THE EFFECTS OF FEMORAL ANTEVERSION ON KNEE POWER IN CHILDREN WITH CEREBRAL PALSY

by

Seçil Önal

B.Sc., Electronics Engineering, Işık University, 2009

Submitted to the Institute of Biomedical Engineering
in partial fulfillment of the requirements
for the degree of
Master of Science
in
Biomedical Engineering

Boğaziçi University
2015

THE EFFECTS OF FEMORAL ANTEVERSION ON KNEE POWER IN CHILDREN WITH CEREBRAL PALSY

APPROVED BY:

Doç. Dr. Can A. Yücesoy (Thesis Advisor)	....
Prof. Dr. Muharrem İnan	....
Assist. Prof. Dr. Bora Garipcan	....

DATE OF APPROVAL: 23 December 2014

ACKNOWLEDGMENTS

I would like to express the deepest appreciation to Dr Can A. Yücesoy who has shown the attitude and the substance of a true teacher and a very wise advisor. Without his supervision and constant help this thesis would not have been possible. I have learnt a great deal of work, significant, scientific knowledge and organization behavior from him.

I would like to thank Professor Muharrem İnan for making time for me in between saving lives and building better quality of life for children. His team at Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital was a brilliant team to work with and they were eager to learn more so it triggered me in every path of the way.

I would like to thank Professor Bora Garipcan for accepting to be in the jury committee and introducing me to a new division of science, which is genuinely exciting for me.

At last but not least I would like to thank to my beloved family, Ma Inci, Dad Resat Kaptan, Sis Ozgus and the cat Nuri, for understanding my way and blessing me every day with their beautiful, unique love.

ABSTRACT

THE EFFECTS OF FEMORAL ANTEVERSION ON KNEE POWER IN CHILDREN WITH CEREBRAL PALSY

The knee is the most adversely affected joint in children with cerebral palsy (CP). The aim is to assess wheter a correlation can be found between femoral anteversion (FA) and knee power in children with CP. If there is a relation, the surgery to fix FA may better control an arthosis, which occurs at very young ages in children patients with CP.

The measurements conducted using motion analysis techniques allowed determination of the degree of FA without doing a CT scan. 23 children with CP participated. Human gait analysis was performed using the Vicon System with the Berthec force plates. The particular analysis is done at the instant the knee atteins a full extension position because of presence of a neglectable muscle activity occurring at that time.

Data of this research led to the conclusion that the Pearson and Covariance coefficients do show a perfect correlation. However, Covariance coefficients also define the direction that the variables move. Direction of the variables may not have significance in anatomical correlations as in FA and knee power relation. In this research, a relationship between the increase in knee extension and the loading on the knee may conclude to one of FA's effects on knee. This result contributes to the thought that states the increased femoral anteversion (IFA) can develop early arthosis. Since there isn't a linear relationship, the findings suggest that the surgery to fix FA to delay the arthosis may not be a priority action to take on CP children who have IFA.

Keywords: cerebral palsy, femoral anteversion, knee power, arthosis, linear correlation, human gait analysis..

ÖZET

SEREBRAL PALSİLİ ÇOCUKLARDA FEMORAL ANTEVERSİYONUN DİZ GÜCÜNE ETKİLERİ

Serebral palsili (SP'li) çocuklarda en çok etkilenen eklemlerden biri dizdir. Bu araştırma SP'li çocuklarda diz gücü ve femoral anteversiyon (FA) derecesi arasında bir korelasyon bulabilmek için yapılmıştır. Eğer aralarında direkt bir ilişki bulunursa, FA ameliyatı SP'li çocuklarda erken gelişebilen artrozu geciktirmeyi sağlayacaktır. Protokolde yapılan ölçümler FA açısını ve ilgili benzerlerini CT taraması yapmadan öğrenmeyi sağladı. 23 kişilik SP'li bir grup çocuk ile çalışıldı.Insan yürüme analizi Vicon System ile gerçekleştirilmiştir. Bu sistemde gereken kinetik değerler yer tepkime kuvvetlerini gösteren Berthec güç plakaları yardımıyla elde edilmiştir. Diz maksimum ekstansiyona geldiği saniyede kaslar çalışmaya başladığı için kinetik bir değer olan diz gücüne o zaman çerçevesinde bakılmıştır. Pearson ve Covariance katsayıları çalışmanın limitli datasının etkisiyle FA ve düz gücü arasında lineer bir ilişki olmadığını göstermiştir. Covariance katsayısı parametrelerin ilerledikleri yönleri de belirleyebilmektedir. Fakat parametrelerin ilerledikleri yön bilgisi FA ve diz gücü korelasyonunda anlam göstermeyebilir. Bu çalışmada kinetik grafiklerin diz extansiyonunda gösterdiği artış, diz extansiyonundaki artış ile diz gücü arasında bir ilişki gözetilebilir ve bu da FA'nın diz gücüne etkilerinden olmasına dair bir bulgu niteliği taşımaktadır. Bu bulgu artmış FA'nın erken artroza sebep olduğu fikri ile bağdaşmaktadır. IFA ve diz gücü arasında bir bağlantı bulunamamasından dolayı artrozu önlemek amacıyla yapılabildiği bilinen FA ameliyatı öncelikli hareket niteliği taşımamaktadır. Buna rağmen klinik olarak tespit edilen anteversiyon sonuçlarda görülmemiştir.

Anahtar Sözcükler: serebral palsi, femoral anteversiyon, diz gücü, artroz, lineer korelasyon, yürüme analizi.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

p	Pearson correlation coefficient
r	Covarance Coefficient

LIST OF ABBREVIATIONS

CP	Cerebral Palsy
CT	Computer Tomography
EMG	Electromyograpy
AFO	Ankle Foot Orthosis
US	Ultrasound
NA	Neck Axis
AV	Anteversion Angle
CNS	Central Nervous System
WHO	World Health Organization
RF	Rectus Femoris
IR	Internal Rotation
ER	External Rotation
MAS	Modified Ashworth Scale
FA	Femoral Anteversion
IFA	Increased Femoral Anteversion
NIFA	Neurologically Intact Children with Increased Femoral Anteversion
CPIFA	Spastic Diplegic Children with Increased Femoral Anteversion
TD	Typically Developing

1. INTRODUCTION

Cerebral palsy (CP) is a general term described by loss or impairment of motor function. In this section, first general information about CP is given. Secondly, femoral anteversion (FA) as the main point of this study is explained in details. Subsequently, a general introduction is made to the gait analysis, kinetics and the relationships of kinetics and CP is explained. Additionally, there is a literature section which shows the past studies accomplished in this subject. Finally, there is a section introducing the goals of this study.

1.1 Cerebral Palsy

Brain injury, brain malformation or exceptional development of the brain that may occur before, during, or immediately after birth can cause CP. It is a central nervous system (CNS) disorder with frequency of 1–5 per 1,000 live births [1]. Spasticity typically develops between 6 and 18 months of age and alters the previously normal skeletal anatomy [2]. The most commonly affected muscles are the paraspinal muscles, hip flexors, hip adductors, hamstrings, gastrocnemius, and soleus. The type and timing of the injury to the developing brain lead to the idea that every individual having CP has different symptoms. Effects are mostly seen in control, coordination or tone of muscles. Reflex, posture and balance may also be affected and so as gait. Perlstein [3] categorized the information relevant for CP by looking at the following issues:

1. Clinic indications
    - (a) Spasticity
        - i. Upper Extremities
        - ii. Lower Extremities
    - (b) Dyskinetic
    - (c) Atactic

2. Dispersion to the extremities
    (a) Diplegia
    (b) Paraplegia
    (c) Monoplegia
    (d) Triplegia
    (e) Quadriplegia
    (f) Hemiplegia
    (g) Double hemiplegia
3. Intensity of the disease
4. Etiology
    (a) Prenatal
        i. Femoral Anteversion
        ii. Knee Flexion Deformity
        iii. Equinus Deformity
        iv. Hip subluxation and dislocation
    (b) Natal
    (c) Postnatal
5. The anatomic placement of the brain lesion

Regarding etiology, FA (see below section for more information) can be diagnosed as an incident in the prenatal period. In essence, while the impaired limb is maturing in the fetus, the femur grows with an irregular rotation, which causes a movement disorder.

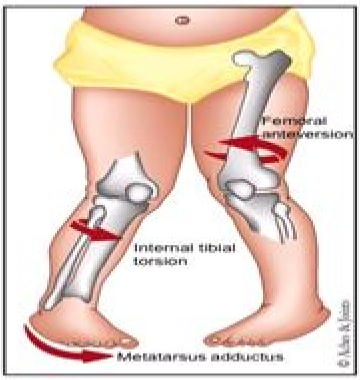

Figure 1.1 Knee and foot rotates towards the midline of the body, illustration by Navina Chabria.

1.1.1 Femoral Anteversion

FA is an inward twisting of the thigh. The femur begins at the hip and goes along the upper leg to the knee. When the femoral neck inclines forward with the rest of the femur and a “leaning forward” (i.e., anteversion) occurs, the condition is called FA. As it is seen in Figure 1.1, the knee and foot rotates towards the midline of the body because the lower extremity on the distressed side rotates internally. Majority of FA incidents engage with CP [4]. The appearance of the child’s leg while walking or running can be an indicator of this condition. A healthy child rarely has pain. However, children walking with their toes inward (in-toeing) mostly suffer from FA. In-toeing is not only dependent on CP but it is commonly a result of CP.

Furthermore, approximately 10% of children can have FA [5]. Related medical examination includes looking at the the patella to see if it is turned toward the midline of the body as well as observing to see if the child walks with the toes inward. Children with this condition generally sit in the "W" position, with their knees bent and their feet flared out behind them [6].

The torsional malalignment can also be a symptom for FA, tibial torsion, or pelvic rotation. At the time this condition is fixed, the treatment will improve the child’s ability to sit, also affecting the balance of the gait. Forwhy the most common complication is overcorrection of a deformity, especially in correction of FA, creation of any compensatory deformities during any treatment isn't recommended. It is important to have careful intraoperative evaluation meetings after the fixation as the laboratory for this study holds.

External rotation (ER) data is a crucial source of information in the treatment plan analysis to characterize any hip joint pathology. ER can be less problematic with degrees of 0°to 20°by the rule of thumb. However, too much ER, meaning greater than 20°, is said to be worse than a little IR of 0°to 10°. The goal should be having 0°to 10°of FA, and 5°to 20°of ER of the femur internal rotation (IR) during stance. The first cause of increased IR in children who had hip surgery is thought to be the increased FA even before the measurement of FA with US or with a CT scan. Although there may be many other possible reasons, kinematic measures seem to suggest that this may be the first target of an intervention [7].

When there is an increase of FA, the femur deviates from its healthy range. The gait shows some symphtoms of affection in different ways, such as the knocking of the knees. Knee motion and hip extension can be in normal ranges when the derotation is fixed and rotated back to its range to fix the gait [8].

The primary etiology to investigate have to be the increased femoral anteversion (IFA) and secondly the contracture of the internal rotators whether the problem is the increased IR. The compensatory effect for asymmetric pelvic rotation and external tibial torsion is mainly an increased case of IR and so as the IFA [7].

FA is also ranked among the causes for the spastic hip condition by various authors. An adductor spasticity and weakness at gluteus medius muscle can result to a femoral neck valgus, which dislocates the femur [11-13]. Main reasons for spastic hips are the IFA as well as the increase of the IR and also the coxa-valga condition [14]. Since positioning of the limb is very important, this condition is worth considering.

FA includes torsion of the femur when the anteversion increases or when contractures and limb rotations occur. Consequently, the hamstrings and the hip flexors are affected as the knee kinetics and kinematics of the patient are affected. Anteversion may have some indirect influence in developing decreased knee power as the effect on the kinetics [15].

Measuring the FA can be done via US in addition to a CT scan. US is an appropriate solution for FA measurement depending on the abnormality.

1.1.2 Femoral Anteversion Angle

The measure of the rotation of the neck of the femur around the diaphysis is anteversion angle. A normal healthy child is born with 30°degrees of anteversion at birth. Many morphological changes occur during development of the proximal femur. The anteversion angle gradually decreases to 15°by skeletal maturity [16].

In certain cases such as in children with CP , anteversion degree increases marginally and remains at that point throughout development [17]. Previous models have proposed that cyclic hydrostatic stress decreases this ascending rate while cyclic octahedral shear stress increases the ascending rate. In which the FA decreases rapidly in the first few years of normal growth and may increase in children with CP [18].

Usually an incidental finding, unrelated to any degenerative arthritic processes or disability can start the investigations [19]. The only surgical treatment currently used is called a "femoral derotation osteotomy." The pediatric orthopaedic surgeon intentionally starts with the cutting of the femur, rotation of it, and then fixation in the healthy anatomical position. The surgery requires children to be at a specific age and in a severe case.

The FA angle measurement is crucial for hip stability so as the individual's gait. The treatment requires the observation of the children highly forwhy the child must be examined carefully [15].

1.1.3 Spasticity

Although the observation of spasticity shows issues with the muscular structure, indeed spasticity is caused by an injury to a part of the CNS that controls voluntary movements. The balance of signals between the nervous system and the muscles is affected by the damage. This imbalance leads to increased excitability in the muscles [7]. In children with CP, spasticity causes an increased muscle tone. An increased sensitivity of the stretch reflex in addition to a velocity-dependent increase in resistance to motion, which may initiate also a muscle contraction, are the most characteristic aspects of spasticity [21].

1.2 Gait Analysis

Walking arises from repetitive movements of limb sequences. For the movement, energy is needed for muscular contraction. Measurement of the metabolic energy expenditure provides information for the overall gait performance. Therefore, differentiating pathological gait can be possible with energy expenditure. However, gait analysis has a more informative role in the planning part of the treatment. Firstly, the regular periodic physician evaluations are needed. Secondly, the use of available gait measurement tools is a necessity and these altogether give the clinician the best opportunity to make an optimal treatment plan. Since it is a non-invasive and non-radiogenic procedure, doing a pre-operative or post-operative gait analysis for evaluation of the surgical treatment is a big advantage. Gait is cyclic and the stance and the swing phases are a first classification of one cycle (Figure 1.2).

The stride starts with a step and concurrent strides complete the periods. Periods complete the gait. “Double support” refers a time range when both feet are on the ground. On the contrary, “flight times” is a term that means none of the foot is in

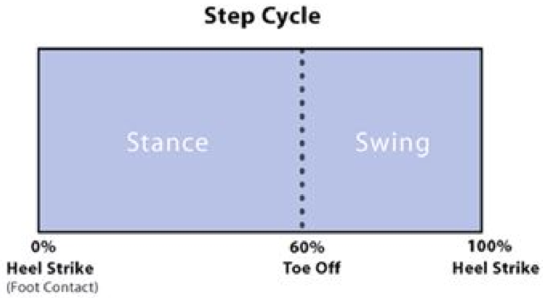

Figure 1.2 The periods of gait, step cycle.

contact with the floor.

Stance phase: The body is supported on the floor. It is measured by the time that foot spends on the floor. Heel strike represents the transition from swing phase to stance phase. Designating the weight-bearing limb for a child with CP during gait is necessary to determine some features about the mechanical abnormalities, such as FA. In addition, heel strike in children with CP may not form as an initial contact because the first contact may even be with the toe. Correspondingly, the "initial contact" term has been used in the results part of this study.

Swing phase: Allowing forward movement of the foot is the start of this phase. It is measured by the time that the foot is moving forward. The first third of swing phase is the time of initial swing. Flight time is in the swing phase range.

Starting from the begining, the foot contact initially is the heel strike (Figure 1.3). The tibia rolls forward during the mid-stance, which comprises the first half of the single-support timephase. Loading response of the right foot lasts until the left foot's toe-off movement and vice versa. Terminal stance is described as the rising of heel and in another term as the late stance. Pre-swing is the foot contact of one side (left or right side) and it ends with the toe-off movement of the opposite side. It is the second double-support time just before swing phase [15].

Initial swing, mid-swing, and terminal swing are the three divisions of the swing

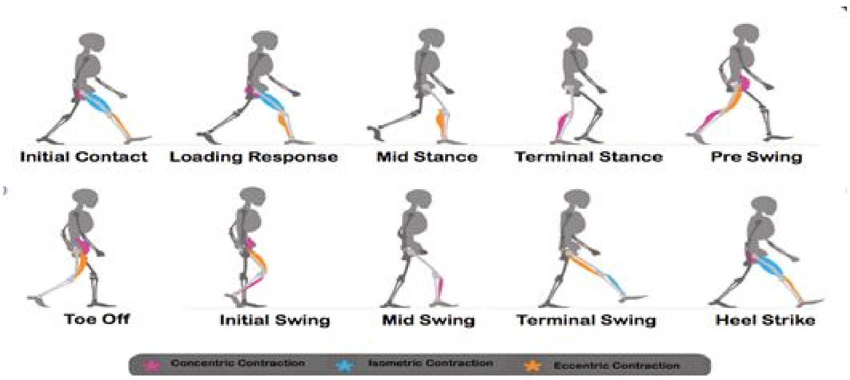

Figure 1.3 Detailed phase list [15].

phase. The swing events start with toe-off. Mid-swing and terminal swing comprises the other divisions of the swing phase, which end with heel strike. Mid-swing takes up approximately 50% of the swing phase and terminal swing occurs with the knee extending and the leg getting prepared for foot contact with the floor.

Ankle rockers come up as another classification. 1st rocker is defined in the time range that foot contact turns onto foot flat. 2nd rocker is the time from foot flat to heel rise. And the 3rd rocker is the time from heel rise to toe-off.

Foot contact is provided by isometric contractions. The gastrocsoleus muscle is the main controller of the knee position in the mid-stance and terminal stance phase. In the swing phase, the rectus initially controls knee flexion through an eccentric contraction.

1.2.1 Kinetics and Kinematics

Gait analysis involves measurement of kinetics and kinematics. Kinetic parameters are moments, power, ground reaction forces, pressures. The joint angles reflecting e.g., flexions, dorsiflexions, extensions, hyper-extensions are the kinematics parameters in addition to angular and linear velocities and accelerations. The temporal spatial characteristics are some basic quantative terms. They include the step length, stride length and step width. The distance that the foot covers during only one swing phase is called the step length. The step width is the medial lateral distance between the two feet during the gait cycle.

1.2.2 Efficiency of the Gait of Children with Cerebral Palsy

The knee's main function is to provide stability and change the limb's length between the stance and the swing phases. Therefore, more power absorption is expected in the knee than the power generation. The knee needs to use the power, by absorbing it. The moment and power produced in the knee is minimal when it's in the stance phase. Efficiency of the gait is investigated with the kinematics and the kinetics of the knee. At heel strike, the knee is flexed approximately by 5°and when the knee in almost full extension, the step length is maximized.

1.3 Arthrosis

Arthrosis is a chronic degenerative disease of the joints based on the degeneration of articular cartilage with a subsequent change in the bony articular surfaces, the development of marginal osteophytes, deformation of the joint, and the development of moderate synovitis. The International Classification of Diseases currently lists osteoarthrosis, arthrosis, osteoarthritis, and deforming arthrosis as synonyms. Arthrosis is a normal degenerative condition associated with aging. It affects mainly cartilage which becomes rugged, irregular and worn out. This wearing out of cartilage can cause pain, loss of mobility and loss of muscle strength [22].

1.4 Literature on Femoral Anteversion and Knee Kinematics

Bilgili et al. [20] reviewed the causes of the knee and hip flexion contractures, clinical evaluations, and treatment principles in children with CP. The crouch gait pattern, instability in stance phase of gait, difficulties during standing/sitting and other daily activities are investigated. As the study follows, the hip flexion contracture in crouch gait is mostly compensation of the knee flexion contracture. It is stated that children with CP may even give up walking due to the high-energy-demand in the adult period. The biomechanical reasons of knee and hip flexion deformity are discussed in the light of previous studies and gait analysis data. That study assessed the knee power-CP-sourced FA relationship. The authors argued about the suitable and possible treatment plans that should be determined through an adequate assessment of the flexion contracture in the hip and knee. Potential treatments included the recurrence or partial correction of knee flexion deformity.

Akalan et al. [24] studied the effects of IFA on gait in children with CP. They worked with a large group of children with CP. FA was measured geometrically. The hip IR angles of all the children in Neurologically Intact Children with Increased Femoral Anteversion (NIFA) and Spastic Diplegic Children with Increased Femoral Anteversion (CPIFA) groups were $>70°$and ERs were $>20°$bilaterally. No tibial torsion was detected in any of the participants. The peak power absorption and generation were addressed in the stance phase for the hip, knee and ankle. The authors showed that the mean anterior pelvic tilt and knee flexion at heel strike are increased in NIFA and CPIFA groups compared to the typically developing (TD) group. However, the results showed no difference between NIFAFA and CPIFAFA groups. On the other hand, the decrease in maximum plantar flexion in terminal stance was not found significantly different in NIFA and CPIFA groups, but it was also not different in TD and NIFAgroups. The results also include that IR increment is related with IFA. In addition, since power absorption and generation were seen in the stance phase, the knee power is also affected in various-caused-CP patient groups.

Beng et al. [25] worked on the impact of IFA on knee kinetics and kinematics in children with CP. Their objective is investigating internal-rotation-gait, a common case. They investigated power and moment changes in the knee in these patients. They evaluated 17 patients with IR gait all being diplegic. Two groups were selected; those with hip IR more than 30°(Group1), and those with less than 30°(Group2). As a result they found that power, moment and loading on the knee increased in Group 1. Therefore, they concluded that this abnormal loading might lead to early arthrosis in the knee.

1.5 The Goal of the Study

The main objective of this study is to analyze the effects of FA caused by CP on the knee power of children. The hypothesis tested is that the increasing flexion motion and power at the knee during stance phase, which are seen in children with CP frequently, might have a relavence with FA.

The definitions of knee power related with FA are highly questionable. The knee power depends on many structures in the body. Human gait analysis can determine the kinetics and kinematics of the subject, but the influence of different structures on the knee power is not segregated. The main reason for many disagreements may be hidden under the complexity of the nature of the CP, which combines multiple muscle spasticities, selective motor control difficulties, coping responses and sensory-motor problems. It would also contribute to achieving the correct level of treatment and developing treatment strategies.

The positive power means that the power is absorbed and the negative power means that power is generated. The kinetics graphs during knee extension can denote a relationship between the increase in knee extension and the knee kinetics, which may indicate a FA effect on the knee power. The study results may contribute to a thinking of FA as a potential source of arthosis development. Such arthosis occurs at very young ages in patients with CP. FA impair the loadings on the joints and degeneration might be expected in the further periods.

2. METHODS

Data is collected and analyzed in Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital and further analyzed in Biomechanics Laboratory of Biomedical Engineering Institute in Boğaziçi University. Physical examinations and gait analyses were accomplished for 23 patients ages ranged from 5 to 17. Subjects and their parents/guardians were informed about the study and their informed concents were taken before the analyses.

2.1 Gait Analysis Studies

The system used for clinical gait analysis in Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital is the Vicon System (Motion-Capture System, Oxford/UK). The system includes the Vicon Nexus capture application software. The calibration of the system has to be done in order with the help of calibration wands included in the system package. This study follows a protocol starting with the physical examination (done by physician Pınar Benek from Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital). The passive range of motion, spasticity and muscle strength of patients were measured in this physical examination part. Plug-in-Gait marker placement is where the external markers are arranged on the patient's body. The patient stands with arms open and stays straight along with being stabilized in astatic posture. Nexus software detects fourteen external markers and after that placement of the markers on digital context is done. Subsequently, the subject walks across the capture volume a number of times. The Vicon system optimizes this process itself by automating the recording. During the procedure, the tracking is done with eight Vicon Infrared cameras of the external markers (Vicon stick markers, 3 -4 -6.35 -9.5 -14 -19 -25 mm sizes) positioned on the subject's body as well as the monitoring (with two Vicon computers) of the patient and the ground reaction forces (Bertec Force Plates) are accomplished. The following figure (Figure 2.1) shows the force plates. Among a wide range of force plate producers including AMTI, Kistler, Bertec and Ky-

Figure 2.1 Photos of the Bertec force plate and the position.

owa Dengyo, Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital uses Bertec Force Plates (System no: S007001, OH/USA) intheir system to obtain the ground reaction force data as the patient starts to walk on the plates. The positions on the force plate relative to the Vicon cameras are known. As shown in Figures 2.1, one relative position is defined as two consecutive steps being on the force plate in sequence. The joint range of motion characteristics, temporal and spatial parameters throughout the gait cycle are gathered in this position.

The computation of kinematics and kinetics are used for an objective understanding of the abnormality of walking biomechanics of each patient. Then the treatment plans for patients are arranged with the report from the Gait Analysis Laboratory of Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital.

2.2 Patient Preparation and Physical Examination

The physical examination process takes approximately two to three hours depending on the anomalism and hardship of the patient. Furthermore, walking the capture volume for several times can be challenging for some of the patients but working with the parents/guardians makes the patient as comfortable as possible throughout the process. The laboratory has colorful walls and drawn animations for children to provide an optimal environment for recording movement (Figure 2.2).

Figure 2.2 A panoramic photograph of the labroratory environment.

Devices that the subject typically uses such as braces, crutches or walkers for walking considered adequate but the kinetics comprehension of the system software does not recognize those varied materials. In this study kinematics/kinetics are important so data of patients with devices are not used. There is clothing (shorts and short tops) for walking because non-restrictive clothing for the procedure is crucial. If necessary it is asked to shave the legs before the analysis to ease the placement of markers. The physical examination involves the comprehension of the following:

1. CP classification and posture analysis
2. Alignment
3. Plug-in gait parameters
4. Passive range of motion
5. Spasticity
6. Muscle strenght

2.3 Marker Set Placement

Vicon systems include fourteen external markers to be placed on the patient's lower body. The placement template is important for the digital context to be created on the software.

Figure 2.3 The retro-reflective markers.

The positions of the retro-reflective markers (Figure 2.3) are measured by the system. The cameras measure the infrared light that is generated near the camera's lens. Digital context is created on the software when the cameras designate the place of the markers by the help of the light getting reflected from the markers. Although the anthropometry of the patients and counterbalanced soft tissue movement in relation to the bones underneath are becoming a problem for accurate answers, there are many studies investigating techniques for using functional tests to determine joint centres and axes of rotation [26].

2.3.1 Helen Hayes Marker Set System

Since there are different capture systems, diverse marker sets have been proposed in the literature. However, the majority of them in use is based on some variation of the Helen Hayes set An example to such variations is the one used in University of Delaware, Biomechanics & Movement Science of Health Department where Helen Hayes Marker Set is considered as a "Simplified Marker Set" without the requirement of the static data collection step, and hence the system is considered as a time saving one in comparison to others. In Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital it is considered that the static data collections carry much importance forwhy the resultant report can be comrehensive by the help of this data. Besides, most of the marker sets used earlier are developed for imaging systems with low resolution. Therefore,

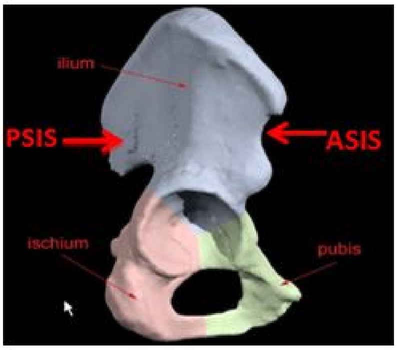

Figure 2.4 Places of PSIS and ASIS (adopted from The Indiana Osteopathic Association (IOA) Manuals) in lateral view of pelvis

the rational move to go through is to have fewer markers so that data merging can be avoided. In agreement with these, the laboratory has the facility to use the Plug-in-Gait Marker Placement as the marker placement set.

2.3.1.1 Sagittal Plane Landmarks. The posterior and anterior landmarks are calibrated with respect to PSIS and ASIS. Figure 2.4 indicates the places of PSIS and ASIS in lateral view of the pelvis. Since the hip joint is a ball-and-socket joint, it is a difficult anatomic reference point, but the greater trochanter, which is the only obvious bony mark that lends assistance throughout the physical examination. These marker placement issues can affect the results. Since the transverse axis of the knee joint passes between medial and lateral epicondyles, knee joint anatomy becomes plainly decisive.

2.3.1.2 Coronal Plane Landmarks. The vertical plane going through the body side to side dividing it into anterior and posterior parts is called as the coronal plane. Figure 2.5 shows the patella corresponding to the anteriror center of the knee. That makes the placement easy and not problematic when results are concerned.

2.3.1.3 Transverse Plane Landmarks. The subjects with appearent pathological sympthoms obstruct the work of using anatomical landmarks as maps to place the

Figure 2.5 Patella, corresponding the anterior center of the knee.

markers. The issue is apperent even when the sympthoms are observable to naked eye, the arcs of rotation causes the capture to be ineffective.

The template's lower body part, which Input Devices and Music Interaction Laboratory (IDMIL) presented, is reformed as the protocol in the study. Figure 2.6 describes in detail where the Plug-in-Gait markers should be placed on the patient.

There are a few indications about some marker's placements. They may vary from subject to subject but general patterns are included below.

Placement regularities, which are the common grounds for human gait analysis is very adaptable via the known centers and planes of human body. Joint centers and planes of subject's body are attained as the map for the regular placement.

Retro-reflective markers follow the trail of the alignment and assist the reflection of the light for the Nexus System Software to create a digital context, the graphs, the plots and a 3D image of the subject's body on the computer screen.

Whilst prosecuting various sortsof marker placement procedures the conformity

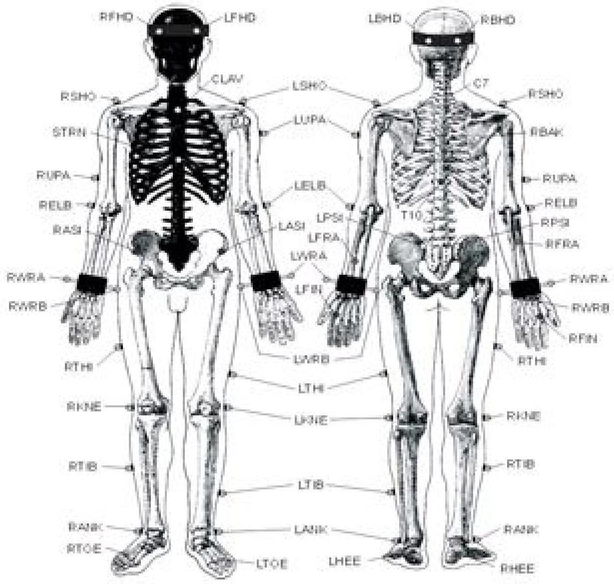

Figure 2.6 This figure describes in detail where the Plug-in-Gait markers should be placed on the patient. Where left-side markers only are listed, the positioning is identical for the right side.

of markers to the system and patient become substantial. A standart marker kit includes a base plate and couple of wands with different sizes. These materials are requisites when the markers should point out a digital context of a body-track and end up fitting a few inches away from the direct skin. There are myriads oftypes of humanbody, therefore different placements are developed in time to increase the visibility of the markers in the digital context. In case of obesity and similar cases as such hardships involving the LASI and RASI markers, visibility of the markers ceases. The solution to amplify visibility found to be sliding both markers to the lateral with an equalling degree through the line up of LSIAS-RSIAS areas. If this solution is applied, procedures for parameter forms of each differed subject should be improved. The actual physical distance between LSIAS-RSIAS areas must be keyed in in the parameter form for the Nexus and Polygon System Softwares to follow through as a model and create the digital context and also to avoid complications. For instance, the posterior pelvic markers are placed towards the center closer than the anterior pelvic markers for the pelvis markers to fix their position via abdominal arcs properly.

It is an important fact that needs to be posed about another marker, which is the LKNE marker. Some required positions emerge for the LKNE marker to be placed

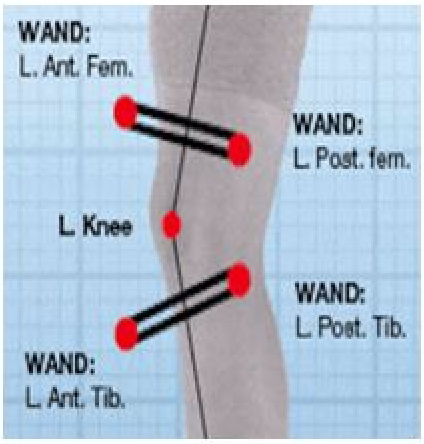

Figure 2.7 The wands following the trail.

regularly. Subject's knee has to be in flexion-extension position passively, following skin-trail on the lateral surface of the knee-joint. Meanwhile the skin surface that stays fixed on femur has to be found in the knee-joint-access. This LKNE marker also displays the onset point of lower-leg rotation, which is marked by a pen. LKNE marker should be 1,5 cm up of the knee joint line. That point must be the exact spot to locate the LKNE marker. The Figure 2.7 represents the procedures mentioned above and the wands.

Markers usually pass through a few sectors of the subject's body at once for a proper alignment. Likewise the LTIB marker has to traversesome sectors at the same time. LTIB marker gets through the knee and ankle-joint-center and also the plane that formed by the flexion-extansion-access of the ankle. The ankle-joint-access, which normally stays between the medial and lateral malleolus is in ER at 5-15 degrees with respect to knee-flexion-access. The placement of the LTIB marker had to be compatible with this configuration [27].

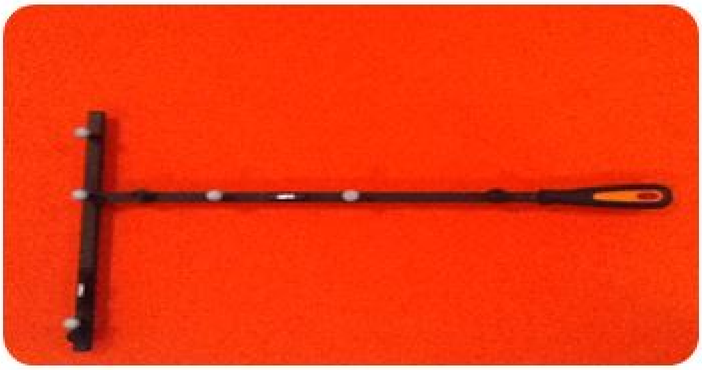

Figure 2.8 The calibration stick.

2.4 Calibration of the System

The system is reqired to be calibrated before the analysis. Checking the calibration for the patient group is a very cooperative step [28].

1. **Arranging angles for the cameras:** Provides a large range for the completion of the patient's body visual on the coordinate system.

2. **Applying the masking feature on the correction pane that automatically appears in the software:** The unwanted reflection spots are defined as the ghost markers and masking feature clarifies all of the ghost markers. Source of a ghost marker can be a kind of a metal in the room or an unreal reflection.

3. **Calibration for Bonita Cameras:**

   i. Arranging the blur vision, the lighting and resolution, controlling the masking feature.

4. **Specifying an origin:** A reference point, an origin, is crucial for the analysis.

5. **Calibration for DV (Sony) cameras:** i. Arranging the position of the cameras depending on the patient's abnormality. The calibration is done with a calibration stick, which has markers on in a specific alignment. The wand is seen in Figure 2.8 and the shape looks like the T letter to cover a large geometric projection during calibration.

3. ANALYSIS

This chapter explains the analysis phase of study.

3.1 Subjects of the Study – Patients

The following listed names are the children who have FA with CP. In the next sub sections there will be results of this study for each child listed below.

A.E., B.E., C.T., E.E., E.S., G.K., G.Y., H.A., K.M.Y., M.G., S.T.O., T.G., Y.O., Y.E.S., Z.B., E.Z.Y., S.E., B.Y., E.Y., İ.S., Y.H., N.A., B.K.

3.2 Measurements

The measurements are done in a regular pattern to avoid the possible confusion during the reading of the data. Three walks of each patient are recorded using the evaluation form given in the Table 3.1 below:

3.2.1 Modified Ashworth Scale

Ashworth scale measures the spasticity. It is necessary to state that normal muscle tone is the resistance of a muscle when it is stretched without resistance. A scale to assessthese kind of tone variations is called the modified ashworth scale MAS. Bohannon and Smith generalized the routines in literature in 1987.

Table 3.1
The evaluation form.

Name:	
Age:	
Sex:	
History:	
CP classification	
Range of Motion	
Hips	Knee
Flexion:	Flexion:
Extension:	Extension:
Abduction:	Rectus femoris length:
Adduction:	Ankle
Internal rotation:	Dorsi flexion:
External rotation:	Plantar flexion:
Alignment	
Femoral anteversion:	
Tibia femoral angle:	
Genu valgum:nosymbol	Genu varum:nosymbol
Spasticity (MAS, R/L)	
Hips	Knee
Flexor:	Hamstring:
Adductor:	Duncan-Ely Test:
Internal rotator:	Ankle
Extensor:	Dorsi flexion:
Abductor:	Tibialis anterior:
	Plantar flexion:
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length:	
Bicondylar distance:	
Bimalleolar distance:	
Weight:	
Height:	

Table 3.2
The MAS scoring classification.

0	Indicates no increase in muscle tone.
1	Indicates a slight increase in muscle tone.It's 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.
1	Indicates a slight increase in muscle tone. It's manifested by a catch, followed by minimal resistance throughout the remainder of the ROM.
2	Indicates more increase in muscle tone through most of the ROM, but affected part(s) easily moved.
3	Indicates considerable increase in muscle tone, passivemovement difficult.
4	Indicates affected part(s) rigid in flexion or extension.

3.2.2 Duncan-Ely Test

The aim of the Duncan-Ely Test is to obtain the amount of tonus increase and shortening of the Rectus Femoris (RF) muscle. The result of the test is implied as rather positive or negative. Nor it is a quantative measurement neither the performance of the Duncan-Ely test is usually clinical [26], it is still the main way to assess the RF spasticity.

3.2.3 CP Classification and Posture Analysis

Depending on the dispersion to the extremities: Dispersion to the extremities is checked for the evaluation form.

- **Diplegia:** The lower extremities are affected at most and rarely the upper extremities.
- **Paraplegia:** Two lower extremities are both affected from CP.

- **Monoplegia:** Only one of the extremities is affected from CP.
- **Triplegia:** Three extremities are affected from CP.
- **Quadriplegia:** All four of the extremities are affected.
- **Hemiplegia:** Semi-body is affected from CP.
- **Double Hemiplegia:** The spasticity, which occurs at both two parts of the patient's body is seen less at the lower extremities and more intensive at the upper extremities.

Depending on the clinical symptoms: Three classes of spasticity, dyskinesia and ataxia for CP depend on the clinical symptoms of the patient [30].

3.2.3.1 Spasticity. The lesion in the brain is in the pre-motor area and the pyramidal track. It mostly contracts the antigravity muscles. For example, the deep tendon and the surface reflex contractions occur. Also spasticity for different extremities:

- Control for contraction at the upper extremities can be done via checking: Shoulder flexion/retraction/ adduction/ internal rotation, elbow flexion/ pronaction, wrist flexion, finger flexion.
- Control for contraction at the lower extremities can be done via checking: Hip flexion/ adduction/ internal rotation, knee flexion, ankle plantar-flexion/ eversion/ inversion.

3.2.3.2 Dyskinesia. The lesion is in the basal ganglia in the brain. Muscles can contract well particularly. The only abnormality that separates this class of CP from healthy patients is the anomaly of spontaneous movements. There are different types for this class of CP:

- Korea: Sudden, fast, desultory movements.
- Athetosis: Involuntary, heavy and snake-like movements.
- Ballismus: Involuntary drifting of the hands and legs occur.
- Tremor: The rhythmic-reciprocal movemensts.
- Rigidity: A widespread hypertonus is observed.
- Dystonia: It is mostly seen on the muscles of body trunk.

3.2.3.3 Ataxia. It is the defect of posture and muscle synergy, which involves cerebellum.

Depending on the brain lesions and reasons

The patient histories are taken to have a better comprehension.

- Prenatal: Blood incompatibility, kin marriage, deficient doctor control, infection during pregnancy. The rate of causing CP is %30.
- Natal: Premature or problematic deliveries, asphyxia, false drug usage by the mother, forceps c-section. The rate of causing CP is %60.
- Postnatal: Traumas, high fevers, poisoning and tumors during infancy. The rate of causing CP is %10.

Cerebral Palsy Motor Evaluation Form

The form is given in the below, please see the Table 3.3.

Table 3.3
CP Motor Evaluation Form - The postures and movements.

Postures and Movements for CP Testing	
Supine Position	1.Hips and knees are in full flexion, arms crossed and palms are at shoulders.
	2.When hips and knees are in full flexion, test for right and left leg extensions are done via MAS.
	3.Lifting the head up.
	4.Turning to prone position.
Postures and Movements for CP Testing	
Prone Position	1.Arms are stretched up over the head, head stays in the middle and test of posture control is done.
	2.Arms and palms are looking downwards in extension and stay right beside the body trunk.
	3.Hips are in extension. So flexions of the right and left knee are tested by MAS.
	4.Remaining on forearms as arms are in straight vertical position, test of posture control is done.
	5.Remaining on forearms as body trunk, elbows and hips are in extension, test of posture control is done.
	6.Switching to active sitting position.
	7.Sitting upright as hips are in flexion and 45°external rotation while soles of feet are adjacent. Test for external rotation control is done.
	8.Sitting upright as legs are extended outwards, knees are in flexion and hips are fixed. The test for capacity of sitting up straight while legs are extended is done.
	9.While both legs lean out from the examination desk, the extension of right and left knees are controlled.
	10.Switching to active crawling position.
	11.Remaining on knees and hands, laying the weight on knees to test flexion and laying the weight to hands to test extension.
	12.Sitting laterally on left and right hips in sequence to test the capacity of body trunk to adjust to differences in gravity.
	13.Standing upright on knees to test the front-and-back control on femurs of pelvis and body trunk.
	14.Standing upright on one knee, laying the weight on the right and left knees in sequence to do the posture control test.
	15.Body trunk and head standing straight in full flexion, heels of the foot are wide-open, knees and toes are in the same direction to test the capacity of recovering from hypertonus of extensor.
	16.Standing straight on feet to test the posture.
	17.Bringing forward right and left legs in sequence while standing to test the posture.
	18.Lying the weight to right and left legs in sequence separately during midstance position to test the posture.
	19.Testing the posture during heel strike at right and left feet.

3.2.4 Alignment

FA measurement is based on degree of anteversion of femoral neck in relation to the femoral condyles. Normal FA is 30-40°at birth and it typically decreases in time. This typical minimal change in FA occurs after age 8 and the decline is to normal adult range of 15°by skeletal maturity.

Evaluation for in-toeing FA is the beginning to comrehend the conditions. Hip motion issues indicate the existence of FA if IR is increased over 70°-healthy range: 20-60°- and also if ER is decreased under 20°-healthy range: 30-60°-. Additionally, the anteversion estimated on degree of hip IR when greater trochanter is most prominent laterally.

Patella getting internally rotated on gait evaluation and this information marks a symptom that is crucial for designating the degree of FA. Figuring the FA angle from the form of tibial torsion depends on the thigh-foot angle in prone position. This angle is meaningful for FA. Healthy range is 0-20°of ER and less then -10°ER implies the tibial torsion existence.

As far as the metatarsus adductus is concerned for the FA measurement, the adducted forefoot deformity depicts a certain point. Also the lateral border is straight and a medial soft-tissue crease indicates a more rigid deformity when there is FA.

3.2.5 Normal Range of Aligment Data

Following Table 3.4 shows the normal range of alignment data.

Table 3.4
Alignment Normalization.

Normal Range of Alignment Data	
Femoral anteversion	8°-14°
Tibia femoral angle	7.1°-6.5°[41]

3.2.6 Genu Valgum- Genu Varum

Genu valgum occurs when the condition affects both sides of patient's body, and it is also called X-shaped legs or knock-knee. This condition is also one of the most frequent causes of medial gonarthrosis. Arthrosis happens to be an issue with CP children.

The Q-angle measurement is described as a helpful tool performed by physicians at the laboratory for the calculation of the genu valgum's degree. The Figure 3.1 represents the Q-angle that is formed by a line drawn from the anterior superior iliac spine through the center of the patella and a line drawn from the center of the patella to the center of the tibial tubercle.

Genu Varum show in Figure 3.2 is also called O-shaped legs or bow-leggedness.

3.2.7 Plug-in Gait Parameters

System requires certain parameters to work with. Overground walking kinetics is designated by the patient's gait performed with own choice of comfortable walking speed. The speed also depends on the abnormality. Furthermore, patients pass over the Berthec force-plates centered in the middle of the walking path. Overground and gait analysis data are evaluated using Vicon Plug-in-Gait. The differences between the maxima and minima of kinematic and kinetic parameters for overground gait are evaluated. So the parameters needed to start-up the system template for every different

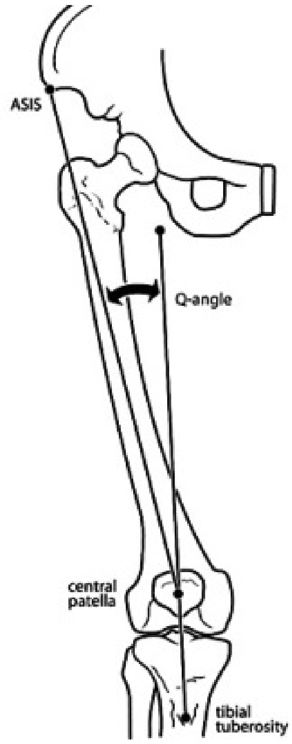

Figure 3.1 Q-Angle.

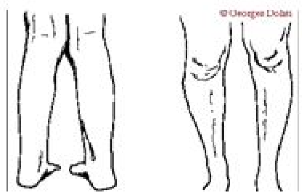

Figure 3.2 Ganu Varum and Genu Valgum illustrations in sequence.

Table 3.5
Plug-in Gait Parameters

Vicon System Measurements	
Leg length	
Bicondylar distance	
Bimalleolar distance	
Weight	
Height	

patient are below:

Plug-in Gait Parameters are given in the following Table 3.5.

The weight measurement is done with a simple scale. Measurements of height and leg length are done with a meter. Besides the bicondylar distance is a very essential detail. Patient sits down on a chair with legs parallel to the floor, reaching the floor with their feet. Physician stands in front of the patient and applies the caliper's handles on the epicondyles to measure the bicondylar distance [31]. Furthermore, the bicondylar distance, the bimalleolar distance is also one crucial parameter for the Vicon System to start the plug-in gait template. Measurement method of bimalleolar distance starts with placing the foot on a stool and continues with applying the handles of anthropometry gauge with a 45°angle on the malleols. Lastly the measurement is obtained by summing up both of the values.

3.2.8 Passive Range of Motion

The moving of a joint through its range of motion without exertion or any power from the patient indicates the available motion capacity of the patient. Performance of an external force or therapist/physician is necessary. The real capacity of the motion that patient's body is competent for is implied.

Table 3.6
Passive range of motion form

<table>
<tr><td colspan="2">Range of Motion</td></tr>
<tr><td>Hips</td><td>Knee</td></tr>
<tr><td rowspan="3">Flexion:
Extension:
Abduction:
Adduction:
Internal rotation:
External rotation:</td><td>Flexion:
Extension:
Rectus femoris length:</td></tr>
<tr><td>Ankle</td></tr>
<tr><td>Dorsi flexion:
Plantar flexion:</td></tr>
</table>

The form for range of motion is given below as Table 3.6:

The capacity of the hips movement to be in the healthy range of flexion/extension, abduction/adduction and also finding the IR and ER degrees of hips play a role in this study. Dorsi flexion and plantar flexion degrees are noted as the other parameters to check the healthy range. Comprehension of the relation between the noted data and FA plays a role on the effects of FA on knee kinetics on children with CP.

3.2.9 Normal Values Range of Motin, R/L

Table 3.7 shows the normal valuses ROM.

There is a large difference between the measurements with the knee extended -which measures the length of the gastrocnemius muscle- and the measurement of ankle dorsiflexion with the knee flexed -which measures the soleus length- in some children with CP. This is an important difference that is in the results of symptoms of children with CP.

Table 3.7
Normal values of ROM

<table>
<tr><td colspan="2">Normal Values Range of Motion, R/L</td></tr>
<tr><td>Hips</td><td>Knee</td></tr>
<tr><td rowspan="3">Flexion: 0°-120°
Extension: 0°-30°
Abduction: 30°/ 40°
Adduction: Hip 0°-Knee 0°: 0°-45°
Hip 0°-Knee 90°: 0°-45°
Internal rotation:
Prone: 0°-45°
Supine: 0°-45°
External rotation:
Prone: 0°-45°
Supine: 0°-45°</td><td>Flexion: 0°-135°
Extension: 0°-120°</td></tr>
<tr><td>Ankle</td></tr>
<tr><td>Dorsi flexion: Knee 90°: 0°-20°
Knee 0°: 0°-20°
Plantar flexion: 0°-50°</td></tr>
</table>

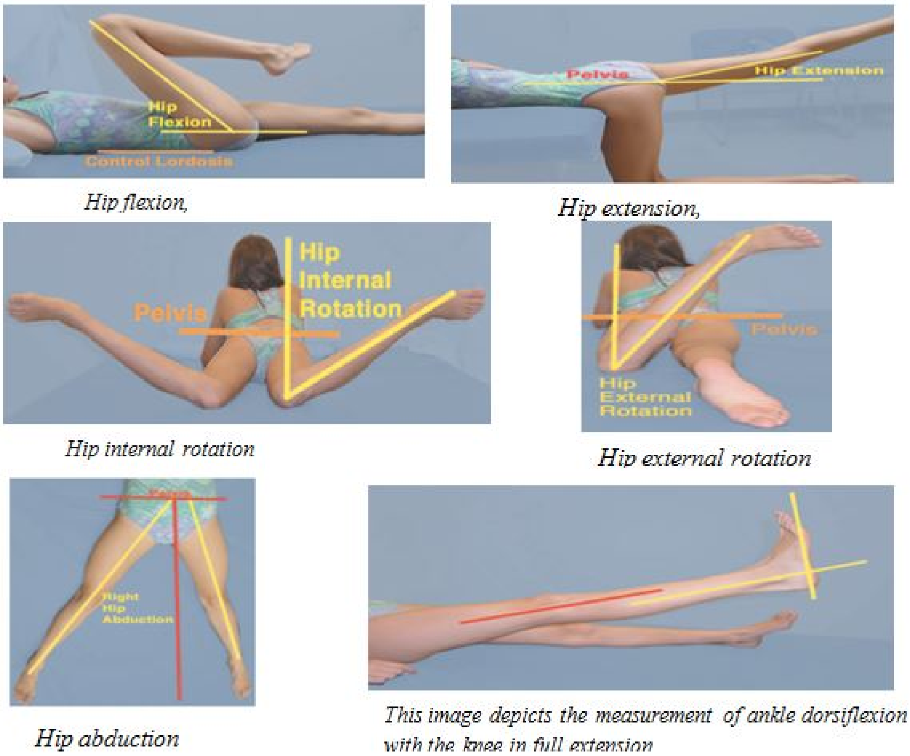

Figure 3.3 Clinical measurements for joint rage of motion capacities (Miller 1995)

3.2.10 Spasticity Data Information

It is a crucial issue whether some muscle structures show a healthy range without CP. Their effect is also worthy of speech in this study. For example, the iliopsoas muscle of the hips should be noted as the flexor muscle of the hips. Additionally the magnus muscle is the adductor muscle of the hips. Also the gluteus minimus muscle is indicated as the internal rotator as the gluteus maximus muscle is the extensor of the hips. Plus the abductor of the hips is stated as the gluteus medius muscle. Their spasticity is noted in terms of MAS.

The hamstring muscle's spasticiy is noted such as the result of the Duncan-Ely test, the test, which implies the spasticity of RF muscle in the knee. When it comes to the ankles the dorsi flexion, tibialis anterior and plantar flexion degrees is necessary for us to define which part is relevant with FA.

Table 3.8
The spasticity data form

Modified Ashworth Scale	
Hips	Knee
Flexor:	Hamstring:
Adductor:	Duncan-Ely Test:
Internal rotator:	
Extensor:	
Abductor:	
	Ankle
	Dorsi flexion:
	Tibialis anterior:
	Plantar flexion:

Please see the following Table 3.8 for the spasticity data form.

3.2.11 Marks on the form and their indications

The marks on the form and the explanations of them are given in the table 3.9.

3.3 Treatment of Data

The correlation between FA and knee power helps tofind the effects of FA on knee kinetics on children with CP.The knee power at the second that the knee is in full extension is correlated with the FA angle. Figures 3.4 and 3.5 given below represent knee flexion and power graphs over time.

Correlation involves dependence. Measuring the degree of correlation depends

Table 3.9
Marking map

R, L	Right/ Left
×	There isn't a value in the designated position
plus minus	Test result is negative/ positive
x	The designated application can't be completed with a valid value
✓	There is a valid positive answer for the designated test

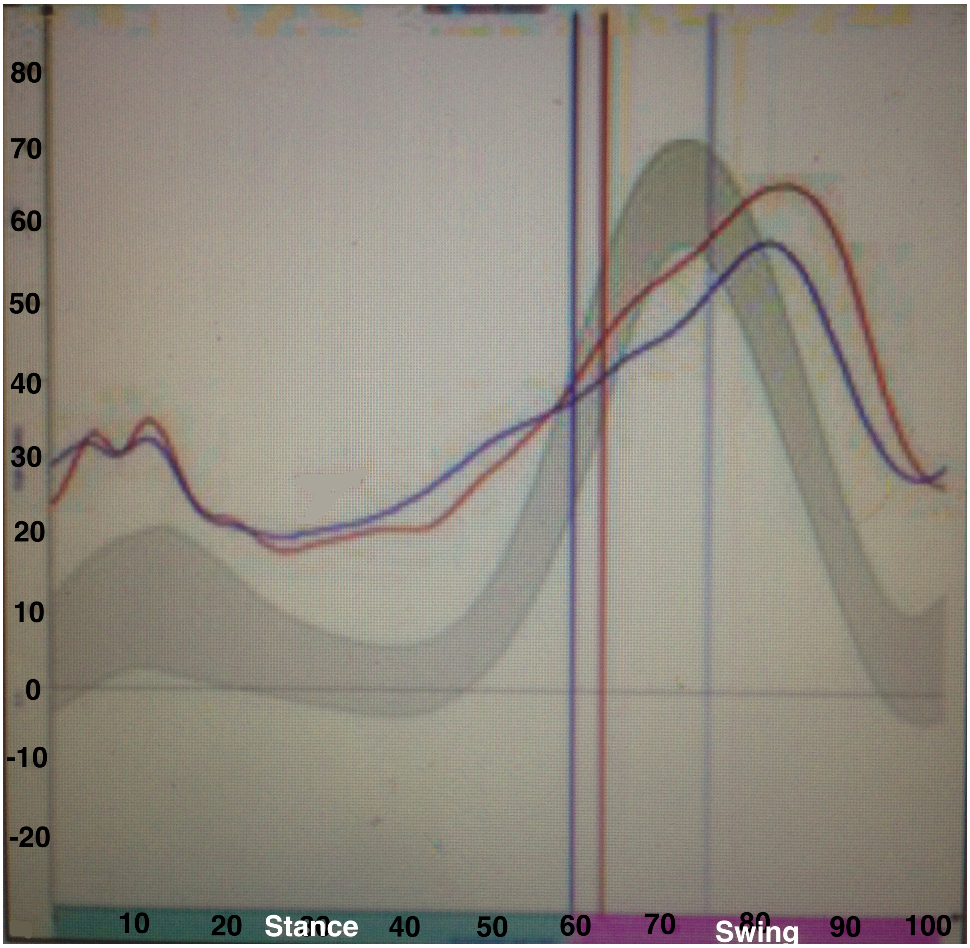

Figure 3.4 Knee Extension over Time

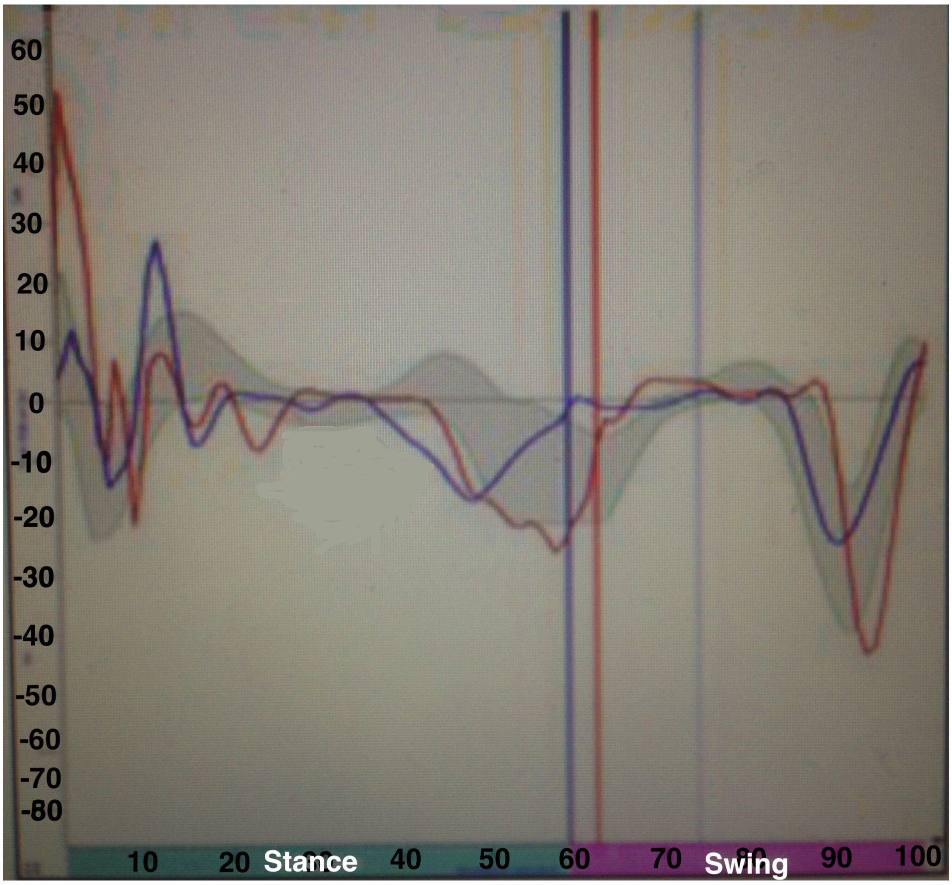

Figure 3.5 Knee Power over Time

on the correlation coefficients, and they are often denoted as p or r. Covariance of two variables divided by the product of their standard deviations (SD) gives the correlation coefficient.

This study uses the most common one of the coefficients, which is known as the Pearson correlation coefficient. It is cognoscible and a very good method to exhibit a linear relationship between two variables [32].

Measure of linear correlation between two variables such as X and Y, in this case the knee power and the FA angle as X anD Y, can be performed with the Pearson coefficient (r, PPMCC, PCC). A value between plus 1 and minus 1 is put into equation inlusively [33].

4. RESULTS

The results of the study are illustrated in this chapter to include for each patient, information about the motion pathology, and knee kinematics and kinetics. The gray areas in the graphs mark the normalized data of healthy subjects.

4.1 Patient 1 – A.E.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.1.1 Patient Information

4.1.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=1.523 sec, during the stance phase. The right knee power value at t=1.523 sec equals -0.078. The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.513 sec, during the stance phase. The left knee power value at t=1.513 sec equals -0.037. The patient is taking his steps with an increased knee flexion. The right knee is not in an adequate amount of extension during the mid-stance phase. The right foot does the first contact with the floor with the forefoot. There is increased flexion at the left hip and the knee during first contact. The left hip is not in maximum extension at the terminal stance phase. The left foot does the first contact with the entire sole. Knee flexion is increased for both knees during the heel strike. Flexor moment is also increased at the heel strike. Both knees suffer from late or inadequate knee flexion. The kinematic graphs should show the maximum extension to point out the power at that second for a relation between FA angle and knee power. But the knee is not at its full extension as the video analysis shows.

Table 4.1
Results of all patients

	Femoral Anteversion (°)		Knee Power (w)			Y.O.	20	30	t=2.238	t=1.188
A.E.	Right	Left	Right	Left					-0.037	-0.097
	30	20	t=1.523	t=1.513		Y.E.S.	75	70	t=2.937	t=8.085
			-0.078	-0.037					0.001	-0.001
B.E.	40	30	t=2.804	t=2.354		Z.B.	60	50	t=2.632	t=1.919
			0.038	-0.063					0.186	-0.101
C.T.	40	45	t=2.132	t=2.513		E.Z.Y.	30	45	t=2.623	t=1.697
			-0.027	0.155					-0.011	0.047
E.E.	50	40	t=3.264	t=3.591		S.E.	30	30	t=1.452	t=2.056
			-0.044	-0.043					0.124	-0.007
E.S.	50	55	t=1.708	t=1.708		B.Y.	30	40	t=2.554	t=3.236
			-0.031	0.101					0.089	0.012
G.K.	30	40	t=3.16	t=2.435		E.Y.	25	25	t=2.730	t=3.874
			0	-0.034					0.051	-0.143
G.Y.	40	60	t=5.45	t=6.285		İ.S.	45	30	t=1.989	t=2.795
			0.002	-0.014					0.083	0.021
H.A.	55	50	t=3.379	t=3.884		Y.H.	30	40	t=3.187	t=3.732
			0.538	-0.047					0.049	-0.024
K.M.Y.	17	10	t=2.242	t=1.687		N.A.	40	25	t=1.506	t=1.948
			-0.073	0.029					0.172	0.057
M.G.	40	40	t=1.453	t=1.887		B.K.	20	30	t=4.252	t=3.799
			-0.041	-0.068					-0.051	-0.04
S.T.O.	60	50	t=2.920	t=2.574						
			0.03	0.008						
T.G.	40	50	t=2.746	t=2.455						
			-0.056	-0.044						

Table 4.2
Patient Information of A.E.

Name:A.E.	
Age:12	
Sex:Male	
History: Diagnosed with CP when 1-year-old and started crawling on all fours	
CP classification:Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 115°/ 115°	Flexion: 130°/ 130°
Extension: 10°/ 10°	Extension: -23°/ -10°
Abduction: 30°/ 40°	Rectus femoris length: 1cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 10°/ 10°
Internal rotation: Prone: 55°/ 55°	Knee 0°: -10°/ 10°
Supine: 40°/ 40°	Plantar flexion: 50°/ 65°
External rotation: Prone: 45°/ 50°	
Supine: 80°/ 80°	
Alignment	
Femoral anteversion: 30°/ 20°	
Tibia femoral angle: 6.6°/ 6.6°	
Genu valgum:✕	Genu varum:✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor:0/ 0	Hamstring: 2/ 1
Adductor: 0/ 0	Duncan-Ely Test: +/ +
Internal rotator: 0/ 0	Ankle
Extensor: 0/ 0	Dorsi flexion: 4/ 4
Abductor: 0/ 0	Tibialis anterior: 0/ 0
	Plantar flexion: 3/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 75/ 75	
Bicondylar distance: 9.0/ 8.8	
Bimalleolar distance: 6.3/ 6.3	
Weight: 31kg	
Height: 1.40cm	

Figure 4.1 At the lab before the construction, the mid-swing stages from different sides, B. E.

4.1.3 Varus-Valgus Graphs

The varus and valgus stress of A.E. during maximum femoral rotation in stance for the right leg is determined. The femoral rotation reaches its maximum at t=1.301 sec. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of A.E. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=1.989 sec. The left leg rotation graph is investigated at this maximum point, of the stance phase in order to see whether the valgus strees occurs at that time.

4.2 Patient 2 – B.E.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.3
Patient Information of B. E

Name: B.E.	
Age: 12	
Sex: Male	
History: Diagnosed with CP when few months, has a CP diagnosed twin	
CP classification: Quadriplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/ 110°	Flexion: 125°/ 115°
Extension: 10°/ 12°	Extension: -10°/ 0°
Abduction: 45°/ 45°	Rectus femoris length: 1cm/ 1cm
Adduction: Hip 0°-Knee 0°: 25°/ 30°	Ankle
Hip 0°-Knee 90°: 25°/ 30°	Dorsi flexion: Knee 90°: -5°/ 8°
Internal rotation: Prone: 10°/ 20°	Plantar flexion: -20°/ -5°
Supine: 10°/ 20°	
External rotation: Prone: 10°/ 10°	
Supine: 10°/ 10°	
Alignment. R/L	
Femoral anteversion: 40°/ 30°	
Tibia femoral angle: -10°/ -5°	
Genu valgum: ✕	Genu varum: +
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 0/ 0	Hamstring: 1/ 0
Adductor: ✕	Duncan-Ely Test: +/ +
Internal rotator: 1/ 1	Ankle
Extensor: 0/ 1	Dorsi flexion: 0/ 0
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: 3/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 75/ 75	
Bicondylar distance: 8.7/ 8.8	
Bimalleolar distance: 6.4/ 6.4	
Weight: 32kg	
Height: 1.40cm	

4.2.1 Patient Information

4.2.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.804 sec, during the stance phase. The right knee power value at t=2.804 sec equals 0.038. The left knee angle graph of the patient shows the maximum knee extension occurs at t=2.354 sec, during the stance phase. The left knee power value at t=2.354 sec equals -0.063.

Although the left knee flexion looks right at the first heel strike, it goes to hyperextension during the loading response. The left knee flexion decreases during the swing phase. Right knee flexion is increased on the first heel strike and doesn't show full extension during the mid-stance. The dorsiflexion increase on both of the ankles is seen on the evaluation form and grahics but it isn't compatible with the video analysis. This finding on the kinematic graphics can be because of the false placement of the retro-reflective markers.

If the power is a negative value on the kinetic graphs, the knee is absorbing the power. If it is positive then the power is generated as a healthy child. Here while the subject's right knee can generate power, the left knee performs absorption of the power. The kinetics graphs show increment on knee flexion, so this finding could denote a relationship between the increase in knee flexion and the knee kinetics, which concludes to FA effect on knee power. The covariance coefficient may apply here.

4.2.3 Varus-Valgus Graphs

The varus and valgus stress of B.E. during maximum femoral rotation in stance for right leg is determined. Femoral rotation reaches its maximum at t=3.234. The right leg rotation graph is investigated at the maximum point, of the stance period in order to see whether the valgus sress occurs at the time. The varus and valgus stress of

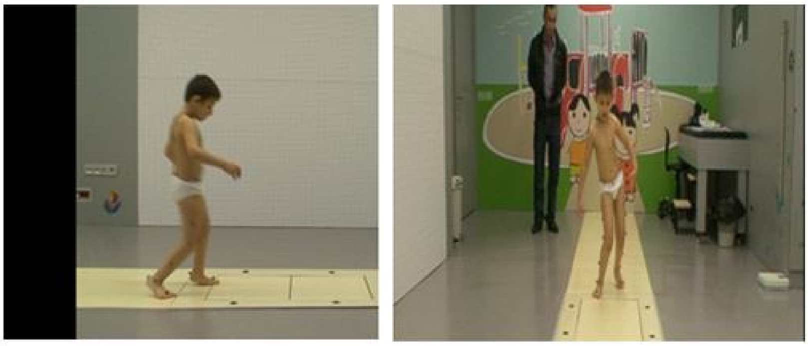

Figure 4.2 The patient's gait from different sides, C.T.

B.E. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=2.760. The left rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.3 Patient 3 – C.T.

4.3.1 Patient Information

4.3.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.132 sec, during the stance phase. The right knee power value at t=2.132 sec equals -0.027. The left knee angle graph of the patient shows the maximum knee extension occurs at t=2.513 sec, during the stance phase. The left knee power value at t=2.513 sec equals 0.155.

Knees are in flexion on the first heel strike, which is very visible especially on the right knee and they don't do the extension during the mid-stance phase. Left foot isn't capable of doing the heel strike. The knee flexion increases on the first contact. Dorsiflexion is seen on the kinematic graphics although video analysis doesn't show the

Table 4.4
Patient Information of C.T.

Name:C.T.	
Age:7	
Sex:Male	
History:Diagnosed with CP. First born, late baby cry after birth.	
CP classification: Quadriplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 100°/ 100°	Flexion: 130°/ 130°
Extension: 10°/ 12°	Extension: -10°/ -10°
Abduction: 45°/ 45°	Rectus femoris length: 0cm/ 3cm
Adduction: Hip 0°-Knee 0°: 40°/ 35°	Ankle
Hip 0°-Knee 90°: 40°/ 35°	Dorsi flexion: Knee 90°: 20°/ -20°
Internal rotation: Prone: 65°/ 55°	Plantar flexion: 40°/ 40°
Supine: 65°/ 55°	
External rotation: Prone: 40°/ 40°	
Supine: 40°/ 40°	
Alignment, R/L	
Femoral anteversion: 40°/ 45°	
Tibia femoral angle: 0°/ 5°	
Genu valgum: ×	Genu varum:×
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ×/ 2	Hamstring: 0/ 2
Adductor: ×	Duncan-Ely Test: -/ +
Internal rotator: 0/ 0	Ankle
Extensor: 0/ 0	Dorsi flexion: 0/ 0
Abductor: ×	Tibialis anterior: ×
	Plantar flexion: 2/2
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 60/ 60	
Bicondylar distance: 8.5/ 9.0	
Bimalleolar distance: 5.5/ 5.5	
Weight: 21kg	
Height: 1.16cm	

Figure 4.3 The patient's gait from different sides, E.E.

left heel strike. There may be two reasons for this; firstly the anterior tilt of the pelvis and secondly the stance of the tibia, which is toward front because of the knee-flexion.

4.4 Patient 4 – E.E.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.4.1 Patient Information

4.4.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=3.264 sec, during the stance phase. The right knee power value at t=3.264 sec equals -0.044. The left knee angle graph of the patient shows the maximum knee extension occurs at t=3.591 sec, during the stance phase. The left knee power value at t=3.591 sec equals -0.043.

Patient completes the gait with the head in front and also increased arms and trunk swings. It is seen that pelvic oblicity and rotation is increased. Both hips are in IR in the stance phase and the right hip performs abduction during the swing phase.

Table 4.5
Patient Information of E.E.

Name: E.E.	
Age: 11	
Sex: Male	
History:Diagnosed with CP when 3-years-old for starting to walk late.	
CP classification: Quadriplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/ 110°	Flexion: 135°/ 135°
Extension: 20°/ 20°	Extension: -5°/ -10°
Abduction: 40°/ 30°	Rectus femoris length: 3cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 30°/ 20°
Internal rotation: Prone: 30°/ 45°	Plantar flexion: 30°/ 20°
Supine: 30°/ 45°	
External rotation: Prone: 50°/ 50°	
Supine: 50°/ 50°	
Alignment, R/L	
Femoral anteversion: 50°/ 40°	
Tibia femoral angle: -20°/ -13°	
Genu valgum: +	Genu varum:✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor:2/ 2	Hamstring: 3/ 3
Adductor: 3/ 3	Duncan-Ely Test: +/ +
Internal rotator: 1/ 1	Ankle
Extensor: 0/ 0	Dorsi flexion: 0/ 0
Abductor: ✕	Tibialis anterior:✕
	Plantar flexion: 3/ 2
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 77.5/ 77.5	
Bicondylar distance: 8.0/ 8.0	
Bimalleolar distance: 6.5/ 6.5	
Weight: 29kg	
Height: 1.33cm	

Additionally both of the patellas are inwards. There is increased flexion on the right knee on the kinematic graphics on the heel strike and there is no maximum extension during the terminal swing.

And added that while right knee is in flexion on the heel strike, it doesn't have the maximum extension at the mid-stance phase. Also it is observed that heels strike earlyin the mid-stance phase. Inadequate dorsiflexion is conferred in the right and left feet during the swing phase. Whilst increased flexion is seen at the left hip on the first contact, it doesn't have the maximum extension at the terminal stance phase. On the contrary while left knee goes through the first contact with an increased flexion as the left hip, it can't reach to the maximum extension at the mid-stance phase. When the time and distance parameters are evaluated; cadence and velocity decline, the double support phase elongation, single step and stride length shortenings are noticed.

It is also seen in the kinetic graphs that there is insufficient power generation during the pre-swing phase on both feet and ankles. This is considerable information to take into account whilst the constitution of the treatment plan for this patient.

4.5 Patient 5 – E.S.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.5.1 Patient Information

4.5.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=1.708 sec, during the stance phase. The right knee power value at t=1.708 sec equals -0.031. The left knee angle graph of the patient shows the maximum

Table 4.6
Patient Information of E.S.

Name:E.S.	
Age: 11	
Sex: Male	
History: Early delivery, diagnosed with CP when 15-months-old	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 125°/ 125°	Flexion: 130°/ 130°
Extension: 10°/ 15°	Extension: 0°/ 0°
Abduction: 40°/ 40°	Rectus femoris length: 1cm/ 1cm
Adduction: Hip 0°-Knee 0°: 40°/ 40°	Ankle
Hip 0°-Knee 90°: 40°/ 40°	Dorsi flexion: Knee 90°: 30°/ 25°
Internal rotation: Prone: 30°/ 45°	Plantar flexion: 50°/ 50°
Supine: 30°/ 45°	
External rotation: Prone: 50°/ 50°	
Supine: 50°/ 50°	
Alignment, R/L	
Femoral anteversion: 50°/ 55°	
Tibia femoral angle: 0°/ 0°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: ✕
Adductor: ✕	Duncan-Ely Test: +/ +
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 0/ 0
Abductor: ✕	Tibialis anterior: 1/ 2
	Plantar flexion: 1/ 1
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 79/ 79	
Bicondylar distance: 8.4/ 8.4	
Bimalleolar distance: 6.6/ 6.6	
Weight: 29kg	
Height: 1.44cm	

knee extension occurs at t=1.708 sec, during the stance phase. The left knee power value at t=1.708 sec equals 0.101.

Hips and knees are in flexion at both sides during the swing phase. Especially right knee extension seems adequate at the terminal swing phase. The dorsiflexion of the ankles increased on the first contact and the plantar flexion of the ankles decreased during the pre-swing. Additionally; 1st, 2nd and the 3rd rockers are compeleted with success. There is increased flexion on both knees on the kinematic graphics during the first contact and there is a minimal increased flexion on the first contact during the terminal swing.

There is increased EMG activity on both of the hamstrings, which can be visualized more on the right knee. Although the kinematic graphics, video analysis and the EMG data supports the hamstring spasticity, the result of the physical examination which is done for the hamstring's spasticity is 0 and in normal, healthy ranges. Furthermore the effect of hamstring spasticity can be seen on the FA angle as much as the walking quality through video analysis and the kinetic/ kinematic graphics.

The patient's gait seems adequate. The muscle strength and normal motion gaps are in acceptable ranges. The FA pathology has an effect on the patient's gait and the knee power that can be seen both on video analysis and the kinematic graphics is the tibialis posterior spasticity. In this case it is seen that FA angle and spasticity at different areas (i.e., tibialis posterior) has a negative effect on knee power.

4.5.3 Varus-Valgus Graphs

The varus and valgus stress of E.S. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=2.096. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of E.S. during maximum femoral rotation in stance for left leg is determined.

Figure 4.4 At the lab before the construction, the patient's gait from different sides, G.K.

The femoral rotation reaches its maximum at t=1.559. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.6 Patient 6 – G.K.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.6.1 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=3.16 sec, during the stance phase. The right knee power value at t=3.16 sec equals -0.000. The left knee angle graph of the patient shows the maximum knee extension occurs at t=2.435 sec, during the stance phase. The left knee power value at t=2.435 sec equals -0.034.

The left and right knees are in increased flexion during the initial contact and they aren't capable of extension during the mid-stance. The left and right knee flexion seems inadequate during the swing phase. Both knees are in flexion during terminal swing. Right foot also does the heel strike as the initial contact. There is increased

Table 4.7
Patient Information of G.K

Name: G.K.	
Age: 12	
Sex: Male	
History: Diagnosed with CP when 4-years-old for developmental retardation.	
CP classification:Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 105°/ 100°	Flexion: 110°/ 100°
Extension: 0°/ 10°	Extension: 0°/ 0°
Abduction: 25°/ 28°	Rectus femoris length: 3cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 0°/ 10°
Internal rotation: Prone: 23°/ 20°	Plantar flexion: 40°/ 40°
Supine: 23°/ 20°	
External rotation: Prone: 12°/ 10°	
Supine: 15°/ 10°	
Alignment, R/L	
Femoral anteversion: 30°/ 40°	
Tibia femoral angle: -15°/ -10°	
Genu valgum: ×	Genu varum: ×
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ×	Hamstring: 0/ 0
Adductor: 0/ 0	Duncan-Ely Test: +/ +
Internal rotator: ×	Ankle
Extensor: 0/ 0	Dorsi flexion: ×
Abductor: 0/ 0	Tibialis anterior: ×
	Plantar flexion: 3/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 88/ 88.5	
Bicondylar distance: 12.5/ 12.5	
Bimalleolar distance: 7/ 7	
Weight: 60kg	
Height: 1.55cm	

anterior pelvic tilt that can be seen via video analysis and the kinematic graphics. Bilateral rectus spasticity exists because increased knee flexion and the lack of knee extension at right and left knees, which can be seen via video analysis and the kinematic graphics. The improportionate power generation that is shown in the kinetic graphics and the rectus spasticity occurs at this subject who suffers from increased FA angle.

4.6.2 Varus-Valgus Graphs

The varus and valgus stress of G.K. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=3.163. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of G.K. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=2.643. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.7 Patient 7 – G.Y.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.7.1 Patient Information

4.7.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=5.45 sec, during the stance phase. The right knee power value at t=5.45 sec equals 0.002. The left knee angle graph of the patient shows the maximum

Table 4.8
Patient Information of G.Y.

Name: G.Y.	
Age: 16	
Sex: Female	
History: Diagnosed with CP, late baby cry after birth, asphyxia	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 120°/ 105°	Flexion: 130°/ 135°
Extension: 5°/ 10°	Extension: 0°/ -20°
Abduction: 40°/ 30°	Rectus femoris length: 3cm/ 1cm
Adduction: Hip 0°-Knee 0°: 40°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 20°	Dorsi flexion: Knee 90°: 0°/ -30°
Internal rotation: Prone: 65°/ 80°	Plantar flexion: 60°/ 50°
Supine: 65°/ 80°	
External rotation: Prone: 25°/ 30°	
Supine: 25°/ 30°	
Alignment, R/L	
Femoral anteversion: 40°/ 60°	
Tibia femoral angle: 0°/ 0°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: ✕/ 4
Adductor: 2/ 3	Duncan-Ely Test: +/ +
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: ✕
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: 3/ 4
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 82/ 82	
Bicondylar distance: 8.5/ 9.0	
Bimalleolar distance: 5/ 5.5	
Weight: 38kg	
Height: 1.48cm	

knee extension occurs at t=6.285 sec, during the stance phase. The left knee power value at t=6.285 sec equals -0.014.

The gait's balance is decreased and the power consumption isn't as expected. Both hips are in IR and adduction during the terminal stance. IR is affected from FA angle as seen on kinetic graphics.

Right and left extremities are in IR during the terminal stance. As other CP children with an IFA angle, right and left knees do the initial contact with an increased flexion and they aren't capable of adequate extension during mid-stance phase. During the investigation of the swing phase, knee flexion is shown as decreased.Bilateral FA occurrence is seen and it has two evidences; first one is that the right and left hips being in IR. This finding is also compatible with the video analysis and observed more on the right hip. Second of all, FA is both of the foot stride angles are seen in internal in the kinematics graphics and the video analysis.

Both knees are in increased flexion on the initial contact in the kinematics graphic. It is thought that this finding depends on the hip flexor spasticity and the contracture of the ankle plantar-flexor of both feet.

4.8 Patient 8 – H.A.

4.8.1 Patient Information

4.8.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=3.379 sec, during the stance phase. The right knee power value at t=3.379 sec equals 0.538. The left knee angle graph of the patient shows the maximum knee extension occurs at t=3.884 sec, during the stance phase. The left knee power

Table 4.9
Patient Information of H.A.

Name: H.A.	
Age: 11	
Sex: Female	
History: Diagnosed with CP when 52-days-old when came to hospital with heart disease	
CP classification:Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 100°/ 120°	Flexion: 125°/ 135°
Extension: 15°/ 10°	Extension: 10°/ 20°
Abduction: 45°/ 20°	Rectus femoris length: 1cm/ 0cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 20°	Dorsi flexion: Knee 90°: 10°/ 10°
Internal rotation: Prone: 60°/ 80°	Plantar flexion: 45°/ 50°
Supine: 60°/ 80°	
External rotation: Prone: 20°/ 30°	
Supine: 20°/ 30°	
Alignment, R/L	
Femoral anteversion: 55°/ 50°	
Tibia femoral angle: 5°/ 0°	
Genu valgum: ×	Genu varum: +
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ×	Hamstring: ×
Adductor: 2/ 2	Duncan-Ely Test: +/ +
Internal rotator: ×	Ankle
Extensor: ×	Dorsi flexion: ×
Abductor: ×	Tibialis anterior: ×
	Plantar flexion: 3/ ×
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 74/ 74	
Bicondylar distance: 8/ 8	
Bimalleolar distance: 6/ 5.5	
Weight: 31kg	
Height: 1.35cm	

Figure 4.5 At the lab before the construction, the patient's gait from different sides, H.A.

value at t=3.884 sec equals -0.047.

Right patella is inward during the mid-stance. Left foot stride angle is neutral and right foot stride angle is in internal position. Left hip, knee and ankle angles seem normal throughout the gait. Right hip and right knee angles seem normal on the initial contact during the mid-stance phase. Right foot does the initial contact with the heel strike and goes into plantar-flexion position quickly. The occurrence of right gastrosoleus spasticity depends on the lack of first rocker movement of the right ankle in the kinematics graphic and double bump moment pattern of the right ankle in the kinetics graphic. And added that the generation of power in the right ankle decreases more then the power generation of left ankle and still stays in the normal range, so that is another reason for the right gastrosoleus spasticity and the changes in the knee power.

4.9 Patient 9 – K.M.Y.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.10
Patient Information of K.M.A.

Name: K.M.Y.	
Age: 10	
Sex: Male	
History: Diagnosed with CP when 10-months-old via MR	
CP classification:Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 90°/ 80°	Flexion: 128°/ 124°
Extension: 20°/ 20°	Extension: -30°/ -30°
Abduction: 30°/ 23°	Rectus femoris length: 2cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 0°/ 0°
Internal rotation: Prone: 17°/ 20°	Plantar flexion: 50°/ 50°
Supine: 17°/ 20°	
External rotation: Prone: 8°/ 8°	
Supine: 8°/ 8°	
Alignment, R/L	
Femoral anteversion: 17°/ 10°	
Tibia femoral angle: -20°/ -20°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 2/ 2	Hamstring: 3/ 3
Adductor: 2/ 2	Duncan-Ely Test: +/ +
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: ✕
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: 2/ 2
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 70/ 70	
Bicondylar distance: 8.5/ 8.5	
Bimalleolar distance: 6/ 6	
Weight: 25kg	
Height: 1.30cm	

Figure 4.6 At the lab before the construction, the patient's gait from different sides, K.M.Y.

4.9.1 Patient Information

4.9.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.242 sec, during the stance phase. The right knee power value at t=2.242 sec equals -0.073.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.687 sec, during the stance phase. The left knee power value at t=1.687 sec equals 0.029.

Both of the knees are in flexion on the initial contact, which is more appearent on the right knee, and they aren't capable of full extension during the mid-stance phase. Knees don't have capacity to reach adequate flexion during the swing phase. Bilateral hamstring contracture occurs because increment of knee flexion is observed on the initial contact. Bilateral rectus spasticity occurrence is based on the retarded maximum knee flexion during the pre-swing phase and inadequate knee extension during mid-stance and terminal swing phases.

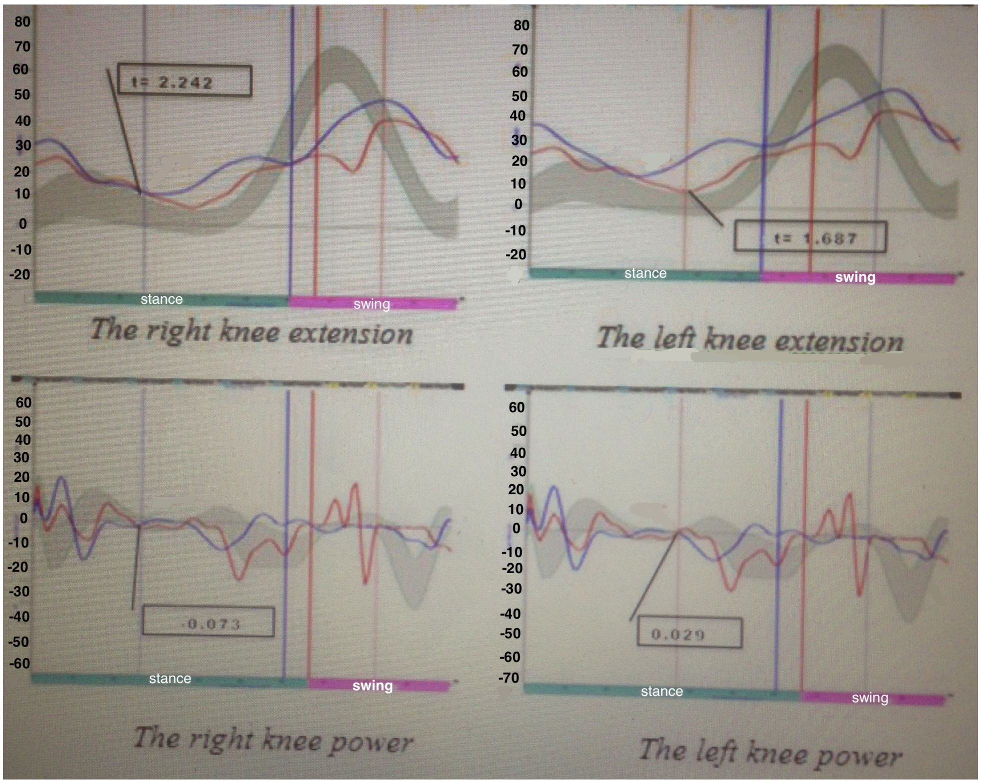

Figure 4.7 Knee extension and knee power of K.M.Y.

4.10 Patient 10 – M.G.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.10.1 Patient Information

4.10.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=1.453 sec, during the stance phase. The right knee power value at t=1.453 sec equals -0.041. The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.887 sec, during the stance phase. The left knee power value at t=1.887 sec equals -0.068.

Table 4.11
Patient Information of M.G.

Name: M.G.	
Age: 5	
Sex: Male	
History: Diagnosed with CP when 2-years-old when he started walking late	
CP classification:(Left) Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 130°/ 130°	Flexion: 120°/ 120°
Extension: 15°/ 15°	Extension: 0°/ 0°
Abduction: 35°/ 20°	Rectus femoris length: 1cm/ 2cm
Adduction: Hip 0°-Knee 0°: 45°/ 45°	Ankle
Hip 0°-Knee 90°: 45°/ 45°	Dorsi flexion: Knee 90°: 10°/ 10°
Internal rotation: Prone: 40°/ 40°	Plantar flexion: 60°/ 70°
Supine: 40°/ 60°	
External rotation: Prone: 60°/ 50°	
Supine: 70°/ 80°	
Alignment, R/L	
Femoral anteversion: 40°/ 40°	
Tibia femoral angle: 10°/ 10°	
Genu valgum: +	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: 0/ 0
Adductor: ✕	Duncan-Ely Test: -/ +
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 0/ 0
Abductor: ✕	Tibialis anterior: ✕/ 2
	Plantar flexion: ✕/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 52/ 52.5	
Bicondylar distance: 7.8/ 8.1	
Bimalleolar distance: 4.8/ 5.1	
Weight: 17kg	
Height: 1.06cm	

Figure 4.8 At the lab, photos of the patient S.T.O

Patient has the capacity to walk independently in normal circumstances but the excitement during marker placement preparation showed some effect. The guardian was asked to hold but not to give support. Both of the patellas are outwards. Right knee is in increased flexion on the initial contact, it's capable of extension during mid-stance. There is peak flexion at the right knee during swing phase. Left knee is in hyperextension at the moment initial contact happens. Left knee flexion during the swing phase seems decreased. The first rocker is not completed and the heel strike is delayed distinctively during the mid-stance. Genu varum at left knee depends on the hyperextension of knee and the increased flexor moment during mid-stance. Physical examination shows that knee flexor strength is can't be evaluated because of the pelvic elevation.

4.11 Patient 11 – S.T.O.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.12
Patient Information of S.T.O..

Name:S.T.O.	
Age: 12	
Sex: Male	
History:Early birth, diagnosed with CP when had an epilepsy seizure at 3-months-old	
CP classification:	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/ 110°	Flexion: 120°/ 115°
Extension: 0°/ 0°	Extension: -5°/ -5°
Abduction: 40°/ 40°	Rectus femoris length: 2cm/ 1cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 5°/ 10°
Internal rotation: Prone: 15°/ 20°	Plantar flexion: 50°/ 50°
Supine: 15°/ 20°	
External rotation: Prone: 15°/ 15°	
Supine: 15°/ 15°	
Alignment, R/L	
Femoral anteversion: 60°/ 50°	
Tibia femoral angle: 20°/ 20°	
Genu valgum: ×	Genu varum: +
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ×	Hamstring: 2/ 2
Adductor: ×	Duncan-Ely Test: +/ +
Internal rotator: ×	Ankle
Extensor: ×	Dorsi flexion: 0/ 0
Abductor: ×	Tibialis anterior: 0/ 0
	Plantar flexion: 3/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 53.5/ 54	
Bicondylar distance: 8.5/ 8.5	
Bimalleolar distance: 5.5/ 5.5	
Weight: 19kg	
Height: 1.05cm	

4.11.1 Patient Information

4.11.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.920 sec, during the stance phase. The right knee power value at t=2.920 sec equals 0.030. The left knee angle graph of the patient shows the maximum knee extension occurs at t=2.574 sec, during the stance phase. The left knee power value at t=2.574 sec equals 0.008.

Both of the patellas are inwards during the mid-stance phase. Knees are in increased flexion on the initial contact and they are suddenly in extension at the moment when the loading response starts. The knee flexion at the swing phase seems adequate. Bilateral hamstring spasticity is based on the increment of knee flexion on the initial contact and during the swing phase. The increased knee flexion at initial contact and swing phase is more distinctive at the left knee. Kinematics graphic shows the increase in knee flexion.

4.12 Patient 12 – T.G.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.12.1 Patient Information

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.746 sec, during the stance phase. The right knee power value at t=2.746 sec equals -0.056.

The left knee angle graph of the patient shows the maximum knee extension

Table 4.13
Patient Information of T.G.

Name:T.G.	
Age: 14	
Sex: Female	
History:Doctors asserted the handicap before birth, diagnosed with CP at 1.5-year-old	
CP classification:	
Range of Motion, R/L	
Hips	Knee
Flexion: 80°/ 95°	Flexion: 80°/ 95°
Extension: 10°/ 10°	Extension: -10°/ -10°
Abduction: 30°/ 40°	Rectus femoris length: 2cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: -10°/ -10°
Internal rotation: Prone: 12°/ 20°	Plantar flexion: 60°/ 60°
Supine: 12°/ 20°	
External rotation: Prone: 20°/ 20°	
Supine: 20°/ 20°	
Alignment, R/L	
Femoral anteversion: 40°/ 50°	
Tibia femoral angle: 12°/ 10°	
Genu valgum: ×	Genu varum: +
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 2/ 2	Hamstring: 2/ 3
Adductor: ×	Duncan-Ely Test: +/ +
Internal rotator: 0/ 2	Ankle
Extensor: ×	Dorsi flexion: 0/ 0
Abductor: 2/ 2	Tibialis anterior: 0/ 0
	Plantar flexion: 4/ 4
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 83/ 83	
Bicondylar distance: 9.5/ 9.5	
Bimalleolar distance: 6/ 6	
Weight: 39kg	
Height: 1.57cm	

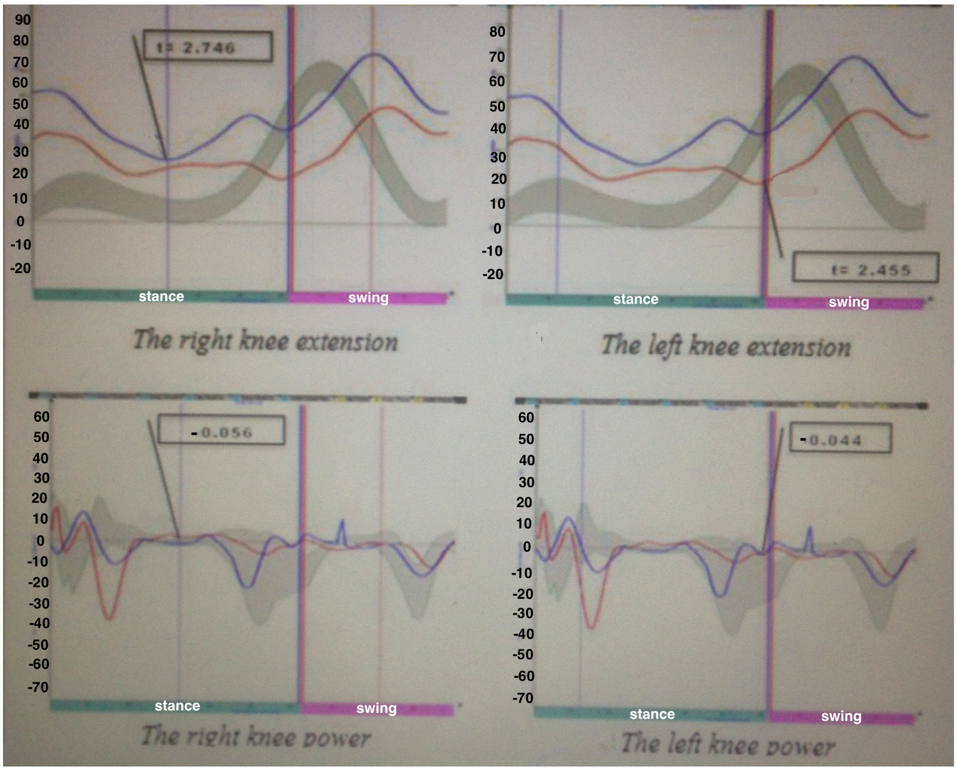

Figure 4.9 Knee extension and knee power of T.G.

occurs at t=2.455 sec, during the stance phase. The left knee power value at t=2.455 sec equals -0.044

Both of the patellas are inwards during the mid-stance phase. Right knee is in increased flexion on the initial contact, it's capable of extension during mid-stance. A peak point occurs when flexion is concerned at the right knee during swing phase. At the moment initial contact happens left knee emerges in hyperextension. Adequate knee flexion at the left during the swing phase is observable. The increased knee flexion at initial contact and swing phase is more distinctive at the right knee. Kinematics graphic shows increment in knee flexion duration.

4.13 Patient 13 – Y.O.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Figure 4.10 At the lab before the construction, the patient's gait, Y.O.

4.13.1 Patient Information

4.13.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.238 sec, during the stance phase. The right knee power value at t=2.238 sec equals -0.037. The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.188 sec, during the stance phase. The left knee power value at t=1.188 sec equals -0.097.

Both of the patellas are inwards during the mid-stance phase. Knees perform the energy absorption via increased flexion on the initial contact. They are also capable of extension during mid-stance. During the swing phase, decrease in knee flexion capacity is observable. These findings designate the presense of the hamstring spasticity. Kinetics graphic couldn't be evaluated because of the anomaly of the patient.

4.14 Patient 14 – Y.E.S.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.14
Patient Information of Y.O..

Name:Y.O.	
Age:5	
Sex: Male	
History:Diagnosed with CP at 9-months-old after a routine control in hospital at 6-months-old	
CP classification:Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 80°/87°	Flexion: 80°/ 95°
Extension: 10°/ 5°	Extension: -10°/ -10°
Abduction: 25°/ 20°	Rectus femoris length: 2cm/ 2cm
Adduction: Hip 0°-Knee 0°: 30°/ 25°	Ankle
Hip 0°-Knee 90°: 30°/ 25°	Dorsi flexion: Knee 90°: -10°/ -10°
Internal rotation: Prone: 15°/ 10°	Plantar flexion: 60°/ 60°
Supine: 15°/ 10°	
External rotation: Prone: 10°/ 10°	
Supine: 10°/ 10°	
Alignment, R/L	
Femoral anteversion: 20°/ 30°	
Tibia femoral angle: 12°/ 10°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 2/ 2	Hamstring: 2/ 3
Adductor: ✕	Duncan-Ely Test: +/ +
Internal rotator: 0/ 2	Ankle
Extensor: ✕	Dorsi flexion: 0/ 0
Abductor: 2/ 2	Tibialis anterior: 0/ 0
	Plantar flexion: 4/ 4
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 54/ 54.5	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 18kg	
Height: 1.07cm	

Table 4.15
Patient Information of Y.E.S.

Name:Y.E.S.	
Age: 10	
Sex: Male	
History: Early birth, diagnosed with CP at 1.5-years-old when he started walking late	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 100°/ 105°	Flexion: 130°/ 135°
Extension: 10°/ 10°	Extension: -20°/ -30°
Abduction: 10°/ 5°	Rectus femoris length: 3cm/ 3cm
Adduction: Hip 0°-Knee 0°: 25°/ 20°	Ankle
Hip 0°-Knee 90°: 25°/ 20°	Dorsi flexion: Knee 90°: 0°/ -15°
Internal rotation: Prone: 30°/ 25°	Plantar flexion: 50°/ 50°
Supine: 30°/ 25°	
External rotation: Prone: 25°/ 25°	
Supine: 25°/ 25°	
Alignment, R/L	
Femoral anteversion: 75°/ 70°	
Tibia femoral angle: 0°/ 0°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 1/ 1	Hamstring: 2/ 2
Extensor: 1/ 1	Duncan-Ely Test: +/ +
Abductor: ✕	Ankle
Adductor: 3/ 3	Dorsi flexion: 0/ 0
Internal rotator: 2/ 2	Tibialis anterior: ✕
	Plantar flexion: 2/ 2
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 60/ 60	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5.5/ 5.5	
Weight: 20kg	
Height: 1.14cm	

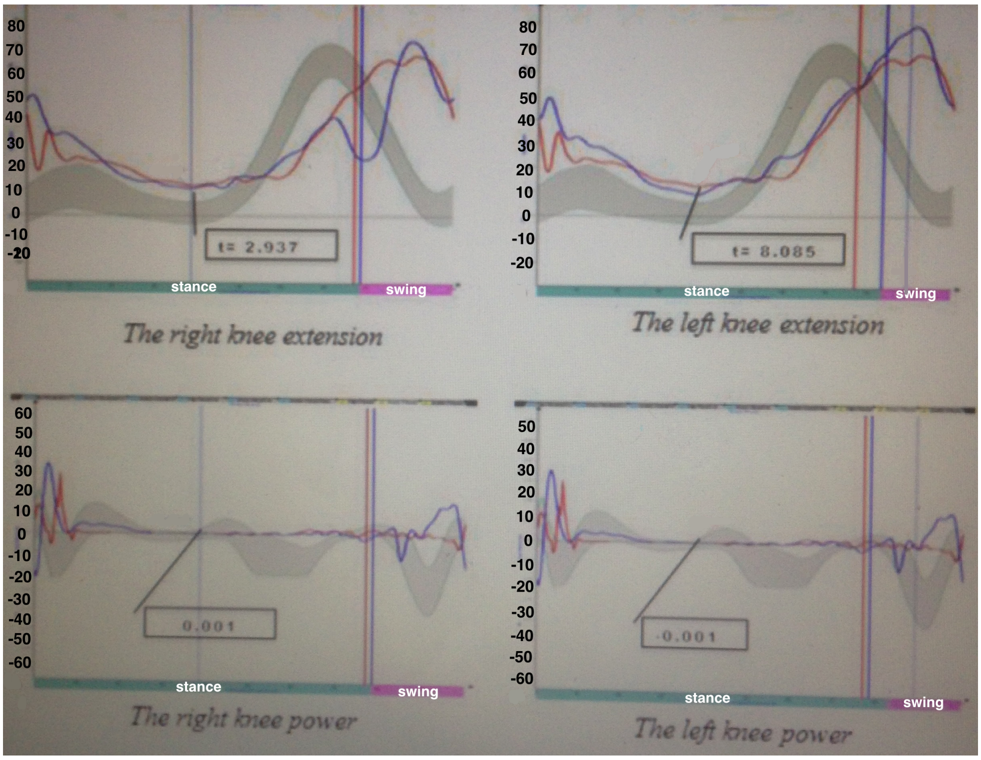

Figure 4.11 Knee extension and knee power of Y.E.S.

4.14.1 Patient Information

4.14.2 Knee Extension and Knee Power of Y.E.S.

The maximum extension occurs at 2.937th second of the stance period for the right knee. The right knee power value at t=2.937 sec equals 0.001. The left knee angle graph of the patient shows the maximum knee extension occurs at t=8.085 sec, during the stance phase. The left knee power value at t=8.085 sec equals -0.001.

The balance of the gait seemed clearly affected by CP and deteriorating so the gait could only be completed with the support of two assistants. Both of the patellas are inward during the mid-stance phase. It is thought that bilateral pes planovalgus deformity occurred. The support that the patient carried along during the gait avoided the evaluation of the joint movements on the sagittal plan. The hips are capable of extension during mid-stance. Knees perform with an increased flexion on the initial contact and show extension during mid-stance. Push-off is decreased during the terminal swing so the hip and knee flexions are increased in order to accomplish the toe-off position. Both knees are in increased flexion on the initial contact and the lack of knee extension during the terminal swing can be seen on kinematics graphics. Additionally, assistant support during the gait affected the kinetics graphics indecipherably.

4.15 Patient 15 – Z.B.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.15.1 Patient Information

4.15.2 Knee Extension and Knee Power

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.632 sec, during the stance phase. The right knee power value at t=2.632 sec equals 0.186. The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.919 sec, during the stance phase. The left knee power value at t=1.919 sec equals -0.101

An increased minimal flexion can be observed when left knee completes the initial contact. The left foot performs the initial contact movement with a heel strike. Both of the patellas are outwards. Knees indicate such volume that they have the maximum extension during the mid-stance phase. Right hip flexion fits into the norms of the initial contact movement and shows adequate extension during terminal stance phase. An increased minimal flexion is in evidence when the right knee executes the initial contact and also during the terminal swing phase maximum extension seems absent. These conditions are compatible with the kinematics graphic. There are two evidences that contribute to a thought that hamstring spasticity is observable. Forwhy bilateral hamstring has spasticity, hamstring spasticity occurs. In addition, the second

Table 4.16
Patient Information of Z.B

Name:Z.B.	
Age: 17	
Sex:Female	
History:Diagnosed with CP at birth, started walking when 1-year-old	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 130°/ 130°	Flexion: 130°/ 135°
Extension: 0°/ 0°	Extension: -40°/ -30°
Abduction: 25°/ 30°	Rectus femoris length: 1cm/ 0cm
Adduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 30°/ 30°	Dorsi flexion: Knee 90°: 10°/ 20°
Internal rotation: Prone: 25°/ 30°	Plantar flexion: 40°/ 30°
Supine: 25°/ 30°	
External rotation: Prone: 12°/ 20°	
Supine: 12°/ 20°	
Alignment, R/L	
Femoral anteversion: 60°/ 50°	
Tibia femoral angle: 10°/ 10°	
Genu valgum: ×/ oksymbol	Genu varum: ×/ oksymbol
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: 2/ 3	Hamstring: 2/ 2
Extensor: 2/ 3	Duncan-Ely Test: +/ +
Abductor: 1/ 2	Ankle
Adductor: ×	Dorsi flexion: 0/ 0
Internal rotator: ×	Tibialis anterior: ×
	Plantar flexion: 3/ 3
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 87/ 87	
Bicondylar distance: 11/ 11	
Bimalleolar distance: 6/ 6	
Weight: 49kg	
Height: 1.59cm	

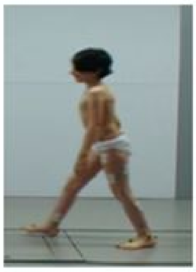

Figure 4.12 At the lab during the tests E.Z.Y.

evidence stands out as popliteal angle measurements. Popliteal angle is 60°on the right side and 50°on the left side. Weakness can be detected at the hip extensors, abductors and knee extensors.

4.16 Patient 16 – E.Z.Y.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.16.1 Patient Information

4.16.2 Knee Extension and Knee Power

The right knee angle graph of the patient shows that the maximum knee extension occurs at t= 2.623 sec, during the stance phase. The right knee power value at t=2.623 sec equals -0.011.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.697 sec, during the stance phase. The left knee power value at t=1.697 sec equals 0.047.

Table 4.17
Patient Information of E.Z.Y.

Name: E.Z.Y.	
Age: 9	
Sex: Female	
History: Diagnosed with CP at her 4th month, because of convulsion	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 120°/ 120°	Flexion: 140°/ 140°
Extension: 20°/ 20°	Extension: 0°/ 0°
Abduction: 25°/ 30°	Rectus femoris length: 0cm/ 1cm
Adduction: Hip 0°-Knee 0°: 60°/ 60°	Ankle
Hip 90°-Knee 90°: 65°/ 65°	Dorsi flexion: Knee 90°: 25°/ 20°
Internal rotation: Prone: 50°/ 70°	Plantar flexion: 50°/ 50°
Supine: 80°/ 75°	
External rotation: Prone: 35°/ 70°	
Supine: 20°/ 70°	
Alignment, R/L	
Femoral anteversion: 30°/ 45°	
Tibia femoral angle: 0°/ 0°	
Genu valgum: ✕/ oksymbol	Genu varum: ✕/ oksymbol
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕/ ✕	Hamstring: ✕/ ✕
Extensor: ✕/ ✕	Duncan-Ely Test: -/ +
Abductor: ✕/ ✕	Ankle
Adductor: ✕	Dorsi flexion: ✕
Internal rotator: ✕	Tibialis anterior: ✕
	Plantar flexion: ✕
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 69,5/ 69,5	
Bicondylar distance: 11/ 11	
Bimalleolar distance: 6/ 6	
Weight: 24 kg	
Height: 1.30 m	

Figure 4.13 At the lab during the tests S. E.

4.16.3 Varus-Valgus Graphs

The varus and valgus stress of E.Z.Y. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=2.519. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of E.Z.Y. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=1.985. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.17 Patient 17 – S.E.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.17.1 Patient Information

4.17.2 Knee Angleand Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t= 1.452 sec, during the stance phase. The right knee power value at

Table 4.18
Patient Information of S.E.

Name:S.E.	
Age: 15	
Sex: Male	
History: Diagnosed with CP	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/ 110°	Flexion: 130°/ 130°
Extension: 10°/ 10°	Extension: -5°/ -5°
Adduction: 40°/ 40°	Rectus femoris length: 1 cm/ 1 cm
Abduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Hip 0°-Knee 90°: 40°/ 30°	Dorsi flexion: Knee 90°: 20°/ 20°
Internal rotation: Prone: 60°/ 45°	Plantar flexion: 50°/ 65°
Supine: 55°/ 40°	
External rotation: Prone: 40°/ 50°	
Supine: 30°/ 50°	
Alignment, R/L	
Femoral anteversion: 30°/ 30°	
Tibia femoral angle: 10°/ 5°	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: 3.80/ 2.75
Extensor: ✕	Duncan-Ely Test: +/ +
Abductor: ✕	Ankle
Adductor: 2/ 2	Dorsi flexion: 5/ 1
Internal rotator: ✕	Tibialis anterior: ✕
	Plantar flexion: 1/ 5
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 85.5/ 85.5	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5.5/ 5.5	
Weight: 39kg	
Height: 1.60cm	

t=1.452 sec equals 0.124.

The left knee angle graph of the patient shows the maximum knee extension occurs at t= 2.056 sec, during the stance phase. The left knee power value at t=2.056 sec equals -0.007

4.17.3 Varus-Valgus Graphs

The varus and valgus stress of S.E. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t= 2.958. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of S.E. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=3.576. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.18 Patient 18 – B.Y.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.18.1 Patient Information

4.18.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t= 2.554 sec, during the stance phase. The right knee power value at t=2.554 sec equals 0.089.

Table 4.19
Patient Information of B.Y

Name:B.Y.	
Age: 10	
Sex: Female	
History: Diagnosed with CP	
CP classification: Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 120°/120°	Flexion: 140°/ 140°
Extension: 20°/ 20°	Extension: 5°/ 5°
Adduction: 50°/ 50°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 70°/ 70°	Ankle
Internal rotation: Prone: 70°/ 65°	Dorsi flexion: Knee 90°: 30°/ 20°
Supine: 80°/ 65°	Plantar flexion: 60°/ 50°
External rotation: Prone: 30°/ 60°	
Supine: 30°/ 60°	
Alignment, R/L	
Femoral anteversion: 30°/ 40°	
Tibia femoral angle: ✕	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: ✕
Adductor: ✕	Duncan-Ely Test: - / -
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 5/ 1
Abductor: ✕	Tibialis anterior: 0/ 2
	Plantar flexion: 0/2
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 75/ 76.5	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 31 kg	
Height: 1.39 m	

The left knee angle graph of the patient shows the maximum knee extension occurs at t=3.236 sec, during the stance phase. The left knee power value at t=3.236 sec equals 0.012.

4.18.3 Varus-Valgus Graphs

The varus and valgus stress of B.Y. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=2.790. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of B.Y. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=3.542. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.19 Patient 19 – E.Y.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.19.1 Patient Information

4.19.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=2.73 sec, during the stance phase. The right knee power value at t=2.73 sec equals 0.051.

The left knee angle graph of the patient shows the maximum knee extension

Table 4.20
Patient Information of E.Y

Name:E.Y.	
Age: 16	
Sex: Female	
History: Diagnosed with CP when she is 4 years old.	
CP classification: Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 125°/125°	Flexion: normal/ normal
Extension: 15°/ 15°	Extension: -50°/ 0°
Adduction: 50°/ 45°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 55°/ 50°	Ankle
Internal rotation: Prone: 65°/ 50°	Dorsi flexion: Knee 90°: -5°/ 25°
Supine: 60°/ 55°	Plantar flexion: 70°/ 60°
External rotation: Prone: 45°/ 70°	
Supine: 30°/ 65°	
Alignment, R/L	
Femoral anteversion: 25°/ 25°	
Tibia femoral angle: 10°eks/ 0°eks	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: 2 / 65°
Adductor: ✕	Duncan-Ely Test: - / -
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: ✕
Abductor: ✕	Tibialis anterior: 3 / ✕
	Plantar flexion: 4 / ✕
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 87/ 85	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 59 kg	
Height: 1.63 m	

Figure 4.14 At the lab during the tests E.Y.

occurs at t=3.874sec, during the stance phase. The left knee power value at t=3.874 sec equals -0.143

4.19.3 Varus-Valgus Graphs

The following graphs show the varus and valgus stress of E.Y. during maximum femoral rotation in stance for right leg. The femoral rotation reaches its maximum at t=3.471. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of E.Y. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=3.524. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.20 Patient 20 – İ.S.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.21
Patient Information of İ.S.

Name:İ.S.	
Age: 16	
Sex: Female	
History: Diagnosed with CP, was born by the help of medical treatment	
CP classification: Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/110°	Flexion: normal/ normal
Extension: 20°/ 20°	Extension: -10°/ 0°
Adduction: 45°/ 45°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 45°/ 45°	Ankle
Internal rotation: Prone: 70°/ 60°	Dorsi flexion: Knee 90°: 0°/ 20°
Supine: 70°/ 55°	Plantar flexion: 60°/ 60°
External rotation: Prone: 20°/ 45°	
Supine: 20°/ 40°	
Alignment, R/L	
Femoral anteversion: 45°/ 30°	
Tibia femoral angle: 10°eks/ ✕	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: 1 / 60°
Adductor: ✕	Duncan-Ely Test: - / -
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 3 / 2 - 5 / 2
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: ✕
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 85.5/ 84	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 51 kg	
Height: 1.58 m	

Figure 4.15 At the lab during the tests İ.S.

4.20.1 Patient Information

4.20.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=1.989 sec, during the stance phase. The right knee power value at t=1.989 sec equals 0.083.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=2.795 sec, during the stance phase. The left knee power value at t=2.795 sec equals 0.021.

4.20.3 Varus-Valgus Graphs

The varus and valgus stress of İ.S. in stance phase during the presence of maximum femoral rotation for right leg is determined. The femoral rotation reaches its maximum at t=2.683. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of İ.S.in stance phase during the presence of maximum femoral rotation for left leg is determined. The femoral rotation reaches its maximum at t=3.143. The left leg rotation graph is investigated at this maximum point of the

Figure 4.16 At the lab during the tests Y.H.

stance phase in order to see whether the valgus strees occurs at that time.

4.21 Patient 21 – Y.H.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

4.21.1 Patient Information

4.21.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=3.187 sec, during the stance phase. The right knee power value at t=3.187 sec equals 0.049.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=3.732 sec, during the stance phase. The left knee power value at t=3.732 sec equals -0.024.

Table 4.22
Patient Information of Y.H

Name: Y.H.	
Age: 15	
Sex:Male	
History: Diagnosed with CP, premature birth	
CP classification: Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/110°	Flexion: 130°/ 130°
Extension: 5°/ 10°	Extension: -15°/ -15°
Adduction: 35°/ 35°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 30°/ 30°	Ankle
Internal rotation: Prone: 55°/ 30°	Dorsi flexion: Knee 90°: 15°/ 15°
Supine: 60°/ 30°	Plantar flexion: 40°/ 40°
External rotation: Prone: 20°/ 50°	
Supine: 30°/ 60°	
Alignment, R/L	
Femoral anteversion: 30°/ 40°	
Tibia femoral angle: ✕	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: ✕
Adductor: ✕	Duncan-Ely Test: + /+
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: ✕
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: ✕
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 83.5/ 82	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 40 kg	
Height: 1.54 m	

Figure 4.17 At the lab during the tests N.A.

4.21.3 Varus-Valgus Graphs

The varus and valgus stress of Y.H. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=3.537. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of İ.S. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=3.982. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.22 Patient 22 – N.A.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.23
Patient Information of N.A.

Name:N.A.	
Age: 9	
Sex: Male	
History: Diagnosed with CP, had rehabilitation for 5 years	
CP classification: Hemiplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 125°/125°	Flexion: 140°/ 140°
Extension: 20°/ 20°	Extension: 0°/ 5°
Adduction: 45°/ 45°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 55°/ 45°	Ankle
Internal rotation: Prone: 60°/ 65°	Dorsi flexion: Knee 90°: 0°/ 30°
Supine: 60°/ 60°	Plantar flexion: 70°/ 50°
External rotation: Prone: 25°/ 65°	
Supine: 30°/ 80°	
Alignment, R/L	
Femoral anteversion: 40°/ 25°	
Tibia femoral angle: ✕	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: ✕
Adductor: ✕	Duncan-Ely Test: - /-
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 1
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: ✕
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 71/ 71	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 33kg	
Height: 1.33 m	

4.22.1 Patient Information

4.22.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=1.506 sec, during the stance phase. The right knee power value at t=1.506 sec equals 0.172.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=1.948 sec, during the stance phase. The left knee power value at t=1.948 sec equals 0.057.

4.22.3 Varus-Valgus Graphs

The varus and valgus stress of N.A. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=1.848. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of N.A. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=2.101. The left leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time.

4.23 Patient 23 – B.K.

The following subsections include patient's anthropometrics and information characterizing his/her clinical condition prior to the results of the motion analyses.

Table 4.24
Patient Information of B.K.

Name:B.K.	
Age: 7	
Sex:Female	
History: Diagnosed with CP, had achilotomy surgery	
CP classification:Diplegia	
Range of Motion, R/L	
Hips	Knee
Flexion: 110°/110°	Flexion: 125°/ 130°
Extension: 20°/ 15°	Extension: -5°/ 0°
Adduction: 40°/ 45°	Rectus femoris length: 0cm/ 0cm
Abduction: Hip 0°-Knee 0°: 45°/ 45°	Ankle
Internal rotation: Prone: 45°/ 40°	Dorsi flexion: Knee 90°: 15°/ 5°
Supine: 60°/ 60°	Plantar flexion: 50°/ 50°
External rotation: Prone: 40°/ 70°	
Supine: 40°/ 70°	
Alignment, R/L	
Femoral anteversion: 20°/ 30°	
Tibia femoral angle: ✕	
Genu valgum: ✕	Genu varum: ✕
Spasticity (MAS, R/L)	
Hips	Knee
Flexor: ✕	Hamstring: 2/70 – 2/70
Adductor: ✕	Duncan-Ely Test: + /+
Internal rotator: ✕	Ankle
Extensor: ✕	Dorsi flexion: 1
Abductor: ✕	Tibialis anterior: ✕
	Plantar flexion: 1/10 – 2/0
Vicon System Measurements (Plug-in Gait Parameters)	
Leg length: 56/ 56.5	
Bicondylar distance: 7/ 7	
Bimalleolar distance: 5/ 5	
Weight: 16 kg	
Height: 1.08 m	

Figure 4.18 At the lab during the tests B.K

4.23.1 Patient Information

4.23.2 Knee Angle and Knee Power Graphs

The right knee angle graph of the patient shows that the maximum knee extension occurs at t=4.252 sec, during the stance phase. The right knee power value at t=4.252 sec equals -0.051.

The left knee angle graph of the patient shows the maximum knee extension occurs at t=3.799 sec, during the stance phase. The left knee power value at t=3.799 sec equals -0.04.

4.23.3 Varus-Valgus Graphs

The varus and valgus stress of B.K. during maximum femoral rotation in stance for right leg is determined. The femoral rotation reaches its maximum at t=3.450. The right leg rotation graph is investigated at this maximum point of the stance phase in order to see whether the valgus strees occurs at that time. The varus and valgus stress of B.K. during maximum femoral rotation in stance for left leg is determined. The femoral rotation reaches its maximum at t=3.068.

4.24 The Correlation Assessments Between the Knee Power and Femoral Anteversion

Covariance coefficients and the correlation data are presented below in order to assess a relationship between the knee power and FA.

4.24.1 The Correlation Data

Table 33 shows the knee power and FA angle data of the 23 patients participated and Table 34 shows the Pearson coefficients calculated. Theoretically, the Pearson correlation seeks a linear relationship. The correlation coefficient approaching to 0 indicates that the correlation between the FA and the knee kinetics become less pronounced. ×

The Pearson product moment correlation coefficient (p) for the data sets, which are the right knee-power and the femoral-anteversion-angle at the right leg, in the table is p = 0.277853684. The Pearson product moment correlation coefficient (p) for the data sets, which are the left knee-power and the femoral-anteversion-angle at the left leg, in the table is p= -0.019500954. These small values close to 0 indicate that there is only a limited correlation between the FA and the knee kinetics.

4.24.2 Covariance Coefficients

The covariance defines a broad range of statistical relationships between observed data values including the linear relationship. The coefficient is denoted as r. The sign of the coefficient defines the nature of the relationship between two values, nature of relationship. A and B are indicated as if they move in the same direction forwhy the coefficient is positive and vice versa. When r=0;

1. Although there is a perfect non-linear relationship between X and Y, “r” measures

Table 4.25
The correlation data

Knee Power		The FA angle		Varus Valgus Stress	
Right	Left	Right	Left	Right	Left
-0.078	-0.037	30	20	0.245	-0.083
0.038	-0.063	40	30	-0.049	-0.049
-0.027	0.155	40	45	0.229	0.048
-0.044	-0.043	50	40	0.04	0.013
-0.031	0.101	50	55	-0.007	0.184
-0.000	-0.034	30	40	0.019	-0.043
0.002	-0.014	50	60	0.062	-0.012
0.538	-0.047	55	50	-0.015	0.03
-0.073	0.029	17	10	-0.016	0.021
-0.041	-0.068	40	40	0.033	0.083
0.030	0.008	60	50	-0.383	0.075
-0.056	-0.044	40	50	0.06	-0.525
-0.037	-0.097	20	30		
0.001	-0.001	75	70		
0.186	-0.101	60	50		
-0.011	0.047	20	30		
0.124	-0.007	30	40		
0.089	0.012	25	25		
0.051	-0.143	30	45		
0.083	0.021	45	30		
0.049	-0.024	40	25		
0.172	0.057	30	30		
-0.051	-0.04	30	40		

Table 4.26
The Pearson coefficients calculated.

Pearson coef. for KNEE POWER&FEMORAL ANT /RIGHT LEG (23 patients) p = 0.277853684	Pearson coef. for KNEE POWER&FEMORAL ANT /LEFT LEG (23 patients) p = -0.019500954
Pearson coef. for KNEE POWER&VALGUS VARUS STRESS/ RIGHT LEG (12patients) p = -0.196569412	Pearson coef. for KNEE POWER&VALGUS VARUS STRESS/ LEFT LEG (12patients) p = 0.374729907
Pearson coef. for FEMORAL ANT&VALGUS VARUS STRESS/ RIGHT LEG (12patients) p = -0.461420521	Pearson coef. for FEMORAL ANT&VALGUS VARUS STRESS/ LEFT LEG (12patients) p = 0.010587374

Table 4.27
Covariance coefficients.

Covariance coef. of KNEE POWER&FEMORAL ANT /RIGHT LEG (23 patients) r= 0.51089603	Covariance coef.Of KNEE POWER&FEMORAL ANT /LEFT LEG (23 patients) r= -0.01705104
Covariance coef. of KNEE POWER&VALGUS VARUS STRESS/ RIGHT LEG (12patients) r= -0.004697167	Covariance coef. Of KNEE POWER&VALGUS VARUS STRESS/ LEFT LEG (12patients) r= 0.004106875
Covariance coef. of FEMORAL ANT&VALGUS VARUS STRESS/ RIGHT LEG (12patients) r= -0.800555556	Covariance coef. Of FEMORAL ANT&VALGUS VARUS STRESS/ LEFT LEG (12patients) r= 0.024583333

the strength of the linear relationship between A and B.

2. X and Y are not necessarily independent.

So r = 0 is a necessary but not sufficient condition for A and B to be independent. On the contrary, for example if A and B are independent then r = 0 definitely. The "r" for the FA and the knee power values is calculated in Excel as well as the Pearson coefficient calculation was calculated.

The covariance product moment correlation coefficient (r) for the data sets, which are the left knee-power and the femoral-anteversion-angle at the left leg, in the table is r= 0.51089603. It's seen that they move in same direction and the size of the coefficient is small, therefore there is a weak or no relationship. The covariance product moment correlation coefficient (r) for the data sets, in the table is r= -0.01705104.

Table 4.28
Pearson and covariance coefficients.

Pearson coef. of KNEE POWER&FEMORAL ANT /LEFT-RIGHT LEG (23 patients) p = -0.002359361	Covariance coef. of KNEE POWER&FEMORAL ANT /LEFT-RIGHT LEG (23 patients) r = -0.002183365
Pearson coef. of KNEE POWER&VALGUS VARUS STRESS/ LEFT-RIGHT LEG (12patients) p = 0.159695676	Covariance coef. of KNEE POWER&VALGUS VARUS STRESS/ LEFT-RIGHT LEG (12patients) r = 0.001575375
Pearson coef. of FEMORAL ANT&VALGUS VARUS STRESS / RIGHT-LEFT LEG (12patients) p = 0.218329903	Pearson coef. Of FEMORAL ANT&VALGUS VARUS STRESS/ LEFT-RIGHT LEG (12patients) p = -0.207799831
Covariance coef. of KNEE POWER&FEMORAL ANT /RIGHT-LEFT LEG (23 patients) r= 0.420833333	Covariance coef. of KNEE POWER&FEMORAL ANT /LEFT-RIGHT LEG (23 patients) r= -0.434305556

Consequently, same conclusion may appear in thoughts.

In addition, there could be a positive direction for the right knee between FA angle and the knee power although there is an opposite direction for the left knee. Performed collateral correlations required the right knee power and left FA angles correlations as well as the right valgus varus stress and left knee power correlations. Also right valgus varus stress with FA correlations are executed as crosswise collateral correlations.

5. DISCUSSION

There are too many muscles and other structures of the musculoskeletal system to take into account such as quadriceps muscles, meniscuses, collateral and cruciate ligaments etc. These structures affect the loading on the knees or the knee power. They may be considered with different technical equipment and with more patients. As far as the other studies [23], [24], [25] are conserned, the lack of patient number of this study is an important issue to state. A broader study should follow to support the idea of this study.

The study that Bilgili et al. [23] had investigated in 2012 is a good example for this study. They assessed the causes of the knee flexion contractures in children with CP, and as an extra input to our study the hip flexion contractures are also investigated in that study. The patient number is higher. Through the similarity of assessing the knee power-CP-sourced FA relationship, high-energy-demand research may be important for the patients having similar conditions.

The study of Akalan et al. [24] conducted in 2009 has similarities with our study. They worked on effects of IFA on gait in children with CP. They worked with 30 children with CP. This study's patient number is near to that number. FA was measured geometrically as this study followed. They measured the hip IR angles. On the contrary most of the rotation angles in our study are not used with major significance. A six-camera motion analysis system (Elite Eliclinic, BTS, Milan, Italy) was used to compute the 3D pelvis, hip, knee and ankle kinematics in the sagittal plane, the ankle, knee and hip kinetics and the temporal-spatial parameters. Working with children who are able to walk and making measurements in the laborotary environment by using motion analysis system is also common. In our study no linear relationship is found between FA and knee power but FA shows significance in slim portions in Akalan et al. [24].

Literature shows the most similar study is done in the Baltalimani laboratory as this study. Beng et al. [25] had worked on the impact of IFA on knee kinetics and kinematics in children with CP in 2013. As a result they found that power, moment and loading on the knee increased in the increased hip IR group. Therefore they concluded that this abnormal loading might lead to early arthrosis in the knee as this study did. Working on children with CP in order to determine a relationship of FA and knee kinetics has a more general purpose then this study. Our study contributes to this conclusion more than any literature reviewed in the thesis. Another point has to be made about the collateral sides. Right and left knee powers can be linked with the FA separately. They still show very small correlations, but larger group of patients may be more meaningful. Also the valgus-varus stress that is applied on the knee is related with the FA from a different view. Nor FA, neither knee power showed meaningful correlations with valgus-varus stress.

6. CONCLUSION

The Pearson (p = 0.277853684 for the right knee, p= -0.019500954 for the left knee) and the Covariance coefficients showed there is no linear relationship between the FA and the knee power. However, Covariance coefficients (r = 0.51089603 for right, r = -0.1705104 for left) also define the direction that variables move. As it is seen there could be a positive direction for the right knee between FA and the knee power (knee kinetics) although there is an opposite direction for the left knee. Also it's seen that mostly right knee generates power, while left knee performs absorption.

Moreover, the varus stress and FA correlation (p= -0.461420521 for the right knee, p= 0.010587374) is another set of data that might help us differentiate the effects that IFA can cause. Although the size of comparison is larger than the knee power correlation, there is yet no linear relationship.

The energy expenditure explains some effects such as the femoral roll back movement. The weight of body that is loaded to knee changes during different stages of gait is an effect. Also for example treatment of gonarthrosis is always searched in the knee. This study contributes to the knowledge of energy expenditure in the knee that it can't hold the gonarthosis treatments permanent, which is done through knees.

Anterior cruciate ligaments are avoiding the IR, since increased IR means IFA, this changes the balance of children's gait and the power expenditure slightly. Human knee needs to absorb the power not the generation of it to complete a stride. They weight on their right limbs more than left and show flexion at 30 degrees. This may contribute to explain the data of right knee generating power while left knee performs absorption.

All in all, results of the Pearson and the Covariance coefficients, showed that there isn't a perfect linear relationship between the FA and the knee power. The study results contribute to a thinking of FA as a potential source of arthosis development. Such arthosis occurs at very young ages in patients with CP.

The aim is to assess whether a correlation can be found between FA and knee power in children with CP, moreover the results stated that a linear relationship between mentioned variables is not found. A linear relationship between FA and knee power could have had a clinical relevance. Also, performing the FA-surgery can be an option to avoid the arthosis developing at early ages. Since there isn't a linear relationship, the findings suggest that the surgery to fix FA to delay the arthosis may not be a priority action to take on CP children who have IFA. Inspite of the anteversion which is clinically–detected, results show a lack of relation between the knee power and the FA. Note however that the lack of a linear relationship between knee power and FA may be ascribable to the smaller size of the subjects and their potential inter-subject variability.

7. REFERENCES

1. DeLuca PA., "The musculoskeletal management of children with CP." Pediatr Clin North Am 1996; 43:1135-1150.

2. West G.,Griffiths S.MD,McCowin P.MD,Turpin L. P.A-C., “A Patient’s Guide to Rotational Deformities in Children", Summit Orthopaedics,e-Orthopod; MMG 2005.

3. Perlstein MA., ”Infantile CP: classification and clinical correlations.”, Journal of the American Medical Association; 1952-149: 30–4.

4. J.Wiley J, "In-Toeing and Out-Toeing in Children.", Can Famn Physician; 1987;33:637-640.

5. Molnar G.E., Alexander M.A., "Pediatric Rehabilitation", Hanley Belfus Inc.; 1999;193-213.

6. Todd L. Lincoln.MD, Patrick W.SuenMD, “Common Rotational Variations in Children.",Journal of the American Academy of Orthopaedic Surgeons; vol.11 no.5 312-320, 2003.

7. Miller Freeman MD, “Cerebral Palsy”, Publication Date: January 4, 2005;ISBN-10: 0387204377, ISBN-13: 978-0387204376. 8. West G.,Griffiths S.MD,McCowin P.MD,Turpin L. P.A-C., “A Patient’s Guide to Rotational Deformities in Children", Summit Orthopaedics,e-Orthopod; MMG 2005.

9. Eilert RE, MacEwen GD., "Varus derotational osteotomy of the femur in CP.", Clin Orthop; 1977:168–72.

10. Fettweis E.,"Spasm of the adductor muscles, pre-dislocations and dislocations of the hip joints in children and adolescents with CP. Clinical observations on aetiology, pathogenesis, therapy and rehabilitation, Part II. The importance of the iliopsoas tendon, its tenotomy, of the coxa valga antetorta, and correction through osteotomy turning the hip into varus (author’s transl.)", Orthop Ihre Grenzgeb; 1979;117:50–9.

11. Fujiwara M, Basmajian JV, Iwamoto M., "Hip abnormalities in CP: radiological study.", Arch Phys Med Rehabil.; 1976;57:278–81.

12. Hoffer MM, Stein GA, Koffman M, Prietto M., "Femoral varus-derotation osteotomy in spastic CP.", J Bone Joint Surg. [Am]; 1985;67:1229–35.

13. Vizkelety T, Renyi-Vamos A, Szoke G., "Surgical treatment of the hip in CP.", Acta Chir Hung; 1991;32:215–24.

14. Yamaguchi O., "A radiological study of the hip joint in CP.", Nippon Seikeigeka Gakkai Zasshi; 1993;67:1–11.

15. Perry Jacquelin M.D., k Slac ThoroFA re, Davids Jon R. M.D., “Gait Analysis: Normal and Pathological Function”,Journal of Pediatric Orthopaedics, November/December 1992; Volume 12 - Issue 6 - ppg 815.

16. J. Shefelbine Sandra, R.Carter Dennis,"Mechanobiological Predictions of FA inCP.",Annals of Biomedical Engineering,Volume 32, Number 2 (2004), 297-305.

17. Terjesen T.,Benum P.,Svein A., Svein S.,"Increased FA and osteoarthritis of the hip joint.",acta orthop. scand.; 53, 571-575, 1982.

18. Jend H.H.,"Computed tomographic determination of the FA. Premises and possibilities." Rofo. 1986 Apr;144(4):447-52. German.; PMID: 3008259 [PubMed].

19. Fabry G, MacEwen GD, Shands AR Jr., "Torsion of the femur., "J of Bone and Joint Surgery”, 1973; 55-A: 1726-38.

20. HilderJoseph M., Zev W. Rymer,"A Stimulation Study of Reflex Instability in Spasticity: Origins of Clonus", IEEE Transactions on Rehabilitation Engineering; 7 (3): 327–340; Retrieved May 6, 2012.

21. Engsberg JR, Ross SA, Olree KS,Park TS.,“Ankle spasticity and strength in children with spastic diplegic CP.", Dev Med Child Neurol; 2000;42:42–7.

22. Van ManenMD, NaceJ, MontMA, "Management of primary knee osteoarthritis and indications for total knee arthroplasty for general practitioners.", The Journal of the American Osteopathic Association, November 2012; 112 (11): 709–715; PMID: 23139341.

23. Bilgili Fuat, Temelli Yener, Akalan N.Ekin, “Assessment of the Hip and Knee Flexion Contractures in CP Patients with Crouch Gait”, 2012, İstanbul.

24. Akalan N.Ekin, TemelliYener, KuchimovShavkat, “Effects of increased femoral anterversion on gait in children with CP.”,Dec 1, 2009, Turkish Journal of Physical Medicine and Rehabilitation.

25. Beng Kubilay,Lapçın Osman,Aydil Sebahat,Atıcı Yunus,Sökücü Sami, Kabukçuoğlu Yavuz Selim, “The impact of increased FA on knee kinetics and kinematics in children with CP.”, J Kartal Tr; 2013 Volume: 24 - 2 , pp 107-109, Metin Sabancı Baltalimanı Osteopathic Training and Research Hospital.

26.Baker Richard, Williamson Hugh, "Gait analysis methods in rehabilitation", Journal of NeuroEngineering and Rehabilitation; 2006, 3:4 doi:10.1186/1743-0003-3-4.

27. MonaghanKenneth,DelahuntEamonn, Caulfield Brian, "Increasing the number of gait trial recordings maximises intra-rater reliability of the CODA motion analysis system." Gait & Posture; Volume 25, Issue 2, February 2007, Pages 303–315.

28. MillsVictoria, “The Gait Wand Set Brochure, Evaluation and calibration of measurement systems.” 2013, Leicestershire, LE7 7PJ, United Kingdom.

29. FoxMelanie D.,"Understanding Biomechanical Causes And Functional Mechanism Of Treatment For Stiff-Knee Gait In CP.", Dissertation to The Department Of Mechanical Engineering, Stanford University, May 2011.

30. Herring JA.,"Tachdjian's Pediatric Orthopaedics", WB Saunders, 2001; 3rd ed, vol. 2., p. 1172, Philadelphia, USA.

31. ZorbaE., ZiyagilM.A., "Vücut Kompozisyonu ve Ölçüm Metotları","Body Composite and Measurement Methods.", Gen Matbaacılık, Trabzon,1995,

32. AitkenAlexander Craig, “Statistical Mathematics 8th Edition. Oliver & Boyd.”, 1957; ISBN 9780050013007.

33. SanjeevSabharwal, Caixia ZhaoJ,"The Hip-Knee-Ankle Angle in Children: Reference Values Based on a Full-Length Standing Radiograph",Bone Joint Surg Am. 2009;91:2461-2468. doi:10.2106/JBJS.I.00015.