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THE EFFECT OF FEMORAL ANTEVERSION ON TRUNK CONTROL AND FUNCTIONAL MOBILITY IN CHILDREN WITH SPASTIC CEREBRAL PALSY

MASTER THESIS

HANDE ÖZLÜ, PT

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated ..... and numbered .....

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Hande Özlü

DEDICATION

I would like to dedicate my dissertation work to my family. A special feeling of gratitude to my loving parents Zehra ÖZLÜ and Bilal ÖZLÜ, and my sister Özge ÖZLÜ.

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LIST OF SYMBOLS AND ABBREVIATIONS

FA	Femoral Anteversion
CP	Cerebral Palsy
IFA	Increased Femoral Anteversion
GMFCS	Gross Motor Function Classification System
ICF	International Classification of Functioning Disability and Health
PVL	Periventicular Leukomalacia
ROM	Range of Motion
BOS	Base of Support
COM	Center of Mass
MAS	Manual Ability Classification System
FMS	Functional Mobility Scale
TPAT	Throchanteric Prominence Angle Test
MAS	Modified Ashworth Scale
PFRT	Pediatric Functional Reach Test
mTUG	Modified Timed Up and Go test
TIS	Trunk Impairment Scale
PBS	Pediatric Balance Scale
TCMS	Trunk Control Measurement Scale
BMI	Body Mass Index
SD	Standard Deviation

ABSTRACT

OZLU, H. (2021). The Effect of Femoral Anteversion on Trunk Control and Functional Mobility in Children with Spastic Cerebral Palsy. Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, MSc Thesis, Istanbul.

This study aimed to examine the effect of femoral anteversion on trunk control and functional mobility in children with spastic cerebral palsy (CP). Thirty spastic CP children aged between 5-12 at the level I and II according to the Gross Motor Function Classification System (GMFCS) was included in the study. Modified Ashworth Scale (MAS) was used for the evaluation of spasticity of lower extremities. Children were separated into Group 1(FA≥30˚) and Group 2 (FA<30˚) as 15 children for each group according to femoral anteversion angles using Craig's Test. Demographic features and clinical information of the children were collected with a questionnaire which was applied to children's parents face to face. Trunk Impairment Scale (TIS) was used for trunk control evaluation; Pediatric Functional Reach Test (PFRT) and Modified Timed Up and Go (mTUG) test were used for the evaluation of the functional mobility of children. SPSS version 22.0 was used for statistical analysis. According to the results of the study; children in group 1 have statistically lower values of total scores and all subscales of TIS than children in group 2 ($p<0.05$). There were also statistically significant differences in PFRT and mTUG scores between the groups ($p<0.05$). For children with IFA; a strong negative correlation was found between the FA angle and TIS coordination ($p<0.05$). In the present study for all children; between the FA angle, PFRT and mTUG findings statistically significant correlations were found, however; for the children with IFA, there was no significant correlation between their FA angle, mTUG, PFRT scores ($p>0.05$). In conclusion; children with IFA; have more impaired trunk control and functional movement ability than children who have lower FA. IFA has a strong relationship with trunk coordination this might be as a result of pelvic rotation movements in children with spastic CP. Between the IFA and functional mobility; the relationship was not found in this study.

Keys Words: Cerebral Palsy, Femoral Anteversion, Trunk Control, Functional Mobility

ÖZET

ÖZLÜ, H. (2021). Spastik Serebral Palsili Çocuklarda Femoral Anteversiyonun Gövde Kontrolü ve Fonksiyonel Mobilite Üzerine Etkisi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon Bölümü, Yüksek Lisans Tezi. İstanbul.

Bu çalışma spastik serebral palsili çocuklarda femoral anteversiyonun gövde kontrolü ve fonksiyonel mobilite üzere etkisini incelemeyi amaçlamıştır. Çalışmaya 5 ve 12 yaşları arasında olan ve Kaba Motor Fonksiyon Sınıflandırma Sistemi'ne (KMFSS) göre seviye 1 ve seviye 2 de olan 30 spastik serebral palsili çocuk dahil edilmiştir. Alt ekstremitelerin kas tonusunun değerlendirilmesi için Modifiye Ashworth Skalası (MAS) kullanılmıştır. Çocuklar her iki grupta da 15'şer kişi olacak şekilde; Craig Testi kullanılarak femoral anteversiyon (FA) açılarına göre Grup 1 ($FA \geq 30^{\circ}$) ve Grup 2 ($FA < 30^{\circ}$) şeklinde ayrılmıştır. Çocukların demografik özellikleri ve klinik bilgileri; bir anket yardımıyla ebeveynlere yüzyüze sorular sorularak alınmıştır. Gövde kontrolü değerlendirmesi Gövde Etkilenim Ölçeği (GEÖ) ile, fonksiyonel mobilite değerlendirmeleri ise Pediatrik Fonksiyonel Uzanma Testi (PFUT) ve Zamanlı Kalk Yürü Testi (ZKY) kullanılarak yapılmıştır. SPSS versiyon 22.0 programı istatistiksel analizler için kullanılmıştır. Değerlendirmeler sonucunda; grup 1'deki çocukların GEÖ alt başlıkları ve toplam puanlarının grup 2'deki çocuklara göre istatistiksel olarak daha düşük bulunmuştur ($p<0.05$). Gruplar arasında; PFUT ve ZKY test skorlarında da istatistiksel olarak anlamlı düzeyde farklılıklar bulunmuştur ($p<0.05$). Artmış femoral anteversiyonu olan çocukların; GEÖ koordinasyon puanı ile FA açıları arasında negatif düzeyde ilişki saptanmıştır ($p<0.05$). Çalışmaya katılan bütün çocukların FA açıları ile PFUT ve ZKY test skorları arasında istatistiksel olarak anlamlı düzeyde ilişki bulunmuştur ancak, artmış femoral anteversiyonu olan çocukların FA açıları ile PFUT ve ZKY test skorları arasında anlamlı düzeyde ilişki tespit edilememiştir ($p>0.05$). Sonuç olarak; artmış femoral anteversiyonu olan çocukların, FA açısı düşük çocuklara göre gövde kontrolü ve fonksiyonel hareket yeteneklerinin daha kısıtlı olduğu görülmüştür. Artmış FA açısı ve gövde koordinasyonu arasında anlamlı düzeyde ilişki bulunmuştur; bu ilişkinin pelvisin rotasyonel hareketlerinden kaynaklandığı düşünülmüştür. Artmış FA açısı ve fonksiyonel mobilite arasında bir ilişki bulunmamıştır.

Anahtar Kelimeler: Serebral Palsi, Femoral Anteversiyon, Gövde Kontrolü, Fonksiyonel Mobilite

1. INTRODUCTION AND PURPOSE

Cerebral palsy (CP) can be described as a disorder that is a consequence of non-progressive lesions in the undeveloped brain. These lesions lead to movement and posture disorders, also activity limitations. Deficits such as sensation, cognition, communication, perception, behavior and seizure often accompany motor disorders of CP. Primary deficits of CP are related to motor disorders. These deficits are not progressive but they lead to motor impairments, spinal deformities, postural disorders, muscle tone and foot deformities (1).

Weakness of muscle, reduction of coordination, muscle spasticity, impaired selective motor control are primary deficits of CP. Also, secondary deficits; contracture of muscles and deformity of bones are frequently seen in children with CP (2). Detection of these deformities is important for that they affect the gait parameters and also affect the activities of daily living in children with CP (3). The incidence of CP is 2 to 2.5 per 1000 live births in the world (4). In Turkey; studies stated that the rate of CP is average 4.4 per 1000 births (5).

A significant deficit that is often considered with cerebral palsied children is the increased femoral anteversion (IFA). A measure of the rotation of the neck of the femur around the diaphysis can be described as a femoral anteversion (FA). At birth, the angle of FA is approximately 30-40 degrees then it decreases to 10-15 degrees in normal development (6). Weakness of motor control and the presence of spasticity in cerebral palsied children prevents normal derotation of the femur and reduction of anteversion angle. Because of this, the FA angle cannot be decreased and it continued with the high level during the growth of cerebral palsied children (7).

Previous studies have demonstrated that FA is a physical deformity that can leads to gait abnormalities, alteration of foot progression angle and other lower extremity deformities in a while (8,9). IFA decreases the functional lever arm relative to the hip joint center and also replaces the abductor muscles of the hip. FA increase may be compensated for by internal rotation of the hip (10). Especially for ambulatory children with CP, IFA is a biomechanical disadvantage during ambulation. These children which

have IFA able to walk independently, but most of them have increased hip internal rotation, knee flexion, lumbar spine lordosis, anterior pelvic tilt, equinus foot position and intoeing that result in postural control, coordination, gait abnormality and balance problems (11).

Postural control comprises control of body position to gain orientation and stability in space. Body orientation includes the control of the association between the different segments of the body. The components of postural control such as sensory inputs from the visual, vestibular, somatosensory systems and motor output are necessary for stabilization and orientation. These components help to retain the body in equilibrium with anticipatory and automatic postural adjustments (12,13). Postural control is a long and complicated process during early life. The mechanism of postural control maintains stabilizing the head and trunk against gravity in a vertical position during this process (14).

The trunk is an important part of the body in retaining postural control and in an arrangement of the balance reactions. The trunk control is needed for performing functional activities for limb movements in the stable base of support. Also, basic trunk movements are essential for maintaining mobility and postural adjustments (15). In literature; it is suggested that the trunk control measurements are considered with balance, walking and functional abilities and also it is an important indicator for daily living activities for instance; sitting, walking, reaching and standing (16).

Neuromuscular problems of cerebral palsied children lead to deficits of selective motor control, abnormal posture, weakness of trunk control and balance which are promoted to poor postural control. Abnormal motor control, loss of primitive reflexes, development of contractures are the other problems in children with CP. Also, these factors lead to balance problems. The combination of these factors causes inadequate corrective and compensatory postural control responses. In addition, muscular coordination problems and sensory-perception-motor integration problems also affect postural control and contribute to existing balance difficulties (17).

Functional mobility and balance are the constituents of the postural control which are needed for children with CP executing social and recreational activities, basic daily activities independently in the community, at school or at home (18,19). Poor postural control mechanism weakens the functional balance. Previous studies stated that cerebral

palsied children have weak static and dynamic balance reactions than the normally developing children (12,13). Balance problems of the cerebral palsied children increased the risk of falls and decreased performing daily living activities, participation and mobility (19).

Several assessment tools are developed to assess the functional ability, balance and mobility of children with CP in a holistic approach (20,21). Although there are many studies that explain the relationship between trunk control and balance in children with CP, the relationship between IFA, trunk control and functional mobility is still a question. Therefore, the main aim of this study is that explains the effect of IFA on trunk control and functional mobility in children with CP. Two hypotheses were identified in this study:

H0: The increased FA angle does not affect trunk control and functional mobility.

H1: The increased FA angle affects trunk control and functional mobility.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Definition of CP

Cerebral Palsy is a reason for physical disabilities which affect children commonly in the world. William James Little who is an orthopedic surgeon presented the first explanation about the spastic rigidity of birth complications and prematurity in 1862. He mentioned this situation as Little's disease. Then the term "Cerebral Palsy" was announced by William Osler in 1888. Sigmund Freud and Phelps also detected that pre and postpartum factors may be related to the CP. Many other researchers tried to found a unified explanation of this disorder (22).

The description which is found by Bax has been used frequently and classically since 1964. He defined the CP as a disorder of movement and posture because of a lesion or defect of the immature brain. Bax stated that the short-term, progressive disorders and only mental impairments must be differentiated from the description of CP. Bax only focused on motor impairments of CP; perceptional, sensational, behavioral and other abnormalities were not described (23).

In 2006, a committee from the International Classification of Functioning Disability and Health (ICF) adjusted the definition and classification of CP. The suggested decription is "Cerebral palsy is a group of stable disorders which are lead to non-progressive disturbances such as posture, movement problems and also activity limitations appeared in the immature brain. Sensation, cognition, perception, behavior (caused by epilepsy), communication, secondary musculoskeletal problems often complement to the motor disorders of CP" (22).

2.2. Epidemiology of CP

In the world, CP is a physical and motor disability that is seen commonly in childhood. The prevalence of this disease depends on multifactorial conditions such as the child's diagnosis, age (during the research), inclusion and exclusion criteria after the neonatal period and ethnic community (24). It is demonstrated by population-based studies that the prevalence of CP is approximately from 1,5-3 to 1000 live births from all around the world (24,25). The prevalence of this disease is in Europe from 1.51-2.2 to 1000, in the USA from 1.7-2.0 to 1000, in China from 1.28-1.92 to 1000 live births (26). It was found that the prevalence of CP is from 1.1-4.4 to 1000 live births in Turkey (27).

Maternal, perinatal and neonatal period rehabilitation of CP has a significant function in CP prevalence. That has endured the same and showed little alteration over past forty years. The ratio of CP was stable with children who were born between 1950-1970. After these years with the new medical developments, although increasing the rate of CP; also the survival rate has increased. It is considered that getting good antenatal care is important for the avoidance of CP (28).

2.3. Etiology and Risk Factors of CP

CP etiology is various and multifactorial. An etiology of 30-40% of cases has still unknown; many factors which are consistent in the time are considered as risk factors. The causes are genetic, inflammatory, infectious, anoxic, metabolic, traumatic and congenital. The injuries which occur in the developing brain may be prenatal, perinatal or postnatal. The cases of 75-80% are due to prenatal injury with less than 10% causing by asphyxia or important birth trauma (29). Prematurity (35% of cases) and low birth weight seem to be very significant risk factors. These factors increase the risk of CP by reducing birth weight and gestational age. The prevalence of CP is very high with the child born before 28 weeks gestation. Also, babies who have 500-999 grams birth weight have a great risk of CP (10-18%) (30). Low birth weight increases the risk incidence of periventricular hemorrhagic infarction. The growth of the spread of hemorrhage leads to periventricular leukomalacia (PVL). In 60-100% of children with cystic PVL is a very important determinant factor of diagnosis of CP (31).

CP appears more frequently in premature or term babies. Even though term babies have a low absolute risk of CP relative to term babies, almost half of the cerebral palsied children are consist of term birth babies. It is considered that perinatal damages, anoxia, ischemic brain injuries can be a reason for CP with term birth babies (32).

The risk factors of CP can be divided into three groups as prenatal, perinatal and postnatal;

Prenatal (Maternal/Fetal/Placental) Risk Factors

- Iodine deficiency, iron deficiency and poor nutrition
- Congenital malformations
- Intrauterine infections, high fever, UTI
- Chorioamnionitis
- Hypertension

- Maternal diseases e.g. diabetes, hypertension, hyperthyroidism
- Maternal epilepsy
- Intermarriage, Rh incompatibility
- Teratogens - drugs, radiation, smoking, alcohol, and environmental toxins
- Fertility problems e.g. advanced age at conception, history of infertility, recurrent fetal wastage
- Poor antenatal care
- Multiple pregnancies
- Poor socioeconomic status
- Placental complications

Perinatal Risk Factors

- Birth asphyxia
- Prematurity (<32 weeks)
- Low birth weight (<2500 gr)
- Intrauterine growth retardation
- Hyperbilirubinemia
- Intraventricular and intracerebral bleeds
- Hypoxia and bradycardia
- Epilepsy
- Trauma
- Hypoglycemia, dyselectrolytemias
- Infections such as sepsis, pneumonia and meningitis
- Premature separation of the placenta

Postnatal Risk Factors

- CNS infections such as viral encephalitis, tubercular meningitis and pyogenic meningitis
- Trauma such as head injuries
- Anoxia
- Intracranial bleeding
- Suffocation
- Electrocution

- Post-operative cardiac arrest
- Post epileptic
- Cerebrovascular accidents
- Gastroenteritis and dehydration (33).

2.4. Diagnosis of CP

The diagnosis of CP involves important clues such as abnormal motor development, unusual posture and abnormal muscle tonus, delayed motor milestones (rolling, sitting, standing and walking) at appropriate chronological age. Assessment of asymmetry, involuntary movements, primitive reflexes, inadequate postural reactions helps to the diagnosis of CP in the clinics (34).

Most primitive reflexes are disappeared within the first 4 to 12 months, but in children with CP, these reflexes may present into adulthood. Abnormalities in muscle weakness, clonus, brisk deep tendon reflexes, asymmetries in muscle tone and functional skills are important for neurologic examination. Muscle tone is also a determinant factor for diagnosis of CP, but before 6 months; spasticity and before 2 years; athetoid movements are not realized in children. When evaluating these abnormalities, progressive genetic and metabolic disorders must be excluded (35).

In addition to clinical examination, physical diagnostic tools such as ultrasound, cerebral imaging using computed tomography, magnetic resonance imaging and targeted laboratory tests are beneficial for detecting the risk of CP. Seizures, vision and hearing impairments, perception problems, cognitive dysfunctions aid to complete assessment and decide diagnosis of disease (36).

2.5. Classification of CP

Classification is necessary for defining the origin and severity of the problem, evaluating alterations in infants and children at different times and guessing the potential upcoming conditions. Classification helps to track incidence and characteristics of the disease, educates the families and contributes to therapists and doctors for the rehabilitation program. Generally; the classification of CP can be divided into three groups; motor types, topographical distribution and functional motor ability (37).

2.5.1. Physiological (motor type) classification of CP

There are two main physiologic classifications of CP according to affected brain areas which are lead to predominant motor disorders; pyramidal (spastic) and extrapyramidal (non-spastic) (Figure 2.1).

Pyramidal (spastic) CP which is also described as upper motor neuron disease, is a consequence of damages or defects arising in the corticospinal pathways of the brain (38).

Extrapyramidal (non-spastic) CP arises outside of pyramidal tracts (cerebellum or basal ganglia) in the brain and is affected by the damage to nerve cells. It is classically divided into three categories; ataxic, dyskinetic and hypotonic (39).

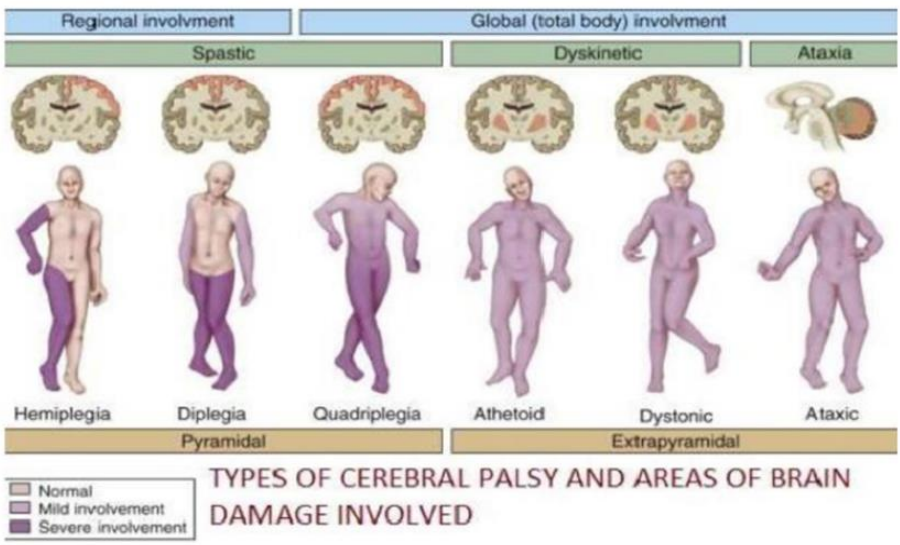


Figure 2. 1. The Classification of CP (40).

2.5.1.1. Spastic type CP

Spastic CP is the most common type of CP. Spasticity is a resistance that is velocity-dependent to passive stretch by the muscles and exaggerated reflexes. Spastic CP is differentiated by excessive tightness of muscles when child enterprises to continue or move a posture to anti-gravity. Hyperreflexia, persistent primitive reflexes, extensor Babinski responses, clonus are visible features of spastic CP. Hypotonia of the trunk, weakness of muscles, slow pattern movements, inadequate protective and balance

reactions, associated movements and stereotypic movement patterns are also seen with spasticity (41).

In the world; this type of CP arises nearly 70% to 80% of all CP cases (42). Spasticity can be affected by the child's emotional situation, alertness, state of pain and activity. For daily activities; physical therapy, occupational therapy, stretching and strengthening exercises are applied to control disorder (43). In addition; musculoskeletal problems (muscle & joint contractures and joint deformities) are most seen in the spastic type of CP (41).

2.5.1.2. Ataxic type CP

Ataxic type CP may appear in 6-10% of all cases of CP and it seems lesser than other CP types. Ataxic CP differs from the other types with cerebellum damage situation (40). Shaky movements which are the most visible feature of ataxia lead to balance and coordination problems. Generally; weakness of muscles, tremor, walking with a wide base of support (BOS), problems with timing of coordinated movements are frequently seen with ataxic CP (44). Also, other associated problems such as nystagmus, poor eye tracking, delayed and poor articulation speech may be considered children with ataxic CP. It is usually seen as a combination of spasticity and athetosis (45).

2.5.1.3. Dyskinetic type CP

Dyskinetic CP is another common type of CP after spastic CP. The prevalence of dyskinetic CP is 10% of all CP cases (40). It is differentiated by fluctuating muscle tone and uncontrolled involuntary movements. Dyskinesia may be arises as a result of damage of basal ganglia, extreme jaundice and perinatal asphyxia (46). Extrapyramidal movement patterns which are athetosis, ballismus, tremor, dystonia, rigidity and choreoathetosis are seen with dyskinesia. A child with dyskinesia has challenges with preserving steady positioning (steady walking and sitting).

Involuntary movements are seen with slow writhing, abnormalities in direction, timing, spatial features and large movements (in proximal joints) also seen in ***athetosis.***

Rigidity is frequently seen as a type of dyskinetic CP which differs from spasticity with a not velocity-dependent resistance to both active and passive movements.

Tremor rarely appears and it is an isolated type of CP (contrary to combination with ataxia and athetosis). Tremor is slow-magnitude rhythmic movements of smaller joints.

Dystonia is distinguished by intermittent and continued muscle contractions which is leads to twisting and repetitive movements. It affects the whole body or one limb with a torsional element in slow motion and its pattern may change in time.

Ballismus is usually seen in a single limb with large and fast motions randomly. It rarely appears than the other movement disorders.

Choreoathetosis includes jerky movements and affects the digits generally and changing in the range of motion (ROM) (47).

2.5.1.4. Hypotonic CP

Hypotonic CP is often stated in classifications of CP as a consequence of delayed motor development. Neuropathy and myopathy must be excluded from being a potential reason for hypotonic CP. Children or infants with hypotonic CP are floppy and have noticeably decreased muscle tone. Because of the weakness of muscles (especially facial and oral), children have associated problems with feeding. Hyperreflexia and persistent primitive reflexes separate CP from lower motor neuron causes of hypotonia. It is a transition phase between spastic and athetotic types usually (38).

Mixed type CP; is seen as a combination of other motor types of CP. Mostly, dyskinetic and spastic disorders appear together. It usually includes athetosis and spastic diplegic type of CP (46).

2.5.2. Topographical classification of CP

The topographic classification which includes the pattern of limb involvement is used for spastic CP. Limb involvement can be separated into two parts; unilateral (monoplegia and hemiplegia) and bilateral involvements (diplegia and tetraplegia). Generally; topographical classification consists of five subtypes; monoplegia, hemiplegia, diplegia, triplegia and quadriplegia. Diplegia, hemiplegia and quadriplegia are seen frequently in all cases of spastic CP, triplegia and monoplegia are relatively rare (Table 2.1) (48).

Table 2.1. Topographical Classification of CP (49).

Subtypes	***Diplegia***: 30-40% of spastic CP; 50% were born preterm
	Hemiplegia: 20-30% of spastic CP; associated with strokes, vascular malformations, unilateral IVH or PVL
	Quadriplegia: 10-15% of spastic CP; associated with severe asphyxia in all infants; severe IVH and PVL in preterm infants
	Monoplegia / ***Triplegia***
Physical Examination Findings	***Diplegia***; Spasticity were lower extremities (can affect upper but to a lesser degree) ; risks for strabismus; learning, attention, and communication disorders common.
	Hemiplegia: Unilateral spasticity; early asymmetry in movements and/or functional abilities (i.e.; asymmetrical crawl or early hand preference); risk for visual field cut, mild to moderate cognitive and communication disorders, high rate of partial seizures
	Quadriplegia: All extremities affected, as well as trunk and oral musculature
	Monoplegia; one limb, ***Triplegia***; three limbs are affected

Monoparetic CP; is used for the definition of one limb (arm or leg) involvement. It is rarely seen and is not diagnosed generally (50).

Hemiparetic CP; is used for the definition of the arm and leg involvements which are on one side of the body. Generally, the upper extremities are more strictly affected than the lower extremities. Hemiparetic CP may be considered with 17% of preterm and %56 of term babies. Children with hemiplegia have problems with voluntary movements about hand functions which are affected mostly. In upper extremities; wrist extension, supination of the forearm and pincer grasp of the hand, in lower extremities; inversion and dorsiflexion of the foot are impaired frequently. Sensory abnormalities, impaired stereognosis function & position sense, impaired performance on two-point discrimination test, homonymous hemianopia, facial nerve palsies, visual field defects, cranial nerve abnormalities and seizures can be seen with hemiparetic CP (51).

Diplegic CP; is used for the definition of the involvement of lower extremities bilaterally. The lower extremities and trunk are affected more than the upper extremities. It is known as Little's disease and it is the most common form of spastic CP (46). Diplegia is mostly seen with low weight and premature babies. Periventricular leukomalacia (PVL) which is an ischemic brain injury in premature babies, is associated with diplegic CP.

PVL has associated problems such as nystagmus, blindness, fixation difficulties, seizures and strabismus. Toe walking due to weakness of dorsiflexors of the ankle, increased muscle tone of hip & knee flexors and hip adductors may be seen frequently and it leads to diplegic gait pattern (scissors gait) (52).

Triplegic CP; is used for the definition of involvement of three extremities. Generally, trunk and lower extremities are affected bilaterally and one upper extremity is also affected. Toe walking and scissor gait may be associated with children with triplegic CP (46,50).

Quadriplegic CP; is used for the definition of head, trunk, lower and upper extremities involvement bilaterally. It is generally associated with hypoxic intrapartum asphyxia or intraventricular bleeding (third or fourth degree) (53). Firstly hypotonia is dominant in babies then the tone of muscle increases marked and flexion or extension pattern is fixed stable. Voluntary movements are mostly restricted. Vasomotor alterations of limbs are frequent. Due to pseudobulbar signs; aspiration of foods and swallowing difficulties may be seen. Half of the children affected from seizures & optic atrophy, hearing problems and also severe intellectual impairments exist. Muscle contractures, joint deformities and hip dislocations may commonly develop in children with quadriplegic CP (46, 51).

2.5.3. Functional classification of CP

Functional motor abilities can be categorized objectively by applying functional scales such as Gross Motor Function Classification System (GMFCS), Manual Ability Classification System (MACS) and Function Mobility Scale (FMS). GMFCS gives information about motor ability of children, the requirement for mobility devices, walking frames or wheelchairs. It helps to understand the severity of limitations of functional abilities. MACS is used for defining hand function abilities about handling objects in daily activities. It is a similar categorization system to the GMFCS and it is usable for an overage of four. FMS evaluates the measurement of differences in walking abilities (22).

2.6. Associated Problems of Spastic CP

Problems and disabilities are associated with the severity of brain injury. They may be range from mild to severe. Most children with CP (approximately 50%) have associated problems that have a great effect on the function of motor impairments (55).

2.6.1. Epilepsy

Most children with CP (35-62%) have epilepsy as an associated problem (55). The frequency and types of epilepsy may vary child by child. Signs of epilepsy may not be realized due to abnormal movements (50). The incidence of epilepsy attacks is higher in the first year of age. The prevalence of epilepsy may differ in types of CP. Spastic hemiplegic and quadriplegic have greater incidence than ataxic or diplegic type of CP. Between epilepsy and mental impairments, there is a strong relationship. Children with mental impairments also have a higher risk of epilepsy than others (55).

2.6.2. Cognitive impairments

In CP; higher cortical functions such as memory, language skills, attention and problem-solving skills are generally affected due to brain injury. Cognitive impairments lead to mental retardation and learning disabilities. Mental retardation is a common disability and it might appear in 30-50% of all cases of CP (46,56). The severity and rate of recurrence of mental retardation are related to the degree of motor disabilities of CP. Children with spastic quadriplegia are more affected by cognitive impairments than other types of CP (46). Not only motor disabilities, but also environmental factors are related to emerging mental retardation. Cognitive assessment tools are used for understanding the effect of the deficits on cognition and testing the language and communication skills of children (57).

2.6.3. Hearing impairment

Hearing impairment emerges in almost 12% of cerebral palsied children. Very low weight birth, severe hypoxic-ischemic injuries, neonatal meningitis and kernicterus are might be the reason for hearing impairments (55). Hearing has an important effect on cognitive, psychosocial development and language & speech abilities of the child. Children who have abnormal neuroimaging studies or mental impairment encounter hearing impairments more than others. As a result of this; hearing tests must be applied by an audiologist to children with neurodevelopmental problems in infancy (56).

2.6.4. Visual impairments

In 55-80% of cases of cerebral palsied children, ocular motility disorders and visual impairments are usually seen. Nystagmus, refractive errors, optic atrophy, strabismus and amblyopia are the most common visual impairments (55). In spastic diplegic CP, the incidence of visual impairments higher than ataxic or dyskinetic CP. Because; in ataxic and dyskinetic CP basal ganglia and cerebellum are affected, but in spastic CP the brain cortex is affected (57). Children who have periventricular leukomalacia might have visual perceptual problems. Premature retinopathy might be seen in premature babies. Hearing screening is essential for newborns, also visual tests must be applied by pediatric ophthalmologist to children with neurodevelopmental problems (31,55,58).

2.6.5. Neurobehavioral problems

Generally; depression, anxiety, aggression, hyperactivity, anti-social, hyperkinesis, shyness, unresponsiveness to stimuli, conduct disorders, inattention problems and dangerous behaviors may be detected in children with CP as neurobehavioral problems. Both CP and mental retardation are allied with CNS dysfunction; prevalence of behavioral problems is greater in children with CP who have mental retardation (59).

2.6.6. Speech and language disorders

Generally, 38% of children with CP affected by speech and articulation disorders. Oromotor and bilateral corticobulbar dysfunctions lead to impairments of speech abilities. In children with CP; central deficits in motor planning (apraxia and dyspraxia) and central language deficits (such as aphasia and dysarthria) might be seen. Speech disorders are related to the type of CP, mental impairments, localization of brain injury and gross motor

function. Previous studies stated that language is important for decision-making and cognitive skills (52,60).

2.6.7. Feeding problems

In children with CP, difficulty in feeding, drooling and swallowing dysfunctions might be present (61). The incidence of feeding problems with cerebral palsied children is 30-90% of all CP cases. Oral dysphagia, chronic aspiration, gastroesophageal reflux and behavioral abnormalities lead to nutritional problems. Nutritional problems influence the life quality and also physical growth of children. Nutritional and feeding matters are important for children with CP because these problems may cause bone diseases such as osteopenia and it results in increasing severity and degree of disability (61,62).

2.6.8. Urinary system dysfunctions

Enuresis, urgency and stress incontinence might be seen in 30-60% of children with CP (63). Neurogenic bladder is the most common problem and it is mostly affected by mobility and upper extremity problems. These problems lead to impairments of cognitive level, toilet abilities and quality of social lives (64).

2.6.9. Respiratory problems

Anatomic and neurogenic dysfunctions cause an increased incidence of primary respiratory problems. Primary respiratory problems include atelectasis, bronchiectasis, recurrent pneumonia, restrictive lung diseases (65). Chronic lung diseases may be caused by increased mortality and morbidity rate in children with CP. Because of scoliosis; chest wall deformities are seen frequently in CP and it leads to restrictive lung disease. Weakness or incoordination of respiratory muscles results in hypoventilation, inefficient coughs and difficulty in throwing pulmonary secretions (66).

2.6.10. Sleeping disorder

The most mutual trouble in all ages with CP is sleeping difficulties. Musculoskeletal pains, muscle spasms, epilepsy, epileptic drug-using, gastroesophageal reflux and sleeping positions lead to sleeping problems (67). Airway problems (tonsillar hypertrophy), obstructive or central apnea, severe visual impairments (circadian rhythms) are also cause the decreasing quality of sleep and sleeping disorder (68).

2.6.11. Musculoskeletal problems

Generally, musculoskeletal problems occur as a consequence of central nervous system injuries. At birth; children with CP have normal skeleton structure, after birth

because of pathologic reasons; the skeletal deformities are progressed in lower extremities. Pathologic situations like impaired joint position sense, decreasing range of motion, muscle imbalances and muscle weakness lead to involuntary contractions of muscles and maldevelopments of joints. If the degree of effectiveness of disease and muscle tone is high, the incidence of the risk of deformities and contractures increases. Orthopedic problems which are bone and joint deformities, hip subluxations, dislocations, dysplasia, foot & hand deformities and scoliosis are usually observed in children with CP (69,70). The most important hip deformities are; adduction contracture, flexion contracture, hip instability and femoral anteversion are often seen in cerebral palsied children (70).

2.7. Femoral Anteversion (FA)

2.7.1. Definition of femoral anteversion

At birth; children with CP have a normal skeleton, although skeletal deformities progress after birth frequently. Different bone deformities might progress with growth. FA is one of the characteristic bone deformities which is often observed in children with CP (71). FA is explained as internal torsion of the femur and this torsion can arises at different parts of the femur (72).

During pregnancy; flexion, abduction and slight external rotation position in the mother's womb is important for the development of the hip. Because of this; most babies are born with femoral torsion. There is a natural angulation between the middle of the femoral neck and distal condyles of the femur. This angulation is defined as FA angle (73). It is also described as between the posterior-condylar axis and neck axis projected onto a plane vertical to the long axis (Figure 2.2).

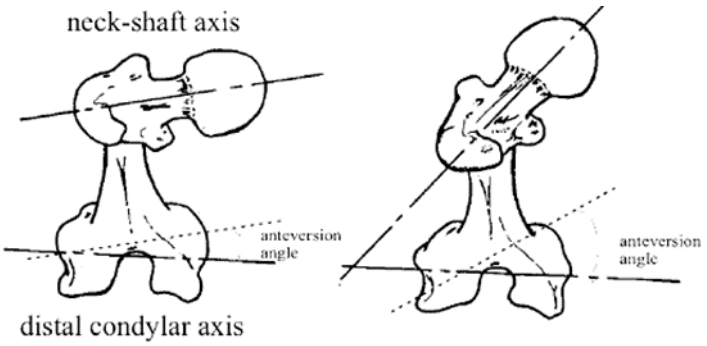


Figure 2.2. Femoral Anteversion Angle (74).

If this angle is 0; the femur head axis and condylar axis are on the same plane. A negative degree of angle indicates “retroversion” and a positive degree of angle is explained as “anteversion” (75). FA occurs with the forward rotation of the neck of the femur throughout the whole shaft of the femur. This condition might be a result of mechanical forces, fetal development, genetic factors and intrauterine position (76).

2.7.2. Increased femoral anteversion (IFA)

IFA is explained with a higher FA angle than normal developmental angle (Figure 2.3) (77). FA increase is physiological and it changes with age. In the intrauterine period, the FA angle is 55-60° and it is approximately 30-40° at birth. It is expected that the FA angle decreases with normal growth. FA decreases to 10-15° in an early adolescent with the effects of genetic factors, muscle power and normal walking process (78). In adults; the FA angle is approximately 15°; it is lesser than the normal value of the angle in males and it is slightly higher in females (approximately 18°).

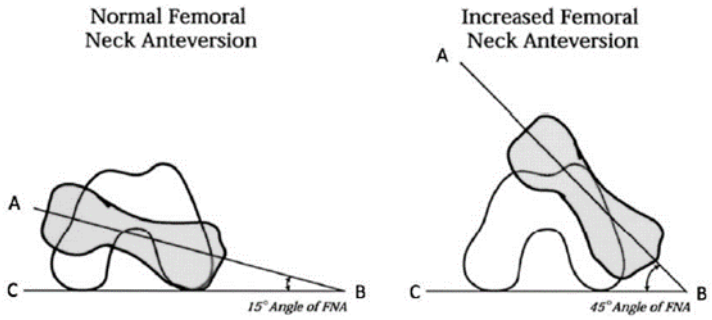


Figure 2.3. Increased Femoral Anteversion (77).

Sommerville et all. explains FA angle decrease as “remodeling mechanism of femoral anteversion”. Normally; when a child starts standing or walking, the FA angle decreases with pushing effects of the iliofemoral (Bigelow) ligament (anteriorly) and gluteus maximus muscle (posteriorly). Due to various reasons, the remodeling mechanism is insufficient in children with CP. They cannot able to stand or walk earlier, thus the hip remains in flexion position and the pushing effect of the Bigelow ligament is ineffective (80). The presence of spasticity, weakness of motor control and mechanical balance defects also prevent the decrease in FA angle. Because of the spasticity; hip and knee flexors muscles are more activated when walking. This leads to prevent the pushing

effect of the Bigelow ligament. Internal rotation contracture which is generally emerged in cerebral palsied children between 3 and 8 years old, restricts physiological decrease of FA (81).

The remodeling mechanism has also a direct relationship with the rate of growth. The growth rate is highest in first age (10-12 months) throughout the life of a child and it gradually decreases. When children with CP start standing or walking; both remodeling and rate of growth are decreased. Therefore; the physiological decrease of FA cannot occur. According to Sommerville's description; "persistent fetal alignment" remains. FA angle continues at high level through the growth of child and it cannot decreases (82).

The rate of proximal femur remodeling decreases consistently with the ambulation degree of children with CP. Robin and colleagues stated that increased FA angle is related to the ambulation level of children with CP. According to GMFCS; for GMFCS I, FA angle was found to be 30°, 36° for GMFCS II, 40° for GMFCS III, 40° for GMFCS IV and V (Figure 2.4) (83). Clearly; a delay in independent walking has a negative effect on remodeling because of the mechanical load imbalances. Cyclic hydrostatic stress and cyclic octahedral shear stress within the proximal femur may also lead to reducing remodeling in children with CP (84).

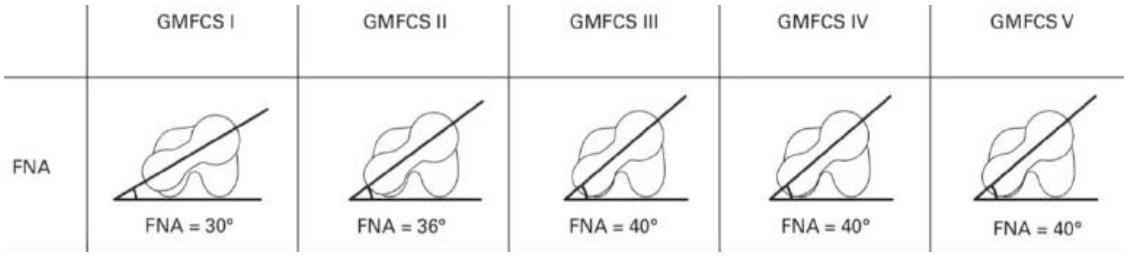


Figure 2.4. Relationship Between Femoral Anteversion and GMFCS (83).

IFA changes the walking biomechanics in the transverse plane primarily, even it affects in the sagittal and coronal plane and it leads to pathological alterations (85). In the physical examination of children; the legs' appearance is an important sign of IFA while walking or running. Knees rotate inwardly in the standing position and internal rotation gaiting can be observed when the external rotation of the tibia is normal (86). IFA affects the abductor mechanism of the gluteus medius muscle and it leads to walking

abnormalities. As a result of this; children with CP walk with internal rotation (internal rotation gaiting) and it is explained as a dynamic compensatory strategy for balance (87). In children with CP who are affected by IFA, in-toeing walking might be observed. Excessive in-toeing is considered with tibial torsion, genu valgum, pes planus and metatarsus adductus. In-toeing is generally seen because of CP but it is not only reliant on CP (88). Children with IFA commonly sit in the "W" position. Children bend their knees and their feet are flared out behind them. They have difficulties in tailor sitting (86).

The main cause of IFA has to be examined for prevention of further damages of hip and lower limbs. Weakness of gluteus muscle and spasticity of hip adductors cause femoral neck valgus. It leads to an increased risk of dislocation and subluxation of the hip. IFA, increased internal rotation of the femur and coxa valga conditions are the main reasons for spastic hips. Because of this, detection of the problem and positioning of the limb are so important for hip (89, 90).

Increased cases of internal rotation contracture of hip and IFA cause to compensatory effect for asymmetric pelvic rotation and external torsion of the tibia. If the IFA, internal rotation contracture and external tibial torsion exist, flexors of the hip and knee will be affected. This results in patellofemoral joint instability and Q angle increasing (78). It means that the knee kinematics and kinetics of the children are also affected by IFA. The power of knees might reduce in time (91).

IFA has not only an effect on the hip and lower limbs, but also affects the whole body. IFA leads to asymmetrical posture, increased lumbar lordosis and thoracic kyphosis. These situations cause scoliosis in the early or late period (92). In children with CP which have IFA; have a higher trip, fall and injury risk than their normally developed peers. IFA restricts their participation in physical activities and affects their daily life negatively (93).

2.7.3. Evaluation of femoral anteversion

IFA is often detected with CP. IFA leads to hip joint instability and walking with feet turned in (in-toeing). The evaluation of FA angle is essential for the stability of hip so as the children's gait. That's why; femoral derotation osteotomies are often applied to these children in severe cases or at specific age. Before the operations; it should be known if the FA angle is normal or increased. Not just for operations; the FA angle of children should be known for also physical therapy programmes. (94, 95). Many different methods

may be used for FA angle evaluation. Each method has advantages and disadvantages. Physical examination, radiographical measurement, computed tomography (CT), ultrasound (US), fluoroscopy, magnetic resonance imaging (MRI) are generally used for the measurement of FA (96).

2.7.3.1. Physical examination

In physical examination; children's prenatal and postnatal history, motor developmental stages and family history should be assessed. Children can be evaluated in walking, standing and running (97). Their walking and running difficulties, activities that involve a higher risk of falling for these children and W sitting habits should be noted (97, 98). Lower extremity evaluation includes joint range of motion (ROM), leg length discrepancy, foot structure and walking analysis. Not only the hip joint is evaluated, but also the children's posture should be assessed totally. A physical evaluation is a practical indirect method and it helps to estimate the problems about FA (78).

Craig Test is the best applicable method for children in clinics. It is known as Ryder or Throchanteric Prominence Angle Test (TPAT). When the child is lying in the prone position, the therapist makes sure that the hip is fixed position (without hip rotation). For the right hip FA evaluation, the therapist stands on the left side of the child. The therapist bent the right knee 90 degrees with her/his right hand and he/she palpates the trochanteric prominence with her/his left hand when the leg is rotated internally and externally. The therapist stops at the point where he/she feels the trochanteric prominence of the femur most prominently with hip rotation internally. Another therapist measures an angle between the tibia and vertical plane with a goniometer. However, it is difficult to distinguish the difference between FA and internal rotation contracture with the physical examination. FA may also be measured in a supine when knees are flexed, drop off the end of a bed. This method is a more suitable and easier method for children who are very slender and have not hip operation history. Otherwise; the tangible landmarks might be obliterated (96).

2.7.3.2. Radiographical measurement

It is used as the first method for the quantitative measurement of FA and coxa valga. The radiographical method is less preferred than the other methods today. This method requires special rulers, measurements and calculations after radiography. When the child is lying; the hip radiograph is taken in two positions: bilateral patella is in the

neutral position and the legs are internally rotated. It is hard to measure the FA with this method in children who have excessive muscle spasticity. If the angle between the femoral neck and shaft (coxa valga) is higher than 150 degrees, this method is not suitable. Since increased coxa valga may obstruct the anterior projection of the femoral neck and head. Radiographical measurement can be used when coxa valga is normal or lesser than 120 degrees (96).

2.7.3.3. Computed tomography (CT) scan

CT scan is the best accurate method for measuring FA. The coxa valga must be comparatively normal for the exact measurement results. CT scan method evaluates the anterior projection of the neck of the femur relative to the knee joint axis as described by posterior condyles of the femur and defined as FA (99). This method is mostly used in children which have hip operation history and normal coxa valga values comparatively (96). When there is a problem with positioning and coxa valga is higher than a normal degree; three dimensional CT scan is more preferred than two dimensional CT scan (100). This method has high reliability but it contains high doses of radiation. Chung and colleagues found that the measurement results between CT and physical examination are parallel (101).

2.7.3.4. Ultrasound (US)

The application of ultrasound (US) is easier and cheaper but it is an inadequate method for children who have proximal femoral surgery or femoral osteotomy. Positioning is important for the exactness of the results, that's why FA measurement is difficult in children who have excessive spasticity and contractures with the US method. It is found that the accuracy and validity of the results of this method are changeable (96).

2.7.3.5. Fluoroscopy

In hip reconstruction surgeries, fluoroscopy may be used for the measurement of FA and femoral neck-shaft angle. This method has not additional benefits (96).

2.7.3.6. Magnetic resonance imaging scan (MRI)

MRI method is also used for the measurement of the FA. The anatomical structures of the body (except bone structure) are seen clearly with MRI method contrary to CT scan and it contains lower doses of radiation. If there is no CT equipment and the child has another reason for an MRI scan, this method might be used for the evaluation

of the FA. In clinics; this method is not much preferred because; it is expensive, takes more time and sometimes requires anesthesia (102).

2.7.4. Treatment of increased femoral anteversion

IFA treatment includes non-surgical and surgical methods. The child's age and severity of deformity are important for deciding the treatment method. Because the IFA is considered as a cosmetic problem, complications of surgery and decrease in FA angle with age; non-surgical (conservative) treatments are preferred primarily (103).

In physical therapy program; hip extensor and abductor muscles strengthening, hip ROM, quadriceps and vastus medialis obliquus muscles strengthening exercises ought to be added to the rehabilitation programme. Gluteus maximus muscle has an important effect on decreasing knee valgus and controlling internal rotation. That's why; concentrating on gluteus maximus strengthening exercises is necessary (104). Swimming and cycling exercises may be included in children's exercise programs for lower extremity function and posture. Walking and postural exercises are also essential for children with CP who have IFA. For symmetry of trunk and knee; trunk stability exercises should be included to rehabilitation program. Cerebral palsied children should undertake these exercises in their rehabilitation programs before 8 years old. Because; impulsive regression of IFA may be seen clearly before 8 years old with extensive physiotherapy (103).

Additional orthotic devices such as twister, wedge, orthosis and night splints have been used for supporting and positioning children in walking or standing positions. However; it is stated that these devices do not much affect the normal development of IFA (105).

Although extensive physical therapy, IFA is persistent; surgical corrections can be executed using femoral derotation osteotomies at different levels (103). Osteotomy operations are done between 8 and 10 years old. Before 8 years old; femoral derotation osteotomies are not generally preferred (78). Proximal femur osteotomy is preferred for correction of intoeing gait when the existence of hip dysplasia or subluxation. Distal femur osteotomy is preferred if the hip is stable. Additional operations may be required because of the risk of the recurrence of in-toeing with aging (106).

2.8. Postural Control

Postural control includes sustaining, controlling and orientating body location in space by using balance mechanisms. Postural control has two main functional aims; postural orientation and postural stability. Postural orientation is described as the capability to sustain between the body and environment and between the body parts for a task. For vertical orientation, the body also uses different sensory references. Somatosensory, vestibular and visual systems are required for maintaining vertical orientation (107). Postural stability is the capability of controlling the center of mass (CoM) relative to the base of support (BoS). CoM is explained as a point of the center of total body mass and BoS is explained as a region of the body that has contact with the surface (107,108).

For maintaining postural stability and orientation; the coordination and complex communication of neural and musculoskeletal systems are required. Musculoskeletal systems are muscle features, range of motion (ROM) of joints, flexibility of spine and biomechanical associations between the body parts. Neural systems have three processes that are essential for postural control; motor, sensory and higher-level processes. Motor processes; organization of all muscles of the body in neuromuscular synergies. Sensory processes include integration and organization of somatosensory, visual and vestibular systems. Higher-level processes (cognitive) are vital for mapping sensation to action and confirming anticipatory and adaptive features of postural control (108).

Postural control has two important theories; reflex-hierarchical theory and dynamic or ecological systems theory. According to reflex-hierarchical theory; postural and movement control is dependent on the emergence and integration of reflexes. Dynamic or ecological theory does not deny the presence of reflexes but it also includes other factors which affect postural and movement control. This theory supports that arising the postural control is concerned with the complex communication of neural and musculoskeletal systems. It is called a “postural control system” (109).

Postural control development is faster in the first 18 months of age because the motor abilities also show rapid development in this period. In the normal development of the child, the postural control process goes in a cephalo-caudal direction. It starts with the infant’s head control and then it continues with trunk control and standing postural control stability (110).

2.8.1. Sitting postural control

Postural control is essential for sitting balance. It is an important parameter for the development of upright posture earlier (111). Infants cannot sit independently before 6-7 months old. Transition between lying to sitting position is hard for them because, support area is decreased while sitting. Arising new motor abilities in infants occurs with the connection of motor response synergies and cognitive information. It is found that the muscle synergies are changeable in 4-5 months old in infants (112). When babies start to sit independently, trunk control improves and the babies learn to control the trunk swings and response to balance impairments. This is seen generally in the first 6-8 months (109).

Sitting postural control is the basis for executing goal-directed reaching activities. For self-care of children and the process of cognitive, perception and social features of children, sitting balance is essential. It also helps to increase the orientation between children and the environment (111). Sitting position is easier than standing position because it provides a wide support area. The sitting position lets more forward direction movements than backward direction movements into stability limits. Projection of CoM is localized in posterolaterally of support area in sitting position (113).

2.8.2. Trunk control

Trunk control is a part of postural control which includes trunk stabilization and selective movements. Trunk control is essential for mobility and sitting. Because the CoM is on the trunk and trunk is known as a center of the body; it has a critical function concerning coordination of postural control and balance responses. Trunk controls the balance reactions and allows executing the lower and upper extremity functions within a stable surface area. Trunk stability is important for head and selective movements of extremities and it is necessary for appropriate and correct movements. The trunk is critical for controlling movements, stabilization, maintaining body position, proper sitting, reaching, feeding, walking and other daily life activities (114). Inefficient trunk control affects gaiting of the child. Trunk has a role as controlling in gait, it decreases the vertical displacement of the upper body and it reduces time-related vacillations in movement of the head (115). It is stated that being able to sit independently before 18-24 months old predicts the potential of walking in spastic diplegic CP (116).

Impaired balance stimulations, muscle control abnormality and existence of primitive reflexes lead to abnormal postural responses. Because of these reasons, trunk

control is generally weak in children with CP. It is difficult to control the body position, anticipatory adjustments for functional activities in space, react to unexpected balance disorders in children with CP. Due to muscle power insufficiency, increased agonist-antagonist muscle coactivation, incoordination of joint segments, decreased ROM, inefficient initiation of motor units which is responsible for coordinated postural responses; cannot manage postural control properly in these children (117).

Children with CP have problems with trunk control according to the degree and topography of their motor impairments. These children have difficulties with maintaining static trunk control and it affects sustain their sitting, standing and walking abilities (118). While walking; weakness of trunk control leads to fluctuations in trunk and compensatory movements in lower extremities such as increased hip flexion, an anterior tilt of pelvis. The functional level of children also affects trunk control. According to GMFCS; children with CP who are at level V, cannot maintain the neuromuscular patterns of the trunk automatically. This situation leads to sitting difficulties and these children need adaptive sitting equipment. Cerebral palsied children generally are able to compose postural adjustments; however, children who cannot sit independently, cannot able to do this. When reaching in the sitting position; these children have deficient information for stimulating postural activity from their body. Spastic hemiplegic children have more advantages to use this information than diplegic children. In children with CP; it is found that intuitive adaptations are less and compensatory adaptations are high. In physical therapy modalities, according to the child's functional level; the therapist focused on maintaining trunk control and emerging the postural reactions with goal-directed activities in continuous repetition and motor control principles (119).

2.8.3. The relationship between IFA and trunk control

It is known that IFA leads to asymmetrical posture, anterior pelvic tilt, increased lumbar lordosis and thoracic kyphosis. Children generally sit in compensatory positions such as forward trunk flexion with anterior pelvic tilt. They try to keep their COM in balance while sitting. That is results in muscle shortness, weight-bearing imbalances and balance disorders in while. Forward trunk flexion decreases the cadence and it also affects their gaiting quality.

Because of the IFA, hip internal rotation might be seen generally as a compensatory mechanism in children with CP. Internal rotation of the hip results in

asymmetrical rotation of the pelvis. If it is not controlled, trunk asymmetries increase and then scoliosis may process (120). Like this postural problems affect the trunk control and function of child. Karabıcak and colleagues stated that IFA affects dynamic reaching movements of the trunk due to excessive internal pelvic rotation (7).

2.9. Functional Mobility

Functional mobility is the ability to transfer oneself from one place to another independently and safely. Mobility includes dissimilar types of tasks such as the ability to stand up from a chair or bed, run, walk and navigate through complex locations. For emerging movement; muscle activation, adaptation to the environment and dynamic stabilization are essential with using minimal energy and stressless (121). The most two important components of mobility are; balance and gait (122). Walking difficulties are at the top of all mobility problems. It influences and decreases the quality of life (123).

In cerebral palsied children, the level of gross motor function is a determinant factor for mobility capability. Musculoskeletal problems, spasticity and muscle weakness affect the mobility and functional level of children and it results in increased energy demands for mobility. Hypotonia, ataxia, balance & sensorial problems, mental retardation and epilepsy are also lead to mobility disorders. All these reasons affect the daily living activities, self-care, walking distance and pattern (124). In the rehabilitation period, the primary aim of treatment is to increase mobility capability as much as possible. The exercises should be managed according to both indoor and outdoor ambulation of children and to raise activity participation and socialization (125).

During life of children; protection of ambulation is significant for their skeletal, cardiovascular, gastrointestinal, pulmonary, urinary systems and neuropsychiatry (126). With preventing loss of ambulation, it is expected that the life expectancy of children with CP approach to the general population. It is seen that children generally give up walking when they become young adults. In young adults with CP, 20 % of them can walk, 40 % of them can assist walking and 40 % of them are cannot able to walk. That’s why; most individuals with CP have been using a wheelchair or additional equipment (127). It is important to provide ambulation of children as soon as possible.

2.9.1. The relationship between IFA and mobility

Musculoskeletal disorders which are classified as deformities may affect the ability to walk in CP. IFA is one of the deformities of the lower extremity. It is known that IFA may cause to increase risk of hip subluxations or dislocations, muscle contractures, structural deformities of foot/feet and pelvis asymmetry (128). Therefore; altered weight-bearing, muscle imbalances and misconfiguration of bones may occur. All these lead to walking difficulties and frequent falls. Also, in some cases; because of the progress of painful joint degeneration children with abnormal hip joint structure may stop walking (129). IFA changes the walking biomechanics in the transverse plane primarily and this results in walking modifications. Because of the IFA; internal rotation gaiting and in-toeing might be seen. These situations also affect the child's balance and posture in walking (87).

3. MATERIALS AND METHODS

This study was accomplished with 30 spastic CP children who were chosen from Ribem Consulting Center (Appendix 1.) to explain the relationship between increased femoral anteversion, trunk control, functional mobility. The evaluations were made between June 2020 and June 2021. This study was approved by Yeditepe University Clinical Research Ethics Committee (No: 1234, 04.06.2020) (Appendix 2.).

3.1. Participants

Thirty children aged between 5 and 12 years who are diagnosed with spastic diplegic or left hemiparetic cerebral palsy were included in this study. Children and parents of children were informed about the study and then a signed consent form was taken from families who agree to participate in the study (Appendix 3.). The sample size was approximated based on effect size from previous studies. The required sample size was calculated as 30 for our study with GPower 3.1 program.

The following criteria have 30 spastic CP children who were comprised in this study:

3.1.1. Inclusion criteria

- Children who have spastic diparetic or hemiparetic (left) serebral palsy diagnosis,
- According to the Gross Motor Functional Classification System (GMFCS), children who have level I and II,
- Children who able to stand and walk without adaptive devices,
- Children aged between 5-12 years,
- Children who able to understand and follow the orders,
- According to the Modified Ashworth Scale (MAS), children who have spasticity of the lower extremities are grade (0), (1), (1+).

3.1.2. Exclusion criteria

- Children who had an orthopedic surgery intervention in lower extremities,
- Children who had phenol and/or Botulinum Toxin-A injection have been applied in the last six months.
- Children who have muscle and bone contractures in lower extremities,

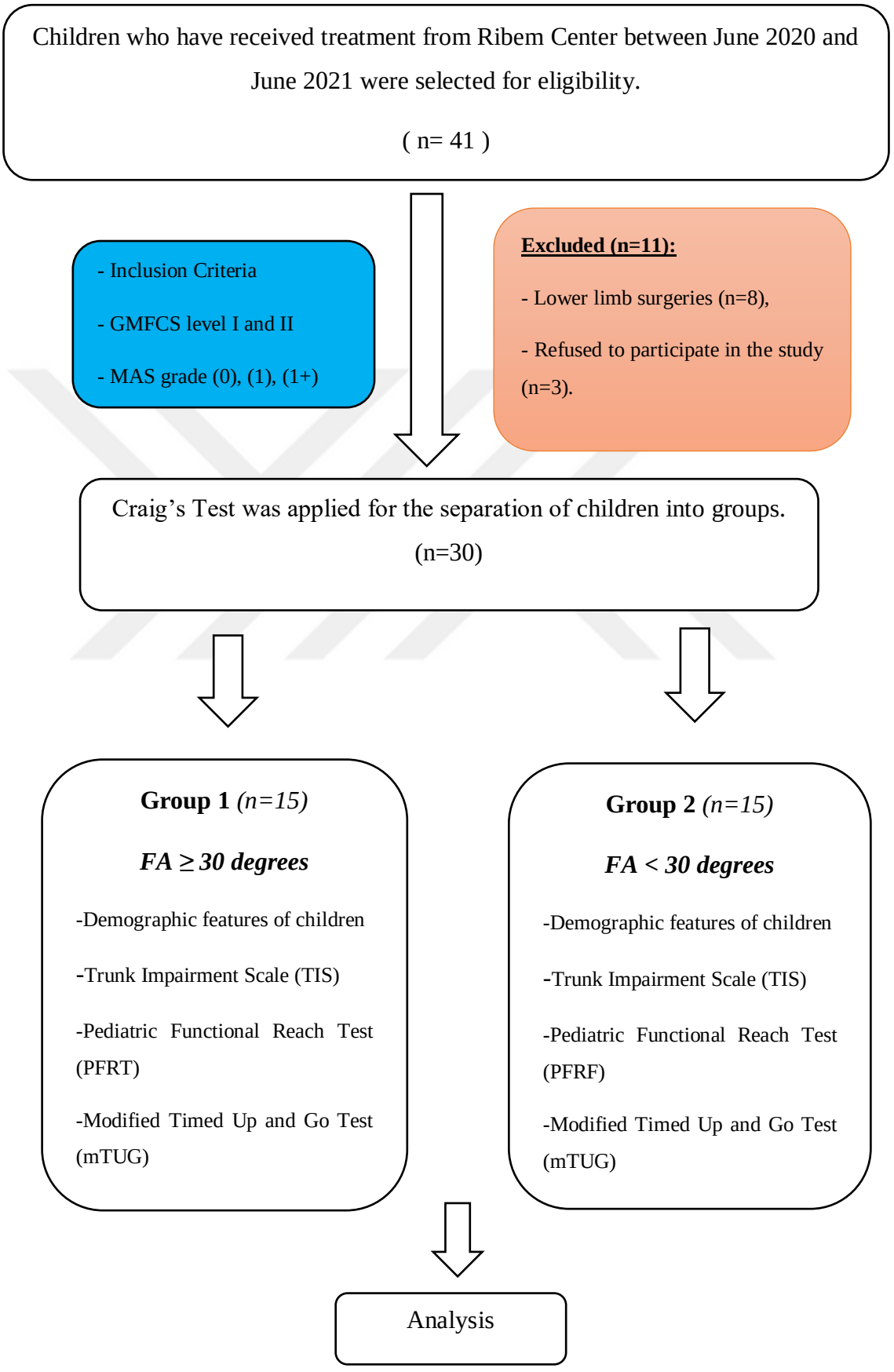
- Children who have visual, auditory problems, systemic other problems, and have epileptic seizures cannot be controlled.

3.1.3. Flow chart: Study Protocol

Primarily, the evaluation of gross motor function was done with Gross Motor Function Classification System (GMFCS) and the muscle spasticity of children was evaluated with Modified Ashworth Scale (MAS). Craig's test was applied to the ambulatory children at levels I and II (according to GMFCS) for measuring the FA angle. Children were divided into two groups according to Craig's test results. Fifteen children with an angle of FA greater than 30 degrees (FA≥30) were determined in group 1 and 15 children with an angle of FA less than 30 degrees (FA<30) were determined in group 2.

The groups are divided into each group as 15 children; The Trunk Impairment Scale (TIS) was applied for trunk control assessment, Pediatric Functional Reach Test (PFRT) and Modified Timed Up and Go Test (mTUG) were used for functional mobility evaluation. All tests were applied without orthosis and three times for the reliability of results.

Table 3.1. Flow Chart of Study



3.2. Methods

3.2.1. Demographic features of children

Demographic features and clinical information of the children were collected with a questionnaire for our study. The questionnaire was applied to children's parents face to face.

- Birth height (cm), weight (kg),
- Current age (years), height (cm), weight (kg),
- Body mass index (BMI),
- Gender (female / male),
- Clinical diagnosis,
- Types of delivery for birth,
- Number of siblings,
- Neurological problems,
- Surgical applications,
- Prenatal-natal-postnatal birth story,
- Participation in a rehabilitation program, it is what is the duration of program (month/year),
- Whether there is an additional supportive device use? It is what is it,
- Drug use was asked (Appendix 4.).

3.2.2. Gross motor function classification system (GMFCS)

GMFCS has been using for over two decades in cerebral palsy rehabilitation which is found by Palisano and colleagues (130). This scale has a five-level and it interprets the gross motor function of children with CP. It defines based on self-initiating movement abilities such as transfers, sitting, and mobility. Distinctions between the levels must be meaningful in daily life and based on functional abilities; the need for hand-held assistive devices (such as canes, crutches, or walkers); and the actual quality of movement but much lesser than function. Functional limitations of children increase from the first level to fifth level. According to ages (0-2, 2-4, 4-6, 6-12, 12-18); limitations between the levels are changed (131) (Appendix 5.).

This classification system consists of five levels;

- Level I – The child able to walks without limitations (indoors and outdoors) and climb stairs (without using hand support). The child can jumping and running but has decreased coordination, speed and balance.
- Level II – The child still can climb stairs with a railing (difficulty with inclines, uneven surfaces or in crowds). They can able to climb and jump at a minimal level.
- Level III – The child able to walks with assistive mobility devices (outdoors, indoors on level surfaces) and can climbs stairs with a railing and has limitations while walking in crowds. The child can use a manual wheelchair independently (but need someone to help on uneven surfaces or long distances).
- Level IV – At this stage, also with assistive devices (such as a manual wheelchair), mobility of the child has limitation severely. Because of the limitations, the child is carried by someone in public or the child able to use a power wheelchair independently.
- Level V – Here, the child has very poor trunk, neck and head control. The child cannot sit and stand independently even with adaptive devices. The mobility of the child is seriously limited and the child is carried in a wheelchair (132).

In our study, GMFCS was used for inclusion criteria of the children. According to the evaluation items of GMFCS inappropriate age ranges; it was applied with making observations of children and asking questions to families.

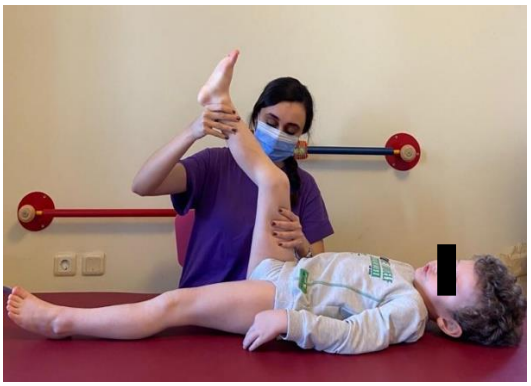
3.2.3. Modified ashworth scale (MAS)

MAS was applied for the evaluation of muscle spasticity. This test is preferred commonly because it does not need any equipment and can be performed easily and quickly in the clinics (133). In this test, muscle spasticity is graded from 0 to 4. Tests resistance to passive movement about the joint with varying degrees of velocity manually. The resistance is scored from 0 to 5. A score of 0 indicates no resistance and 5 shows rigidity (134) (Appendix 6.).

The evaluation items of MAS are;

0. (0) No increase in muscle tone
1. (1) Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension
2. (1+) Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM
3. (2) More marked increase in muscle tone through most of the ROM but affected part(s) easily moved
4. (3) Considerable increase in muscle tone, passive movement difficult
5. (4) Affected part(s) rigid in flexion or extension (135).

In present study; it was also used for inclusion criteria of the children. Hip flexors, hip adductors, knee flexors and plantar flexors of the ankle are tested bilaterally according to the evaluation items of MAS. The test was applied as possible as without clothes (especially lower extremities) on the bed (suitable stiffness). During the test; lower and upper extremities were in extension position and parallel to the body, also head (without pillow) and trunk were in a straight position. For evaluation of muscle spasticity, the joint was moved with constant velocity and passively. The perceived resistance was graded with MAS (Figure 3.1). For the data analysis, left leg assessments were used only.

A)  B) 

C)  D) 

Figure 3.1. Assessment of Spasticity A) Measurement of knee flexors spasticity, B) Measurement of adductors spasticity, C) Measurement of ankle flexors spasticity, D) Measurement of hip flexors spasticity

3.2.4. Craig's test

The FA angle was measured using Craig's test. This test is also called the 'Trochanteric Prominence Angle Test'. Chunk and colleagues found that the validity and reliability of their anteversion measurement with trochanter palpation were very high (136).

In our study; it was used for the separation of children into groups. The FA was evaluated in prone. Hips were in extension position bilaterally with the knee flexed at 90 degrees and the tibial segment inclined laterally to the table. The first therapist stands on the contralateral side for measurement. Then she rotated the hip internally and stoped at the point where the great trochanter was palpated most prominently. The second therapist measured the angle between the long axis of the tibial and vertical segments with a long-arm goniometer (Figure 3.2). This angle was determined as the FA angle. Greater than thirty degrees were considered excessive (7,137). Both two legs were assessed three times

and the average of them was noted. The left leg was used for the data analysis (Appendix 7.).

A)  B) 

Figure 3.2. Measurement of FA Angle; A) Starting position of the test, B) Therapist rotates the hip internally

3.2.5. Trunk impairment scale (TIS)

TIS was used for the evaluation of general trunk stability, trunk movements and postural control. TIS was progressed by Verheyden and colleagues to assess a trunk in individuals affected by stroke (138). Then it is accepted by the studies that this test is appropriate for assessment of cerebral palsied children aged between 5 and 19. TIS evaluates the trunk strength functionally while sitting position. The TIS assesses static and dynamic sitting balance and trunk coordination in a sitting position. It consists of three subscales: static balance, dynamic balance and coordination assessment. Each subscale has between three and 10 items (Appendix 8.).

- The static subscale evaluates the ability to keep a sitting position with feet supported; keeping a sitting position while the legs are passively crossed, and keeping a sitting position when the subject crosses the legs actively.
- The dynamic subscale evaluates the lateral flexion of the trunk and unilateral lifting of the hip.
- To evaluate the coordination of the trunk, the child is asked to rotate the upper or lower part of his or her trunk six times, starting the movements either from the pelvic girdle or from the shoulder girdle.

2-, 3- or 4-point ordinal scale is used for each item. On the static and dynamic sitting balance and coordination subscales, the highest scores that can be reached are 7, 10 and 6 points. The total score for TIS ranges between 0 for a minimal performance to 23 for a perfect performance and higher scores point to better performance (139).

During the test, the children wore footwear, shoes or orthoses or could be shoeless. He/she was allowed to attire comfortable shirts and shorts not so tight clothes**.** A bench (bench's height) which is used in the test allows support for feet. Initially; all positions were demonstrated to children, then to ensure that the children had understood the tasks, directives were prepared and the missions were observed. Each item was performed three times. This test took approximately 10 minutes for every child (Figure 3.3).

A)  **B)**  **C)** 

Figure 3.3. Application of TIS; A) Starting position of test, B) Static sitting balance, C) Dynamic sitting balance

3.2.6. Pediatric functional reach test (PFRT)

PFRT is developed for children with a diagnosis of cerebral palsy, aged 3 to 14 years. PFRT is a simple, valid, and reliable measure that can be used with children. PFRT is a modified version of Functional Reach Test and assesses children's mobility & balance in forward and lateral directions when both standing and sitting (Appendix 9.) (140).

We evaluated functional mobility and balance in the forward direction when standing, we did not evaluate in lateral directions. In a standing position, we asked the child to stand independently (with or without gait aids) for 15 seconds. During the test, the child worn his/her regular footwear (orthoses or shoes) or could be barefoot. Then the

child was instructed to next to the wall, but without touching. The child's arm was positioned with a closed fist that is nearer to the wall at 90 degrees of shoulder flexion (non-hemiplegic side is chosen for children with hemiplegic CP). The therapist recorded the starting position at the 3rd metacarpal head on the yardstick. The therapist asked the child; "Reach as far as you can forward without taking a step." The location of the 3rd metacarpal was recorded. Scores were decided by evaluating the difference between the starting and ending position (reach distances). It is measured in inches generally. Three trials were done and the average of the last two of them was given the child's score (Figure 3.4).

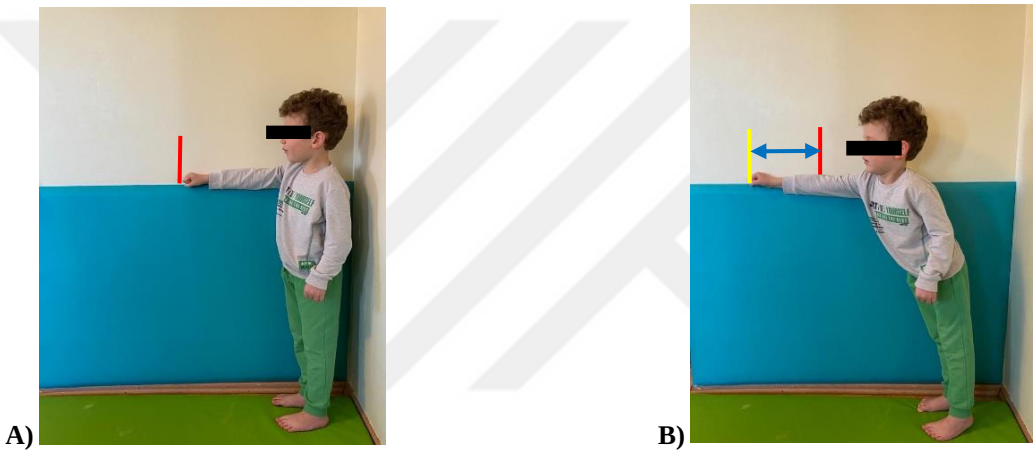


Figure 3.4. Application of PFRT; A) Starting position for forward reaching, B) Ending position for forward reaching

3.2.7. Modified timed up and go test (mTUG)

Modified TUG was used for the assessment of functional mobility in our study. This test measures various components such as walking speed, postural control, functional mobility and balance (141). mTUG test has great validity and reliability in cerebral palsied children aged between 3–12 years (142).

Beginning of the application, we ensure that the child's knee is positioned at 90 degrees of flexion, and feet in a flat position on the floor. We marked off the 3m distance with a red cone.

Performing TUG test;

- Child sat on a stable stool or chair (without armrest support) and asked to stand up,

- Walked 3 meters in a line comfortably to the mark (red cone) on the floor,

- Then returned and sat down (Figure 3.5).

No physical support was provided. The timing was started when the child leaves the seat and stopped as the child's bottom touches the seat. The test was applied three times and the average of trials is recorded (Appendix 10.).

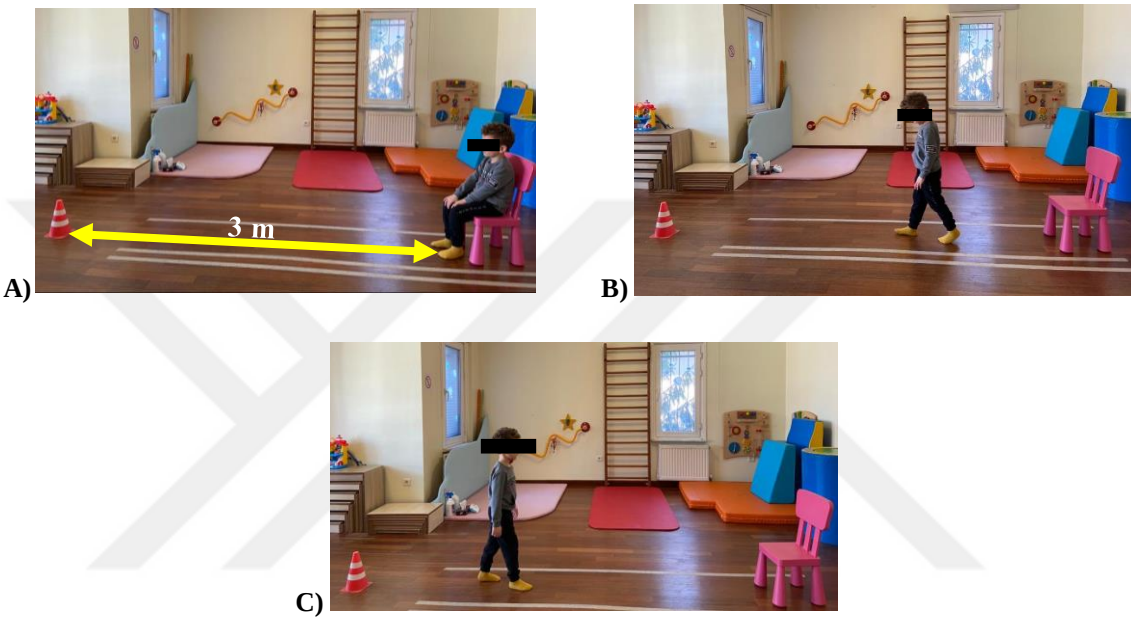


Figure 3.5. Application of mTUG; A) Starting position of the test, B) The child walks 3 meters to the mark on the floor, C) Then he returns and sits down

3.2.8. Data analysis

The SPSS (Statistical Package for Social Sciences) Version 22.0 was used for calculations of data acquired from our study. Quantitative variables were presented by mean and standard deviation. Qualitative variables (categorical variables) were presented by frequency and percentage values. Shapiro-Wilk test was used to examining the normal distribution of the quantitative variables. The Chi-Square test was used for comparing qualitative variables. If data were parametric; the Independent Samples T-test and if data were non-parametric Mann-Whitney U test was used for the analysis. Also, for correlation of data Spearman Correlation Analyses were used. In all statistical analyses; $p< 0.05$ was defined as significance.

4. RESULTS

4.1. Descriptive Characteristics of Participants

This study focused on the evaluation of the femoral anteversion, trunk control and functional mobility of children with spastic CP. In the present study, 30 children were included. As a result of Craig's tests; children were separated into groups as group 1 (FA≥30˚) and group 2 (FA<30˚). Means and standard deviation values of FA angle in the groups and differences between the groups are showed in Table 4.1. There was a statistical difference between the groups in terms of FA angles of children who participated in the study ($p<0.05$).

Table 4.1. Comparison of Femoral Anteversion Angles Between the Groups

	Group 1 FA≥30˚ Mean ± SD	**Group 2 FA<30˚ Mean ± SD**	**U**	**p value**
FA angle (degree)	38.93 ± 1.14	23.27 ± 0.76	U= 0.000	**0.000***

SD: Standard deviation, FA: Femoral anteversion, U: Mann-Whitney U test, *p<0.05

The comparison of femoral anteversion angles according to gender is presented in Table 4.2. There was no statistical difference between the girls and boys among the femoral anteversion angle ($p>0.05$).

Table 4.2. Comparison of Femoral Anteversion Angles According to Gender

	Boy Mean ± SD	**Girl Mean ± SD**	**U**	**p value**
FA angle (degree)	29.63 ± 1.92	33.64 ± 2.79	U= 76.000	0.232

SD: Standard deviation, FA: Femoral anteversion, U: Mann-Whitney U test

The demographic characteristics of children the mean values of age, height, weight and body mass index (BMI) are presented in Table 4.3. According to our findings, there was no statistical difference between the groups in terms of their age, height, weight and BMI ($p>0.05$).

Table 4.3. Demographic Characteristics of Children with Spastic CP

	Group 1 Mean ± SD	Group 2 Mean ± SD	t/U	p value
Age (years)	7.80 ± 0.68	7.87 ± 0.69	U= 112.000	0.983
Weight (kg)	32.13 ± 3.75	31.27 ± 4.17	U= 101.500	0.648
Height (cm)	129.26 ± 18.51	130.93 ± 17.53	t= -0.253	0.802
BMI (kg/m^2)	18.45 ± 4.05	17.32 ± 4.50	t= 0.718	0.478

SD: Standard deviation, BMI: Body mass index, U: Mann-Whitney U test

The distribution of gender, topographical classification and GMFCS levels of children are given in Table 4.4. There was no statistical difference between the groups in terms of their gender and topographical classification ($p>0.05$). According to topographical classification; group 1 consisted of thirteen diplegics and two left hemiplegic children, group 2 consisted of eight diplegic and seven left hemiplegic children. There was a statistically significant difference between the groups in terms of their GMFCS levels ($p<0.05$). In group 1; there were three children at GMFCS I and twelve children at GMFCS II. In group 2; there were twelve children at GMFCS II and three children at GMFCS I.

Table 4.4. Comparison of Gender, Topographical Classification, GMFCS Levels Between the Groups

		Group 1 (n=15) n(%)	Group 2 (n=15) n(%)	X^2	p value
Gender	**Male**	8(53)	11(73)	1.29	0.256
	Female	7(46)	4(26)		
Topographical classification	**Diplegic**	13(86)	8(53)	3.96	0.054
	Hemiplegic	2(13)	7(46)		
GMFCS	**GMFCS I**	3(20)	12(80)	10.80	**0,001***
	GMFCS II	12(80)	3(20)		

SD: Standard deviation, GMFCS: Gross Motor function classification system, X^2: Chi-Square Test, *$p<0.05$

According to the MAS scores; there were statistically significant differences in hip flexors, hip adductors, knee flexors and ankle plantar flexors spasticity between the groups ($p<0.05$) (Table 4.5).

Table 4.5. Comparison of Spasticity of Muscles Between the Groups

MAS	Group 1 Mean ± SD	Group 2 Mean ± SD	U	p value
Hip Flexors Spasticity	2.80 ± 0.10	2.13 ± 0.09	37.500	**0.000***
Hip Adductors Spasticity	2.73 ± 0.11	1.60 ± 0.13	18.000	**0.000***
Knee Flexors Spasticity	2.53 ± 0.13	1.87 ± 0.13	49.500	**0.003***
Ankle Plantar Flexors Spasticity	2.27 ± 0.18	1.60 ± 0.13	55.500	**0.009***

SD: Standard deviation, MAS: Modify Ashworth Scale, U: Mann-Whitney U test, *$p<0.05$

4.2. Comparison of TIS, PFRT and mTUG Findings Between Groups

There were statistically significant differences in all subscales of TIS which are static sitting balance, dynamic sitting balance, coordination and total TIS between the groups ($p<0.05$). It is found that children in group 2 had statistically higher values of subscales and total scores of TIS than group 1 (Table 4.6).

The comparison of PFRT findings between the groups was presented in Table 4.6. There was a statistically significant difference in PFRT scores between the groups ($p<0.05$). Children in group 1 had statistically lower PFRT scores than group 2.

According to the data analysis, a statistically significant difference was found between the groups in mTUG test findings which are presented in Table 4.6 ($p<0.05$). The mTUG results of children with CP have found that group 1 scores were statistically higher than group 2.

Table 4.6. Comparison of TIS, PFRT and mTUG Findings Between the Groups

	Group 1 Mean ± SD	Group 2 Mean ± SD	t/U	p value
TIS Static	5.73 ± 0.46	6.87 ± 0.13	U= 73.500	**0.029***
TIS Dynamic	3.73 ± 0.59	8.13 ± 0.52	U= 16.500	**0.000***
TIS Coordination	1.33 ± 0.21	2.80 ± 0.38	U= 48.000	**0.004***
TIS Total	10.80 ± 4.32	17.80 ± 2.98	t= -5.158	**0.000***
PFRT (cm)	15.42 ± 3.64	22.98 ± 2.84	t= -6.334	**0.000***
mTUG (sn)	17.90 ± 1.96	10.04 ± 0.81	U= 29.500	**0.001***

SD: Standard deviation, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, U: Mann-Whitney U test, *p<0.05

4.3. Comparison of FA angle, TIS, PFRT and mTUG Scores According to CP Types

When the statistical data are analyzed, between the CP types; there were no statistical differences in the FA angles, TIS, PFRT and mTUG scores (Table 4.7) (p>0.05). However; hemiplegic children had statistically higher results than diplegic children in all subscales of TIS and total TIS, PFRT findings and had lower results in mTUG test. The mean FA angle of hemiplegic children was lower than diplegic children.

Table 4.7. Comparison of FA angle, TIS, PFRT and mTUG Scores According to CP Types

	Diplegic Mean ± SD	Hemiplegic Mean ± SD	t/U	p value
FA Angle	32.43 ± 2.01	28.00 ± 2.38	U= 71.500	0.294
TIS Static	6.00 ± 0.35	6.99 ± 0.30	U= 63.000	0.054
TIS Dynamic	5.62 ± 0.73	6.67 ± 0.79	U= 78.000	0.450
TIS Coordination	1.81 ± 0.26	2.67 ± 0.55	U= 69.000	0.215
TIS Total	13.43 ± 5.39	16.33 ± 3.87	t= -1.663	0.111
PFRT	18.58 ± 5.27	20.63 ± 4.25	t= -1.123	0.276
mTUG	15.20 ± 1.67	11.11 ± 1.32	U= 64.000	0.167

SD: Standard deviation, FA: Femoral anteversion, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, U: Mann-Whitney U test

4.4. Comparison of FA angle, TIS, PFRT and mTUG Scores According to GMFCS

According to our analysis, statistically significant differences were found in terms of FA angles, TIS, PFRT and mTUG scores of children between the GMFCS levels ($p<0.05$). Children which are at GMFCS I had statistically lower FA angle, lower scores in mTUG test and higher scores in all subscales of TIS, total TIS and PFRT than children who are at GMFCS II as presented in Table 4.8.

Table 4.8. Comparison of FA Angles, TIS, PFRT and mTUG Scores According to GMFCS

	GMFCS I Mean ± SD	GMFCS II Mean ± SD	t/U	p value
FA Angle	25.60 ± 1.46	36.60 ± 2.04	U=36.000	**0.001***
TIS Static	7.00 ± 0.00	5.60 ± 0.45	U=60.000	**0.003***
TIS Dynamic	7.60 ± 0.58	4.27 ± 0.76	U=42.000	**0.003***
TIS Coordination	2.73 ± 0.39	1.40 ± 0.21	U=58.500	**0.016***
TIS Total	17.33 ± 3.39	11.27 ± 4.75	t=4.020	**0.000***
PFRT	21.87 ± 3.81	16.52 ± 4.70	t= 3.420	**0.002***
mTUG	9.68 ± 0.67	18.27 ± 1.90	U=19.500	**0.000***

SD: Standard deviation, FA: Femoral anteversion, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, U: Mann-Whitney U test, *p<0.05

4.5. Relationship Between The FA angle, TIS, PFRT and mTUG Scores According To The Groups

The relationship between the FA angle, TIS, PFRT, mTUG findings in group 1 was presented in Table 4.9. A strong negative correlation was found between the FA angle and TIS coordination (r: -0.648 p<0.00), a moderate negative correlation was found between FA angle and total TIS (r: -0.443 p<0.04) scores. There were strong positive correlations between the TIS static, TIS coordination, TIS total and PFRT. Between the PFRT and mTUG findings; a moderate negative correlation was found (r: -0.513 p<0.02). Also, there was a moderate negative correlation between the mTUG and TIS static (r: -0.539 p<0.01), total TIS (r: -0.467 p<0.04).

Table 4.9. Relationship Between the FA Angle, TIS, PFRT and mTUG Scores According to Group 1

		FA Angle r p	TIS Static r p	TIS Dynamic r p	TIS Coordination r p	TIS Total r p	PFRT r p	mTUG r p
GROUP 1 FA ≥ 30°	**FA Angle**		-0.434 0.053	-0.336 0.110	- 0.648 **0.004****	-0.443 **0.049***	-0.328 0.117	0.242 0.192
	TIS Static			0.535 **0.020***	0.685 **0.002****	0.771 **0.000****	0.751 **0.001****	-0.539 **0.019***
	TIS Dynamic				0.731 **0.001****	0.935 **0.000****	0.407 0.066	-0.367 0.089
	TIS Coordination					0.854 **0.000****	0.622 **0.007****	-0.413 0.063
	TIS Total						0.619 **0.007****	-0.467 **0.040***
	PFRT							-0.513 **0.025***
	mTUG							

SD: Standard deviation, FA: Femoral anteversion, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, r= correlation coefficient,*p<0.05, **p<0.01

In Group 2; between the FA angle and TIS, PFRT, mTUG scores statistically significant correlations were not found (p>0.05). There were positive correlations between the subscales of TIS. It was found that there was a moderate positive correlation between TIS coordination and PFRT scores (r: 0.553 p<0.01). Between the total TIS and mTUG scores, a moderate negative correlation was found as presented in Table 4.10 (r: -0.480 p<0.03).

Table 4.10. Relationship Between the FA Angle, TIS, PFRT and mTUG Scores According to Group 2

		FA Angle r p	TIS Static r p	TIS Dynamic r p	TIS Coordination r p	TIS Total r p	PFRT r p	mTUG r p
GROUP 2 FA < 30°	**FA Angle**		-0.159 0.285	0.105 0.355	0.130 0.323	0.056 0.422	0.128 0.324	-0.103 0.357
	TIS Static			-0.317 0.125	0.131 0.321	0.062 0.431	-0.062 0.413	-0.433 0.053
	TIS Dynamic				0.466 **0.040***	0.825 **0.000****	0.247 0.187	-0.220 0.216
	TIS Coordination					0.821 **0.000****	0.553 **0.016***	-0.284 0.153
	TIS Total						0.396 0.072	-0.480 **0.035***
	PFRT							-0.029 0.460
	mTUG							

SD: Standard deviation, FA: Femoral anteversion, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, r= correlation coefficient,*p<0.05, **p<0.01

For all children who participated in to present study; between the FA angle and TIS, PFRT, mTUG findings statistically significant correlations were found as presented in Table 4.11. There was a moderate positive correlation between the FA angle and mTUG scores (r: 0.587 p<0.01). There were moderate negative correlations between the FA angle, TIS static (r: -0.501 p<0.01) and TIS coordination (r: -0.564 p<0.01). There were strong negative correlations between FA, TIS dynamic (r: -0.703 p<0.01), total TIS (r: -0.725 p<0.01) and PFRT scores (r: -0.700 p<0.01).

Table 4.11. Relationship Between the FA Angle, TIS, PFRT and mTUG Scores According to the Groups

		TIS Static r p	TIS Dynamic r p	TIS Coordination r p	TIS Total r p	PFRT r p	mTUG r p
Group 1	**FA Angle**	-0.434 0.053	-0.336 0.110	-0.648 **0.004****	-0.443 **0.049***	-0.328 0.117	0.242 0.192
Group 2	**FA Angle**	-0.159 0.285	0.105 0.355	0.130 0.323	0.056 0.422	0.128 0.324	-0.103 0.357
All groups	**FA Angle**	-0.501 **0.002****	-0.703 **0.000****	-0.564 **0.001****	-0.725 **0.000****	-0.700 **0.000****	0.587 **0.001****

SD: Standard deviation, FA: Femoral anteversion, TIS: Trunk Impairment Scale, PFRT: Pediatric Functional Reach Test, mTUG: Modified Timed Up and Go Test, r= correlation coefficient,*p<0.05, **p<0.01

5. DISCUSSION

The purpose of this study was to investigate the effect of IFA on trunk control and functional mobility in children with spastic CP. For this purpose; we evaluated the FA with Craig's Test, trunk control and functional mobility of children.

In the present study; there were no statistical differences between the groups in terms of the means of age, weight, height, BMI, gender variables. According to our results; it was found that girls have a higher FA angle than boys. In literature some studies supported our results; it was suggested that FA is higher in the female population than the male population ranging from 2 and 8 degrees (143,144).

To the topographical classification of children with CP as hemiplegia and diplegia; there were no significant differences between the groups in this study. Additionally; it can be stated that hemiplegic children have higher FA than diplegic children. When the studies related to this subject were examined; different opinions were found. Bobroff et al. examined the femoral anteversion children with CP and it was stated that there was no difference among the topographical classifications in hemiplegic, diplegic and quadriplegic children (145). On the other hand; Rethlefsen and colleagues evaluated internal pelvic rotation, internal hip rotation (FA described as IHR in that study) and foot progress angle in children with CP and they stated that IFA is more prevalent in children with bilateral involvement (quadriplegia and diplegia) than the children with hemiplegia (146).

There was a significant difference between the groups in terms of their GMFCS levels. According to our findings; FA angle has increased with GMFCS level and IFA has a relationship with the ambulatory level of children. In previous studies; the effect of gross motor function level on FA has been assessed in children with CP (147,148,149). They have been examined 147 children with CP and it was found that the non-ambulatory children have significantly lower FA and higher NSA than ambulatory children (147). However; the authors cannot able to offer any description for lower anteversion angle for non-ambulatory children. Robin and colleagues have assessed femoral anteversion and femoral neck-shaft angle in 292 children with CP and it has been stated that the mean FA angle and NSA has increased at gross motor function classification system from level I to level V. This had explained by the lack of early remodeling of the femur because of

delayed walking independently and abnormalities in weight-bearing in children with CP (148). Also; Fujiwara et al. studied with 237 hips of children with CP and stated that lack of ambulation is closely related to hip abnormalities such as increased neck-shaft angle and increased femoral anteversion. (149).

In the present study; there were significant differences between the groups according to their spasticity hip flexors, hip adductors, knee flexors and ankle plantar flexors. Children with IFA, have more increased spasticity of the hip, knee, ankle flexors and hip adductors in lower extremities than children who have lower FA.

Spasticity of muscles, joint contractures and functional impairments have been proposed as related factors with IFA. In literature; there are different opinions about the relationship between muscle spasticity and increased femoral anteversion. Cho et al. evaluated the hips of 57 children with CP who had both plain radiography of the hip and three-dimensional CT and they concluded that there does not correlate with femoral anteversion angle, hip adductors and hamstring muscle spasticity (150). However; Gage and colleagues stated that femoral anteversion has increased in children with CP because of spasticity of hip flexors, hip adductors and medial hamstrings. They explained that spasticity of hip flexors: especially iliopsoas muscle, prevents the derotation of the head of the femur. Also; spasticity of hip adductor and medial hamstring muscles creating torsional stress on their antagonists cause anatomic deformities on the bones (151). Tiftik et al. examined the femoral anteversion of 22 children with spastic CP with BT and they found that FA angle was significantly higher in children who have adductor muscle spasticity (152). In literature; no study explained the relationship between the ankle plantar flexor spasticity and IFA directly. However; a previous study described the effect of plantar flexor overactivity (equinus) on internal hip rotation which causes internal rotation gaiting in hemiplegic children. They concluded that the correction of plantar flexor muscles function is important for internal rotation gaiting (153). It is known that children with CP who have IFA generally walk with internal rotation (internal rotation gaiting) and which is explained as a dynamic compensatory strategy for balance (87). That's why; ankle plantar flexor spasticity may be considered with IFA. Explaining the relationship between muscle spasticity and increased femoral anteversion was not the main aim of the present study, but our thing is that the results are important for literature. Spasticity of hip flexors, hip adductors, knee flexors and IFA reciprocally affects each

other and also spasticity of ankle plantar flexors may be contributed to the development of IFA.

Trunk control is essential for controlling movements, stabilization, maintaining body position, proper sitting, reaching, feeding, walking and other daily life activities (114). Children with CP have inefficient trunk control than their healthy peers. The present study is the first study about comparing trunk control between children with spastic CP which have IFA and lower FA. Significant differences were found between the groups in terms of subscales of TIS and TIS total scores of children. According to trunk control assessments; children who have lower FA have better trunk control than children with IFA.

Static sitting balance, dynamic sitting balance and trunk coordination were evaluated with TIS in the present study. For all children who are included in this study; there was a significant correlation between all subscales of TIS and FA angles. Additionally; in children with IFA; it was found that while IFA has no correlation with a static and dynamic sitting balance of the trunk but it has a significant correlation with trunk coordination. In the TIS test; for the assessment of the coordination of the trunk, the child was asked to rotate six times his shoulder and his pelvis respectively. This part of the test focused on the symmetry of the coordination of lower trunk movement. The previous study stated that excessive FA may be compensated by internal hip rotation and increases the length of the gluteus medius lever arm for positioned the neck of the femur into the frontal plane. This compensatory mechanism is related to internal hip rotation and internal pelvic rotation. If hip internal rotation is too excessive; pelvic externally rotated to position, the neck of the femur inwardly into a frontal plane. If the pelvic rotation is too excessive; the hip is internally rotated to position, the neck of the femur inwardly (154). This situation explains the relationship between excessive internal hip rotation and internal pelvic rotation. According to our findings; we thought that IFA has a correlation with trunk coordination because the coordination of trunk movements requires pelvic girdle muscle activation.

In literature; there were a few studies related to trunk and IFA (7,120). Karabıcak and colleagues have been evaluated trunk control with Trunk Control Measurement Scale (TCMS) of 20 children with spastic CP with IFA; they did not found any correlation between static sitting balance and selective motor control of trunk movements; however;

they have shown that dynamic reaching movements of trunk are related with IFA because of excessive internal pelvic rotation (7). This study's findings may also support our results.

Forward positioning of trunk and having forward trunk posture leads to muscle shortness, disruption of biomechanical load distribution and balance problems. Akalan and colleagues studied with 137 healthy children and supported that children with IFA have a greater risk of forward positioning of the trunk than children with normal FA and also they have forward trunk lean when standing in posture analysis. Also, forward flexion posture leads to a decrease in walking cadence (120). These findings may be get considered so that IFA affects the trunk control, balance and even gait features.

In a present study; trunk control was also compared according to GMFCS levels and topographical classification of children with CP. The topographical classification of children with spastic CP as hemiplegia and diplegia; there was no significant difference between the groups in terms of all subscales of TIS. However; it can be concluded that hemiplegic children have better trunk control than diplegic children in this study.

In literature; previous studies have focused on the relationship between trunk control and different CP topographies (140,155,156). Ozal et al. evaluated trunk control, functional mobility and balance of children. They stated that hemiplegic children have better trunk control than diplegic children (140). Sımsek et al. studied with 62 children with CP for investigating the effect of balance and trunk control on upper extremity functions. Diplegic children had statistically lower scores than hemiplegic children in TCMS in that study (155). Heryman and colleagues focused on identifying trunk deficits in children with CP and assessed the trunk control with TCMS in hundred children with CP and the statistical difference did not find between groups. However they stated that children with hemiplegia got the highest scores, it is followed by children with diplegia and children with quadriplegia got the lowest scores (156). These findings also supported our results. The topography of disease may be considered closely with trunk control in cerebral palsied children.

In a present study; according to GMFCS levels of children as level I and II; a significant difference was found between the groups in terms of trunk control. Children at GMFCS level I showed better performance on TIS than children at GMFCS II. It can

be stated that TIS scores significantly decreased with increasing the level of GMFCS to our findings.

Heryman et al. studied with hundred children with spastic CP at GMFCS levels I, II, III and IV; it has been concluded that TCMS scores decreased with increasing the severity of motor impairment (156). Panibatla and colleagues evaluated the relationship between trunk control and balance in 24 children with spastic CP and found that from GMFCS Level I to III there was a decrease in total and subscale scores of TCMS which showed that children at the level I have better trunk function (157). The literature supports our findings and it can be stated trunk control is affected by the severity of motor impairment in children with CP.

Children with spastic diplegia CP have troubles with walking such as increased energy expenditure, reduced speed and decreased functional capacity to their healthy peers (158). They can generally walk independently but with anterior pelvic tilt, knee flexion, internal hip rotation and equine foot. These are all lead to gait abnormalities, balance and coordination problems (11). Additionally, a recent study also reported that IFA leads to lower extremity deformities and abnormal gaiting (85). In the present study; mTUG and PRF were used for the assessment of functional mobility and balance. There were significant differences between the groups in terms of PFRT and mTUG scores. The children with IFA have lower scores in PFRT and higher scores in the mTUG test. This explains that the children with IFA have impaired functional mobility and balance. In literature, there was no study that includes comparing functional mobility of children with CP between higher FA and lower FA angle. That's why; we thought that the findings of the present study contributed to the literature.

This study also focused on the relation between the FA and functional mobility. For all children which participated in our study; significant correlations were found between FA angle, mTUG, PFRT scores. However; for the children with IFA there was no significant correlation between their FA angle, mTUG, PFRT scores.

Previous studies also focused on the relationship between functional mobility, balance and IFA (7,93,159) . Karabıcak et al. studied 20 children with spastic CP for evaluation of the effect of postural control and balance on femoral anteversion, they stated that there was no correlation between Pediatric Balance Scale (PBS) scores and IFA (7). Leblebici and colleagues studied with 65 children with IFA and 32 healthy peers as

control; it is found that children with IFA walk more slowly, fall more frequently than the control group. It was supported that IFA leads to functional problems such as frequent falls and affects the children's walking distance, fatigue onset negatively (93). Our findings of the mTUG test also support the study of Leblebici and colleagues because children with IFA walked in more time in the present study. In another study; Zaky et al. included 40 spastic diplegic CP children for investigating the relationship between FA angle, balance (was evaluated with PBS) and knee flexion angle. They found that IFA has a negative correlation with balance and a positive correlation with knee flexion angle (159). Our results are that children with IFA have lesser PFRT scores may be considered with the study of Zaky et al. because of the impaired balance of children with IFA. It can be stated that the children with IFA have functional mobility and balance problems.

In the present study; functional mobility was also compared according to GMFCS levels and topographical classification of children with CP. To the topographical classification of children with spastic CP as hemiplegia and diplegia; there was no significant difference between groups in terms of PFRT and the mTUG findings. However; according to our findings, hemiplegic children have better scores in PFRT and mTUG tests than diplegic children.

In a previous study; trunk control, functional mobility and balance were assessed in 19 children with spastic CP and stated that hemiplegic children showed better performance in PBS, TUG and Timed Up and Down Stairs (TUDS) tests (140). It was explained with diplegic children have more limitations in postural control and balance leads to limitations in mobility abilities. Simsek et al. had aimed to examine the relationship between trunk control and balance in 62 children with hemiplegic and diplegic CP and stated that hemiplegic children have higher points in PBS than diplegic children (155). Additionally; Kembhavi and colleagues also showed that hemiplegic children have better balance control than diplegic children (160). Simply; it can be said that children's mobility and balance are affected by the topography of disease.

In the study, according to GMFCS levels; there were significant differences in PFRT and mTUG scores between the level I and II. The children in GMFCS I reached further without balance disturbance in PFRT and they walked shorter time than children in GMFCS II in the present study.

In the previous some studies evaluated the relationship between GMFCS level and functional mobility & balance of children with CP (161,162). Gan and colleagues studied with 30 children with CP for examined the validity and reliability of PRT, TUG and Berg Balance Test (BBS). They found that scores in PRT and BBS are decreased, the scores in the TUG test are increased from GMFCS level I to III (161). According to another research by Zaino and colleagues, the mean distances in FRT in 20 CP children at GMFCS level I and II were 29 cm and 22.8 cm respectively, the mean times also measured with TUG for children at GMFCS level I and II were 6.2 and 8.2 seconds, respectively (162). In conclusion; according to our findings which supported the literature; the mobility and balance performance of cerebral palsied children decreased with increasing severity of motor impairment.

In the present study; the relationship between trunk control and functional mobility was also assessed. The significant positive correlations of TIS static, TIS coordination and TIS total were found with PFRT, and TIS static and TIS total scores were also negatively correlated with mTUG test findings for children with IFA. Additionally; PFRT was correlated with TIS coordination positively and mTUG was correlated with TIS total negatively for children who have lower FA. Our findings supported that trunk control is necessary for balance and functional abilities in cerebral palsied children. Panibatla and colleagues examined the relationship between trunk control and balance in 24 children with CP; there was a high positive correlation found between TCMS and PBS findings. They concluded that target interventions of the trunk may increase the performance on PBS and gross motor function (157). Additionally; Verheyden et al. stated that trunk control findings have a close relationship between balance, gaiting and functional abilities, and trunk control has an important role in daily living activities (163).

Limitations of this study: according to topographical classification and GMFCS levels; the distribution of children in our groups was not equal. Group 1 had more children which are diplegic and at GMFCS level 2 than group 2. More children could be included into study. Also; present study included only spastic hemiplegic and diplegic types of CP. Future studies may conduct with different types of CP and larger study groups.

This study was conducted to understand the effect of IFA on trunk control and functional mobility clearly. No other study was found in the literature; which separated

the children with spastic CP according to FA angles as higher & lower and assessed to compare trunk control and functional mobility of them. The study is the first study on this subject. It can be stated that IFA effects trunk control and functional mobility in children with spastic CP. Also, IFA has related to trunk coordination may be a consequence of pelvic rotation movements. Understanding IFA by therapists and selecting goal-oriented exercises for correcting IFA must be necessary for trunk control and functional abilities of children with CP.

Clinical Tips: The following should be considered in the physical therapy program for the treatment of IFA; hip ROM exercises, strengthening of abductor, extensor and external rotator muscles of the hip (especially Gluteus Maximus and Medius), knee extensor muscles strengthening exercises (Quadriceps - V.Medialis Obliquus), trunk stability exercises (such as 4 kneeling and bridge exercises), trunk extensor muscles strengthening exercises, walking exercises (side walking and walking with toes forward), static and dynamic balance exercises, weight-bearing activities to both sides and also postural exercises like swimming and cycling.

6. CONCLUSION

- The children with IFA; have more impaired trunk control and functional movement ability than the children who have lower FA.
- IFA has a strong relationship with trunk coordination.
- The FA angle is related to trunk control and functional mobility in children with spastic CP.
- The relationship between the IFA and functional mobility was not found in this study.
- A significant relationship was also found between trunk control and functional mobility for the children with IFA.

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8. APPENDICES

8.1. Appendix 1. Center Approval

20/02/2020

Konu: Klinik araştırma için
veri kullanım izni hk.

Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurul Başkanlığına

Enstitünüzün Fizyoterapi ve Rehabilitasyon Yüksek Lisans Programı öğrencisi fizyoterapist Hande Özlü tarafından akademik amaçlı olarak yapılması planlanan "***Spastik Serebral Palsi'li Çocuklarda Femoral Anteversiyonun Gövde Kontrolü ve Fonksiyonel Mobilite Üzerine Etkisi***" isimli araştırmayı 01.03.2020 - 30.12.2020 tarihleri arasında ***Ribem Riskli Bebek Danışma Merkezi***'nde yapması uygun bulunmuştur.

Bilgilerinize arz ederim.

Saygılarımla

Kurum Müdürü
Ali İhsan BİLİR

8.2. Appendix 2. Ethical Committee Approval

T.C. YEDİTEPE ÜNİVERSİTESİ

Sayı : 37068608-6100-15- 1897 **04/06/2020**
Konu: Klinik Araştırmalar
Etik Kurul Başvurusu hk.

İlgili Makama (Hande Özlü)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü Dr. Öğr. Üyesi Çiğdem Yazıcı Mutlu'nun sorumlu araştırmacı olduğu **''Spastik Serebral Palsili Çocuklarda Femoral Anteversiyonun Gövde Kontrolü ve Fonksiyonel Mobilite Üzerine Etkisi''** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası **(1883)** kayıtlı Numaralı KAEK Başvuru Dosyası , Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **03.06.2020** tarihli toplantıda incelenmiştir.

Sağlık Bakanlığı'nın Covid-19 pandemisi nedeniyle uygulamakta olduğu ''toplumsal izolasyon veya karantina'' uygulamalarının bitiminde başlanması şartıyla;

Kurul tarafından yapılan inceleme sonucu,yukarıdaki isim belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir. **(KAEK Karar No:1234)**

Prof. Dr. Turgay Çelik

Yeditepe Üniversitesi
Klinik Araştırmalar Etik Kurul Başkanı

Yeditepe Üniversitesi 26 Ağustos Yerleşimi, İnönü Mahallesi Kayışdağı Caddesi 34755 Ataşehir / İstanbul
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8.3. Appendix 3. Informed Consent Form

Araştırmanın Adı: "Spastik Serebral Palsili Çocuklarda Femoral Anteversiyonun Gövde Kontrolü ve Fonksiyonel Mobilite Uzerine Etkisi "

Sayın Anne / Baba,

Yukarıda adı yazılı araştırmaya katılmak üzere çocuğunuz adına davet edilmiş bulunmaktasınız. Bu araştırmada çocuğunuzun yer almasını kabul etmeden önce, araştırmanın ne amaçla yapılmak istendiğini anlamanız ve bu bilgilendirme sonucunda kararınızı vermeniz gerekmektedir. Aşağıdaki bilgileri lütfen dikkatlice okuyunuz, sorularınız olursa sorunuz ve açık yanıtlar isteyiniz.

Bu lisansüstü tez çalışmasında Serebral palsi tanısı almış çocuklarda femoral anteversiyonun gövde kontrolü ve fonksiyonel mobilite üzerine etkisinin incelenmesi hedeflenmektedir. Bu çalışma ile pediatrik rehabilitasyon alanında uzmanlaşan kişilere; femoral anteversiyon açısı fazla olan çocukların gövde kontrolü ve fonksiyonelliklerinin nasıl etkilendiğini göstererek, rehabilitasyon sırasında tedavi programına yenilik katmayı amaçlamaktayız. Araştırma için danışmanlık hizmeti almakta olduğunuz Ribem Riskli Bebek Danışma Merkezi'nden izin alınmıştır. Araştırmaya sizin çocuğunuz dışınızda 29 çocuk daha katılacaktır. Çocuğunuzdan bu çalışmada bir takım değerlendirme testlerine katılması istenilecektir. Çalışma ve deney gruplarının oluşturulabilmesi için Craig testi ile femoral anteversiyon açıları ölçülecektir. Sonrasında her iki gruptaki çocuklara da kaba motor fonksiyon seviyelerinin değerlendirilebilmesi için Kaba Motor Fonksiyon Sınıflandırma Sistem testi, kas tonusu ölçümleri için Modifiye Ashworth Skalası uygulanacaktır. Gövde kontrolü değerlendirmesi için Gövde Etkilim Olçeği, fonksiyonel mobilite ve denge değerlendirmesi için Zamanlı Kalk Yürü Testi ve Pediatrik Fonksiyonel Uzanma Testleri uygulanacaktır. Tüm değerlendirmeler ön test olarak yapılacaktır, ilerleyen bir zaman diliminde tekrarı olmayacaktır. Bunun çocuğunuza hiçbir zararı olmayacaktır. Çalışmaya katılımı onaylamakla parasal yük altına girmeyeceksiniz ve size de herhangi bir ödeme yapılmayacaktır.

Çocuğunuzun bu araştırmaya katılıp katılmamasını onaylamakta tümüyle özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Çocuğunuzun araştırmaya katılmasını istemezseniz burada size verilen hizmet olumlu veya olumsuz şekilde etkilenmeyecektir. Gerekli gördüğü takdirde araştırmanın herhangi bir kısmında katılımcı çocuklar araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir gizlilik kurallarına uyulmak kaydıyla sunulabilir ve yayınlanabilir.

Ulaşım ve sarf malzeme ücretleri araştırmacı tarafından karşılanacaktır. Bu formlardan elde edilecek bilgiler tamamen araştırma amacı ile kullanılacaktır. Araştırmada yapılan değerlendirmelerin sonuçları yalnızca araştırma kapsamındaki çalışmalarda ve sadece sorumlu araştırmacı tarafından kullanılacaktır. Çocuğunuzun kişisel bilgileri herhangi bir amaçla, kurum yöneticileri veya üçüncü kişilerle kesinlikle paylaşılmayacaktır. Bu çalışma için gönüllü katılımcıdan, özel ya da devlete ait sağlık ödeneklerinden hiçbir şekilde ücret talep edilmeyecektir.
Katılımınız için teşekkür ederiz

Danışman Oğretim Uyesi: Dr. Çiğdem YAZICI MUTLU
Araştırmacı: Fzt. Hande OZLU

"**Spastik Serebral Palsili Çocuklarda Femoral Anteversiyonun Gövde Kontrolü ve Fonksiyonel Mobilite Uzerine Etkisi**" adlı araştırmada katılımcıya/gönüllüye verilmesi gereken bilgileri okudum ve çocuğumun katılması istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerimize düşen sorumlulukları tamamen anladım. **Çalışma hakkında yazılı ve sözlü açıklamalar araştırmacı tarafından yapıldı.** Bu çalışmayı istediğimiz zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimizi ve bıraktığımız takdirde herhangi bir olumsuzluk ile karşılaşmayacağımızı anladım.

Bu koşullarda söz konusu araştırmaya çocuğumun katılmasını, hiçbir baskı ve zorlama olmaksızın kabul ediyorum.

Gönüllünün Velisi Adı /Soyadı /Imzası /Tarih

Açıklama Yapan Kişinin Adı /Soyadı /Imzası /Tarih

8.4. Appendix 4. Demographic Features Form

Date:…/…./…..

Child's: ***Parent's:***

- Name - Surname: Name - Surname:……..
- Date of birth: Telefon Number:……
- Age:
- Gender:
- Type of delivery: Cesarean ( ) / Normal ( )
- Birth Height:……cm./ Current Height:……cm
- Birth Weight:……kg / Current Weight:……kg
- BMI:
- Clinical Type/ Diagnosis:
- Siblings:
- Clinical History:
- Surgical Interventions: Yes( ) / No( ) If yes; specify: ……
- Drug Used: Yes( ) / No( ) If yes, specify: ……....
- Assistive Device Used: Yes ( ) / No( ) If yes, specify:…….
- Does he/she continue the rehabilitation?: Yes ( ) / No ( )
  If yes, for how long:…..

8.5. Appendix 5. Gross Motor Function Classification System (GMFCS)

BETWEEN 4TH AND 6TH BIRTHDAY

LEVEL I: Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.

LEVEL II: Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for a hand-held mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.

LEVEL III: Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with a hand-held mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when traveling for long distances or outdoors on uneven terrain.

LEVEL IV: Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a powered wheelchair.

LEVEL V: Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

BETWEEN 6TH AND 12TH BIRTHDAY

Level I: Children walk at home, school, outdoors, and in the community. Children are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Children perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Children may participate in physical activities and sports depending on personal choices and environmental factors.

Level II: Children walk in most settings. Children may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas, confined spaces or when carrying objects. Children walk up and down stairs holding onto a railing or with physical assistance if there is no railing. Outdoors and in the community, children may walk with physical assistance, a hand-held mobility device, or use wheeled mobility when traveling long distances. Children have at best only minimal ability to perform gross motor skills such as running and jumping. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

Level III: Children walk using a hand-held mobility device in most indoor settings. When seated, children may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance of a person or support surface. When traveling long distances, children use some form of wheeled mobility. Children may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

Level IV: Children use methods of mobility that require physical assistance or powered mobility in most settings. Children require adaptive seating for trunk and pelvic control and physical assistance for most transfers. At home, children use floor mobility (roll, creep, or crawl), walk short distances with physical assistance, or use powered mobility. When positioned, children may use a body support walker at home or school. At school, outdoors, and in the community, children are transported in a manual wheelchair or use powered mobility. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

Level V: Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and and/or mobility but limitations are not fully compensated by equipment. Transfers require complete physical assistance of an adult. At home, children may move short distances on the floor or may be carried by an adult. Children may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

8.6. Appendix 6. Modified Ashworth Scale (MAS)

- ☐ **(0)** No increase in tone
- ☐ **(1)** Slight increase in muscle tone, manifested by a catch and release or minimal resistance at the end of the ROM when the affected part(s) is moved in flexion or extension
- ☐ **(1+)** Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM
- ☐ **(2)** More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
- ☐ **(3)** Considerable increase in muscle tone, passive movement difficult
- ☐ **(4)** Affected part(s) rigid in flexion or extension

Score Sheet:

MAS	**Trial One**		**Trial Two**		**Trial Three**		**Total (Average of three trials)**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**
Knee Flexors								
Hip Adductors								
Knee Flexors								
Ankle Plantar Flexors								

8.7. Appendix 7. Craig's Test

Score Sheet:

Craig's Test	**Trial One**		**Trial Two**		**Trial Three**		**Total (Average of three trials)**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**
FA angle (degree)								

8.8. Appendix 8. Trunk Impairment Scale (TIS)

The Trunk Impairment Scale (TIS) for children with cerebral palsy

Starting position for all items: sitting, thighs horizontal, feet flat (if possible) and resting supported, knees flexed 90°, no back support, and hands and forearms resting on the thights. In hypertonia, the starting position is with the arms in natural position. The child has 3 attempts for each item. The best performance is scored. No practice session permitted. The observer may give feedback between the tests. Instructions can be verbal or non-verbal (instruction/guidance).

Item				
	Static sitting balance			
1	Starting position	The child falls or can not maintain starting posiotion for 10 seconds without arm support	☐	0
		The child can maintain starting position for 10 seconds	☐	2
		If score=0, then TIS total score=0		
2	Starting position			
	Therapist crosses the strongest leg over	The child falls or can not maintain sitting posiotion for 10 seconds without arm support	☐	0
	the weakest leg	The child can maintain starting position for 10 seconds	☐	2
3	Starting position			
	The child crosses the strongest leg over	The child falls	☐	0
	the weakest leg	The child can not cross the leg without arm support on bench	☐	1
		The child crosses the legs but displaces the trunk more than 10 cm backward or assists crossing with hand	☐	2
		The child crosses the leg without trunk displacement or assistance	☐	3
		Total static sitting balance		/7
	Dynamic sitting balance			
1	Starting position			
	The child is instructed to touch bed or table	The child falls, needs support from an upper extremity or elbow or does not	☐	0
	with the most affected elbow (by shortening	touch the bench		
	the most affected side and lengthening the not/	The child moves actively without help, elbow touches bench	☐	1
	less affected side) and return to the starting	If score=0, then item 2 and 3 score 0		
	position			
2	Repeat item 1	The child demonstrate no or opposite shortening/lengthening	☐	0
		The child demonstrate appropriate shortening/lengthening	☐	1
		If score=0, then item 3 scores 0		
3	Repeat item 1	The child compensates. Possible compensations are: 1) use upper extremity	☐	0
		2) contralateral hip abduction 3) hip flexion (if elbow touches bench further		
		then proximal half of femur) 4) kneeflexion 5) sliding of the feet		
		The child moves without compensation	☐	1
4	Starting position	The child falls, needs support from an upper extremity or elbow or does not		
	The child is instructed to touch bed or table	touch the bench	☐	0
	with the not/ less affected elbow (by shortening	The child moves actively without help, elbow touches bench	☐	1
	the most affected side and lengthening the not/	If score=0, then item 5 and 6 score 0		
	less affected side) and return to the starting			
	position			
5	Repeat item 4	The child demonstrate no or opposite shortening/lengthening	☐	0
		The child demonstrate appropriate shortening/lengthening	☐	1
6	Repeat item 4	The child compensates. Possible compensations are: 1) use upper extremity	☐	0
		2) contralateral hip abduction 3) hip flexion (if elbow touches bench further		
		then proximal half of femur) 4) kneeflexion 5) sliding of the feet		
		The child moves without compensation	☐	1
7	Starting position			
	The child is instructed to lift pelvis from bench at the	The child demonstrate no or opposite shortening/lengthening	☐	0
	most affected side (by shortening the most affected	The child demonstrate appropriate shortening/lengthening	☐	1
	and lengthening the not/ less affected side) and	If score=0, the item 8 scores 0		
	return to the starting position			
8	Repeat item 7	The child compensates. Possible compensations are: 1) use upper extremity		
		2) pushing off with the ipsilateral foot (heel looses contact with the floor)	☐	0
		The child moves without compensation	☐	1
9	Starting position			
	The child is instructed to lift pelvis from bench at the	The child demonstrate no or opposite shortening/lengthening	☐	0
	not/ less affected side (by shortening the not/less	The child demonstrate appropriate shortening/lengthening	☐	1
	affected side and lengthening the most affected side)	If score=0, the item 10 scores 0		
	and return to strating position			
10	Repeat item 7	The child compensates. Possible compensations are: 1) use upper extremity		
		2) pushing off with the ipsilateral foot (heel looses contact with the floor)	☐	0
		The child moves without compensation	☐	1
		Total dynamic sitting balance		/10
	Coordination			
1	Starting position	The not/ less affected side is not moved 3 times	☐	0
	The child is instructed to rotate upper trunk	Rotation is assymentrical	☐	1
	6 times (every shoulder should move forwards	Roation is symmetrical		2
	3 times), first side that moves must be the	If score=0, then item 2 is 0		
	most affected side., head should be fixated in			
	Starting position			
2	Repeat item 1 within 6 seconds	Rotation is assymentrical	☐	0
		Roation is symmetrical	☐	1
3	Starting position			
	The child is instructed to rotate lower trunk	The not/ less affected side is not moved 3 times	☐	0
	6 times (every knee should move forwards	Rotation is assymentrical	☐	1
	3 times), first side that moves must be the	Roation is symmetrical	☐	2
	most affected side, upper trunk should be fixated	If score=0, then item 2 is 0		
	in starting position			
4	Repeat item 1 within 6 seconds	Rotation is assymentrical	☐	0
		Roation is symmetrical	☐	1
		Total coordiantion		/6
		Total Trunk Impairment Scale		/23

8.9. Appendix 9. Pediatric Functional Reach Test (PFRT)

Instructions:

Instruct the children to: ‘Reach as far as you can forward without taking a step’.

Score Sheet:

Trial One (Practise)	**Trial Two**	**Trial Three**	**Total (Average of trial 2 and 3 only)**
……..cm	..…….. cm	……..cm	……..cm

8.10. Appendix 10. Modified Timed Up and Go Test (mTUG)

Score Sheet:

Trial One	Trial Two	Trial Three	Total (Average of three trials)
……..sn	..…….. sn	……..sn	……..sn