

The relationship between spasticity and motor function in children with cerebral palsy has been widely debated. Some studies report weak associations, suggesting that spasticity is not the sole determinant of functional impairment. However, our findings are in line with studies such as **Ostensjo et al. (2004)**, who found that spasticity, range of motion limitations, and motor control impairments all negatively affect gross motor function [9]. Their **multivariate analysis** revealed that **selective motor control** was the strongest predictor of function, but they acknowledged that spasticity contributes to the impairment by restricting voluntary movement.

The difference in findings across studies may be attributed to **variability in measurement tools**, the **distribution of spasticity**, the **severity of motor impairment**, and **sample sizes**. In our study, the **moderate correlation** may also reflect the biomechanical limitations imposed by spasticity, such as muscle shortening, decreased joint mobility, and inefficient movement patterns—all of which reduce a child's ability to perform functional tasks effectively.

## Limitations

This study has several limitations that should be acknowledged:

- The **small sample size (n = 22)** may limit the generalizability of the findings.
- Balance could have been assessed using **more sensitive and quantitative tools** such as **force platforms** or **posturography**, which provide more detailed analysis of balance control mechanisms.
- The assessment did not include spasticity in the **hip muscles or upper body**, which could influence both balance and gross motor outcomes.
- Other impairments such as **muscle strength, selective motor control**, and **coordination** were not evaluated but could play a critical role in function.

## Conclusion

Based on the results of our study, it can be concluded that in children with **spastic diplegic cerebral palsy**, an **increase in spasticity** is associated with a **reduction in both balance and gross motor function**. Therefore, spasticity is one of the important factors responsible for functional limitations in this population.

**Clinical Significance**

Given that **spasticity negatively correlates with balance and gross motor function**, **spasticity-reduction strategies**—including physical therapy interventions, pharmacological management, and surgical options—may improve postural control and functional mobility. These strategies should be considered essential components of treatment plans aimed at enhancing the quality of life and independence in children with diplegic cerebral palsy.

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**Ethics Declaration**

This study was conducted independently by the primary investigator. All participants and/or their legal guardians were informed about the study's purpose and procedures, and **written informed consent** was obtained from each participant or guardian prior to participation. Ethical principles were adhered to throughout the research process.

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