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FEMORAL ANTEVERSION IN CHILDREN WITH DIPLEGIC CEREBRAL PALSY: REVIEW ARTICLE

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ABSTRACT

Cerebral palsy (CP), a leading cause of childhood disability, results from non-progressive brain lesions that impair movement and posture, leading to activity limitation. Key features include muscular contraction, spasticity, hyperreflexia, motor control deficits, balance impairment, and muscular weakness. The most common type of CP is spastic diplegia. Children affected by it typically struggle with motor control, spasticity, and balance, causing abnormalities in their gait. The femoral anteversion (FA) angle, which quantifies femoral neck rotation relative to the shaft, normally decreases from 30° to 15° during normal skeletal maturation. In contrast, CP children typically maintain a slightly elevated FA angle throughout their development.

Key Words: Cerebral Palsy, Diplegia, Femoral Anteversion

INTRODUCTION

1) Cerebral palsy

Cerebral palsy (CP) encompasses a spectrum of disorders affecting movement, balance, and posture. These conditions stem from non-progressive brain abnormalities occurring during fetal development or the first three years of life. The clinical presentation of CP is heterogeneous, featuring compromised movement often accompanied by heightened reflexes, aberrant muscle tone (either increased or decreased), atypical postures, uncontrolled movements, and gait instability. This complexity in symptoms reflects the diverse nature of brain injuries that lead to CP, which can happen before, during, or shortly after birth **(Gulati and Sondhi, 2018).**

The risk factors for CP are varied and span across different periods of a child's development. Here are some of the key risk factors identified in recent research:

A) Antenatal factors: These include conditions affecting the fetus before birth, such as genetic factors, maternal infections, blood type incompatibility, multiple pregnancies, and birth defects. Infections like rubella or cytomegalovirus during pregnancy are associated with a

higher risk of CP. Maternal health issues like thyroid problems and pre-eclampsia also increase the risk **(Tsibidaki, 2020).**

B) Perinatal factors: These occur during labor and delivery. Significant risk factors include birth asphyxia, low birth weight, premature birth, and neonatal stroke. The use of instruments during delivery and complications such as severe jaundice or infections shortly after birth also contribute to the risk **(Abd Elmagid and Magdy, 2021).**

C) Postnatal factors: These risks occur after birth and include central nervous system infections, severe or untreated jaundice, head injuries, and other incidents that may affect brain development in early childhood **(Owens, Shieh, and Case, 2020; Paul *et al*., 2022).**

Moreno-De-Luca **(2021)** categorized CP based on resting tone and topographic predominance, which refers to the specific limbs affected.

- **Spastic hemiplegia:** It accounts for 20-30% of CP and is characterized by unilateral involvement, affecting an arm and leg on the same body side. The upper extremity usually exhibits more severe spasticity compared to the lower extremity. For example, in right-sided hemiplegia, the right arm would be more affected than the right leg. When both arms show greater involvement than the legs, the condition may be termed double hemiplegia.
- **Spastic diplegia:** It accounts for 30-40% of CP, and predominantly impacts the lower limbs on both sides, with upper limb involvement being less pronounced or absent in certain cases.
- **Spastic quadriplegia:** It accounts (10-15%) of CP affecting all 4 extremities and the trunk (full body).
- **Dyskinetic:** It accounts (10-15%) of CP (athetoid, choreoathetoid, and dystonic), marked by abnormal movements often accompanied by hypertonicity.
- **Ataxic CP:** It comprises less than 5% of CP characterized by disturbed balance and coordination.
- **Mixed CP:** It is distinguished by a mixture of spasticity and dyskinesia with no single predominant tone abnormality.
- **Hypotonic CP:** It is a rare type of CP characterized by low muscle tone in the trunk and extremities, accompanied by hyperreflexia and the persistence of primitive reflexes.
- **Monoplegia:** It is a rare manifestation of CP, affects only one limb, either an arm or a leg, and requires a thorough diagnostic evaluation to exclude other potential causes.

Classification according to functional limitations: The children are divided into mild, moderate, and severe types according to the functional classification system **(Korzeniewski *et al*., 2018).**

Muscle spasticity and contractures are prominent in CP, particularly affecting the muscles involved in maintaining posture and movement.

These conditions often lead to permanent muscle shortening, severely restricting joint mobility and functional capabilities **(Domenighetti *et al*., 2018).**

Muscle weakness is a primary contributor to functional impairment in CP, and research has shown that lower limb strength is a key predictor of gait abnormalities and abnormal walking patterns **(Ross et al., 2007; Desloovere *et al*., 2005).**

Core muscle weakness is prevalent in CP, affecting the trunk muscles, which are crucial for posture control and balance. Weakness in these muscles can lead to difficulties in maintaining a stable and upright posture **(Moreau and Lieber, 2022).**

2) Diplegic cerebral palsy

Diplegia is a form of CP characterized primarily by motor impairments that affect the legs more than the arms, often manifesting with increased muscle tone and spasticity in the lower limbs. It falls under the broader classification of spastic CP, where muscle stiffness predominantly impacts bilateral body parts. The diagnosis is typically confirmed through clinical assessments and may be supported by imaging like magnetic resonance imaging (MRI) to identify brain lesions responsible for the condition **(Patel *et al*., 2020).**

In diplegic CP, the primary impact on gait and mobility stems from issues related to the lower limbs. The central features observed include abnormal gait patterns, such as "crouch gait" and "jump gait," characterized by variations in muscle function that may limit the potential of lower-limb muscles to effectively accelerate the body's center of mass **(Correa *et al*., 2012)**. Additionally, the rotational characteristics of the lower limbs during gait in children with diplegic CP show significant asymmetry between the left and right legs, which can affect the mechanics of walking and require specialized management approaches **(van der Linden *et al*., 2006).**

The spasticity prevalent in diplegic CP affects muscle tone in the lower limbs, leading to an abnormal increase in muscle tone, which restricts movement and can cause joint deformities over time. This spasticity combined with muscular imbalances significantly alters gait dynamics, necessitating targeted interventions like botulinum toxin injections to manage muscle tone and improve function **(Ubhi *et al*., 2000).**

Children with diplegic CP often exhibit delays in motor milestones such as sitting, crawling, and walking. These delays are typically more pronounced than in children without neurological impairments **(Patel *et al*., 2020).**

The diagnosis of diplegic CP is primarily based on a combination of clinical findings, detailed medical history, and neuroimaging results

(Novak *et al*., 2017). Here are the key diagnostic criteria used in recent studies:

A) Clinical assessment: Diagnosis begins with observing the child's motor development and neurological symptoms. Signs include abnormal muscle tone, delayed motor milestones, spasticity primarily affecting the legs, and difficulties with voluntary movements **(Patel *et al*., 2020).**

B) Neuroimaging examination: Magnetic resonance imaging (MRI) is a crucial diagnostic tool that helps identify the type and location of brain damage. MRI findings, such as periventricular leukomalacia, are common in diplegic CP and can support the clinical diagnosis **(Ashwal *et al*., 2004).**

3) Femoral anteversion

A- Definition

Femoral anteversion (FA), also known as medial femoral torsion, is defined as the inward twisting of the femoral neck in relation to the femoral shaft, usually quantified by measuring the angle formed between the femoral neck and shaft **(Scorcelletti *et al*., 2020).**

In normal development, the FA angle starts at approximately 30° and gradually decreases to 15° as the skeleton matures. Conversely, CP children typically maintain a slightly elevated FA angle throughout their development **(Shefelbine *et al*., 2004).**

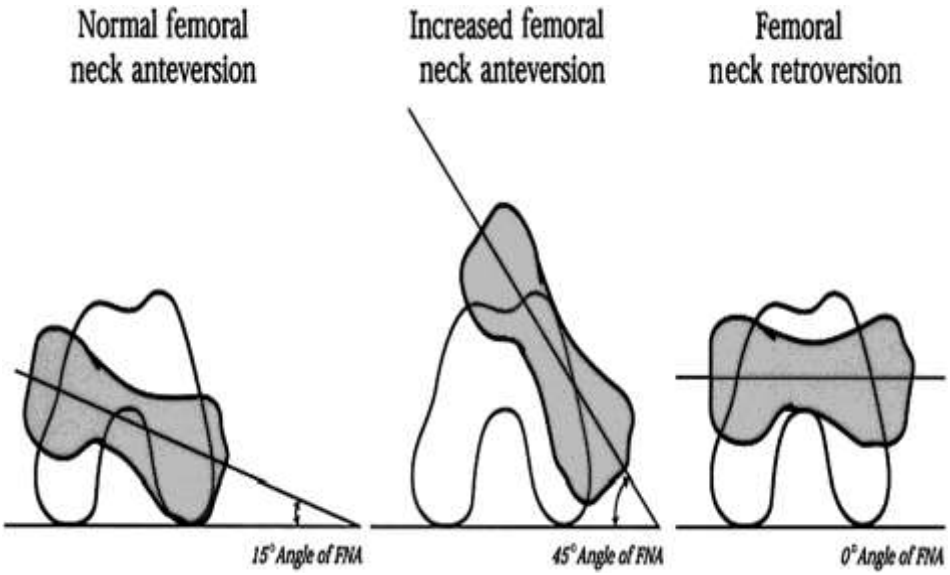

Fig. (1): Axial schematic representation illustrates the right femur and femoral neck anteversion (FNA). The grey coloration identifies the femoral neck, while the distal condylar region is depicted in white (Cibulka, 2004).

B- Developmental changes in femoral anteversion

In typical development, FA is around 30° at birth and gradually decreases to about 15° by skeletal maturity. This reduction is part of the natural development process influenced by growth and mechanical forces during everyday activities. In children with CP, instead of decreasing, FA often slightly increases and remains higher throughout development compared to children without CP. This condition reflects the impact of altered mechanical loads due to neuromuscular abnormalities **(Shefelbine and Carter, 2004).**

C- Causes of femoral anteversion

Causes that increase FA in children with CP include poor motor control, decreased mechanical loading, and internal rotator spasticity **(Yadav *et al*., 2017).**

D- Assessment of femoral anteversion

a) CT-Based Technique: This method allows detailed assessment of rotational differences and is valuable for surgical planning, especially after femoral intramedullary nail insertion, demonstrating high interobserver and intraobserver reliability **(McAlister et al., 2020).**
b) Three-dimensional Computed Tomography (3D CT): This method has been refined to better assess FA in patients with CP. It provides reliable measurements across different neck-shaft angles and is effective in settings where detailed anatomical assessment is required **(Riccio *et al*., 2015).**
c) Parallax Method: It is safe, available, cost-effective, and accurate, making it a viable alternative for measuring FA, especially in complicated cases **(Uma Anand and Moses, 2020).**
d) Fluoroscopic Method: A simple method using a conventional fluoroscope was proposed, showing good correlation with CT measurements and high interobserver and intraobserver reliability. This method facilitates easier intraoperative adjustments of FA and is comparable to CT in accuracy **(Brunner *et al*., 2016).**
e) Magnetic resonance imaging (MRI): It provides femoral cross-sectional images like those obtained through CT scans. By exploiting the paramagnetic characteristics of freely moving protons using strong magnetic fields and radio waves, MRI produces high-quality images without exposing patients to ionizing radiation. Moreover, the MRI has limitations, as it cannot be used on individuals with pacemakers, metal implants, or other contraindications **(Koenig *et al.*, 2012).**

f) Ultrasound imaging (US) method: This method generates two-dimensional cross-sectional images of soft structures and visualizes the external surface of mature, fully mineralized bones. In neonates and young infants, where bones are not yet fully mineralized, US can penetrate and image entire bone cross-sections. This method offers several advantages: it is radiation-free, cost-effective relative to alternative imaging methods, and allows for rapid image acquisition, with the entire protocol typically completed within 10 minutes **(Kulig *et al*., 2010).**

g) Clinical test: It is a method of measuring FA without any imaging. It relies on palpation of the lateral hip to determine the angle of rotation where the greater trochanter is most prominent **(Davids *et al*., 2002)**. This technique, known as the trochanteric prominence angle test (TPAT) or Craig's test, assumes that when the trochanter is most lateral during femoral rotation, the femoral neck is parallel to the floor, allowing the tibial angle to indicate FA. This cheap and practical method only requires a goniometer and utilizes indirect FA indicators **(Van Arkel *et al*., 2015; Chadayammuri *et al*., 2016).** It shows excellent concurrent validity and reliability for measuring FA in CP children **(Chung et al., 2010).**

E- Impact of excessive femoral anteversion

An increased FA is commonly observed in individuals with developmental dysplasia of the hip **(Changzhao *et al*., 2022).** Additionally, research suggests that abnormal FA can predispose individuals to femoroacetabular impingement (FAI) **(Iacono et al., 2021).**

Excessive FA may predispose individuals to more severe hip osteoarthritis **(Parker *et al*., 2021).** It is also associated with ischiofemoral impingement, which presents with aberrant signal patterns in the quadratus femoris muscle and concurrent pain in the ipsilateral hip or buttock **(Dablan *et al*., 2021).**

At the knee, a greater FA angle has been linked to a greater likelihood of anterior cruciate ligament injuries and patellofemoral dysfunction **(Scorcelletti *et al*., 2020).**

In children with diplegic CP, **Lee *et al*. (2013)** found that FA and tibial torsion are structural deformities that can have a substantial influence on the foot progression angle.

Excessive femoral anteversion (FA) is common in CP **(Boyer *et al*., 2016).** In diplegic CP, increased FA angle affects overall and

anteroposterior stability indexes **(Helal *et al.*, 2022**). **Akalan *et al.*** (**2009**) found a relation between increased FA angle and crouch posture in children with diplegic CP.

F- Treatment of femoral anteversion

For patients over 10 years old with unilateral or bilateral idiopathic increased FA, surgical intervention may be considered. Indications include in-toeing gait, hip and/or knee pain, excessive hip internal rotation with less than 15 degrees of external rotation, and a CT-measured anteversion angle exceeding 30–40 degrees **(Horn, 2021).**

De-rotational osteotomy has demonstrated efficacy in treating in-toeing gait in CP children **(Saglam *et al*., 2016; Sung et al., 2018).**

Although conservative management strategies for FA in children are not widely studied, Pilates-based exercises and physical therapy techniques may offer benefits in enhancing strength, balance, and coordination in affected children **(Terrian and Daugherty, 2017).**

CONCLUSION

Femoral anteversion (FA) is common in children with CP and affects their posture, gait, and balance. There are many methods for the assessment of FA. Surgical treatment is effective in severe cases.

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الالتواء الامامي لعظمة الفخذ في الأطفال المصابين بالشلل الدماغي التقلصي المزدوج: بحث مرجعي

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الشلل الدماغي هو مجموعة من الاضطرابات في الحركة والوضعية، والتي تنتج عن آفة غير تقدمية في الدماغ النامي وتؤدي إلى تقييد النشاط. خصائص الاضطرابات الحركية للشلل الدماغي هي الانكماش والتشنج وفرط المنعكسات بالإضافة إلى ضعف التحكم الحركي وضعف التوازن وضعف العضلات. الشلل المزدوج التشنجي هو النوع الأكثر شيوعا من الشلل الدماغي. يعاني الأطفال المصابون بالشلل المزدوج التشنجي في كثير من الأحيان من مشاكل في التحكم الحركي والتشنج والتوازن مما يؤدي إلى تشوهات في المشي. زاوية الانقلاب الفخذي لعظم الفخذ هي مقياس لدوران عنق عظم الفخذ حول الحجاب الحاجز. تبلغ زاوية الانقلاب الفخذي 30درجة في التطور الطبيعي، وتنخفض إلى 15 درجة مع نضوج الهيكل العظمي. يتم زيادة الانقلاب الفخذي قليلاً ويتم الحفاظ عليه عند مستوى عالٍ أثناء نمو الأطفال المصابين بالشلل الدماغي. يعد ضعف العضلات أحد المكونات الرئيسية للشلل الدماغي الذي يساهم في الإعاقة الوظيفية. يؤدي ضعف الطرف السفلي إلى عجز في المشي وأنماط المشي المرضية.