PATTERN OF FOOT AND ANKLE DEFORMITIES IN CHILDREN WITH SPASTIC CEREBRAL PALSY AS SEEN AT A KENYAN HOSPITAL

A dissertation submitted in part fulfilment for the requirements of degree of Masters in Medicine in Orthopaedic Surgery, University of Nairobi

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H58/64166/2010

DECLARATION

I hereby declare that this dissertation is my original work and has not been presented for a degree in any other university.

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DEDICATION

To my father Mr Joseck Gatobu Manyara without whom i would not be here today.

LIST OF ABBREVIATIONS

AFO	Ankle-foot orthotic
CP	Cerebral palsy
GMFCS	Gross Motor Function Classification System
GMFM	Gross Motor Function Measure
ICIDH	International Classification of Impairments, Disabilities and Handicaps
KNH/UoN ERC	Kenyatta National Hospital – University of Nairobi Ethics and Research Committee
OT	Occupational therapy
R1 and R2	R1 is the quick stretch angle achieved at a speed of the limb segment falling or as fast as possible, and R2 is the slow stretch angle achieved
TORCH	Toxoplasmosis, rubella, cytomegalovirus and herpes simplex

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ABSTRACT

Background:

Cerebral palsy (CP) is a leading cause of childhood disability. Life expectancy in children and youth with cerebral palsy is directly influenced by the patients' ability to ambulate and perform activities of daily living. As a result of muscle spasticity and contracture formation, approximately 20-50% of children with cerebral palsy develop lower limb deformities that affect ambulation.

Objective: To determine the pattern of foot and ankle deformities in children with spastic cerebral palsy.

Study design: A six month prospective observational study, conducted at the AIC CURE International Children's Hospital outpatient clinic.

Materials and methods: 176 patients, selected through a non-random convenience sampling, were recruited. Ethical approval was obtained from the KNH/UoN-ERC as well as the AIC CURE International Children's Hospital – Kijabe Ethics and Research Committee. Patients were categorized by type of cerebral palsy and the GMFCS, foot deformity present and their ambulatory status. Combinations of the parametric and non parametric tests, t-test, chi-square test and Kruskal-Wallis tests were used for analysis. Data is presented in tables and figures.

Results

One hundred and seventy six patients, 98(56%) male and 78(44%) females were recruited. Patients were aged between 2 and 15 years with a mean age of 7 years. Commonest type of spastic cerebral palsy was quadriplegia 83(47%), followed by diplegic 40(23%), hemiplegic 39(22%), triplegic 11 (6%) and mixed 3(2%). Spasticity was reported in all the patients. The most common type of foot and ankle deformity reported was equinus 68(38%), followed by pes planovalgus 54(31%), other types of deformities 49(28%) [Neurogenic talipes equinovarus (20%), pes planus (43%), cavovarus (2%), pes planovarus (4%) and calcaneovalgus (20%)], and hallux valgus 5(3%). Plantigrade feet were 96(55%) and tip toe walkers were 73(41%) and heel gait 7(4%). Callosity was found in 59(34%) all children. Most feet were in valgus with foot bisector line passing between 1^{st} / 2^{nd} toe webspace and 1^{st} toe 87(49%), normal foot bisection with the bisector line passing through the 2^{nd} and 3^{rd} toe web spaces was found in 58 patients at 33%, varus feet were 30(17%) with foot bisector line passing between 3^{rd} /4^{th} toe web spaces and 4^{th} toe. Mean thigh foot angle was 5.4 degrees and mean R1-R2 ratio was 6.3 degrees. Most patients had GMFCS V 50(28%), III with 44(25%), II 43(24%), IV 38(22%) and I with 1(0.6%). Most children were non ambulant 82(46%), community ambulators with walking aid were 47(27%) and fully mobile were 47(27%). Bilateral deformities were seen in 127(72%) of the children and unilateral deformities were reported in 49(28%). Mean range of motion of the ankle joint was 7.6 degrees for dorsiflexion and 28.9 degrees for plantarflexion

Conclusion

The foot and ankle deformities are common in children with spastic cerebral palsy; the pattern of the deformities is unpredictable probably because of muscle imbalance resulting from different types of brain injury and aetiology of the cerebral palsy.

LITERATURE REVIEW

BACKGROUND

Cerebral palsy (CP) is described as a group of non-progressive motor or postural disorders of early onset that are due to a static insult to the developing brain. It is a condition that was originally described in 1862 by William Little, an orthopaedic surgeon. By definition, the causative insult has to have occurred between conception and 2 years of age[1]. However, some doctors believe the definitive diagnosis should be delayed up to 5 years to allow for the exclusion of other slowly progressive neurodevelopmental or metabolic diseases[2]. Other manifestations of cerebral palsy include mental retardation in 30 – 50%, epilepsy in 15 – 60%, behavioural, visual, auditory abnormalities and difficulty in bladder and bowel control, sensory impairment amongst other manifestations[2, 3].

It is thought that up to 50% of cases of cerebral palsy have no identifiable aetiology[3]. Causes can be classified by the timing of the insult as prenatal, perinatal and postnatal. They can also be classified by actual cause: congenital (developmental, syndromic, brain malformations) or acquired (vascular, degenerative, traumatic, infectious, inflammatory, others). Cerebrovascular ischaemia, periventricular leukomalacia, intracranial haemorrhage, cerebral dysgenesis, hypoxic-ischaemic encephalopathy, chorioamnionitis, and TORCH infections are known to be amongst the commonest risk factors[3, 4].

Cerebral palsy can be classified by symptomatology as spastic, dyskinetic, ataxic/hypotonic or mixed[2, 3].

Spastic CP is the commonest (up to 80%) and is due to lesions affecting the cerebral cortex or the pyramidal tracts. It can further be classified by anatomical distribution of the lesion as diplegia (30 – 40%), spastic hemiplegia (20 – 30%), spastic quadriplegia (10 – 15%) and other rarer forms, including monoplegia, triplegia and double hemiplegia (an asymmetric form of quadriplegia due to sequential insults to the pyramidal tracts)[2, 3, 5, 6]. Dyskinetic CP is caused by insults to the basal ganglia, with kernicterus being top on the list.

Cerebral palsy is thought to affect 1.5 – 2.5 children per 1000 live births worldwide[3, 7]. Despite changes in health care, the prevalence of CP has hardly changed over the last 40 years. This is thought to be due to an increase in survival of preterm babies counterbalanced by improved antenatal care[3]. In United States of America the prevalence has been reported to be 2.5 to 3 cases per a thousand live births. Similar rates have been reported in developing countries (1.5 – 5.6/1000 live births). However, this figure is thought to be an underestimation of the disease burden because of a scarcity of published literature, poor access to health care facilities and use of inconsistent diagnostic criteria[5]. Further, resource-limited settings found across the African continent may result in a different spectrum of aetiologies, prevalence, severity as well as different management approaches.

Among the risk factors, prenatal complications such as cyanosis, prematurity, jaundice and low birth weight, multiple pregnancy and intrauterine infections were the most frequent factors associated with CP[5, 6, 8, 9]. Most cases were associated with low social economic background[6, 9].

The exact incidence and prevalence of cerebral palsy in Kenya is unknown, but a four year estimate from 2010 to 2013 from AIC CURE children hospital shows that about 2,550 children in Kenya have been diagnosed with cerebral palsy.

FOOT AND ANKLE DEFORMITIES IN CEREBRAL PALSY

Deformities of the foot and ankle are the most common musculoskeletal problem seen in children with spastic cerebral palsy. The severity and pattern of these deformities is variable and unpredictable in young children because of inconsistent pattern of brain injury and aetiology.

As a result of muscle spasticity, disuse or even malnutrition, cerebral palsy has multiple orthopaedic manifestations. Primary disorders include abnormal tone, loss of motor control and impaired balance due to deficit in propelling force and osteoarticular deformities, while secondary manifestations include progressive muscle contractures, bony deformities, joint subluxation and spastic hip dislocation and scoliosis [2, 3].

Foot and ankle deformities have been reported to be common in children with spastic cerebral palsy, however objective data is lacking regarding the prevalence and distribution of foot and joint deformities limiting function in cerebral palsy children. Many reports have described equinus deformity of the hind foot and crouch gait as being common in cerebral palsy[10]. These are empirical judgement and are not based on evidence in literature.

The primary factor responsible for development of these deformities is muscle imbalance.

A spastic muscle or a group of muscles may overpower antagonistic muscles that may be flaccid, less spastic or normal. This will cause skeletal or soft tissue change. For instance, the equinus deformity results from imbalance between the triceps surae (foot plantarflexors) and the muscles of the anterior compartment of the leg, resulting in a fixed plantarflexion deformity[11, 12].

These changes are dynamic initially but progress to be fixed deformities with time[11, 12]. The effects of these deformities include poor ambulation and increased energy expenditure during

ambulation, in toeing and alteration in the thigh-foot angle, soft tissue pathologies such as pressure sores on areas of prominences, bunions and skin calluses, wearing shoes is painful and the shoes are unevenly worn out[13]. Foot deformities may also affect growth of the foot by fostering disuse atrophy as well as destruction of the growth plates of affected bones.

Ruda *et al.* looked at a group of 306 children with cerebral palsy. They reported that 50% of subjects maintained a relatively normal side to side motor balance of their affected feet during development, whereas the other 50% showed foot deformity. Twenty-five percent had valgus deformity and 23% had varus deformity. Contracture of the gastrocnemius-soleus complex (triceps surae) causes equinus deformity of the hindfoot, the most common deformity seen in children with spastic CP.[14]

Children with equinus will present with limited range of motion at the ankle i.e. less than 10^0 of dorsiflexion and toe/heel gait. Approximately 20-25% of children with pure equinus deformity will require surgery for correction with predictably good outcome[15].

Equinovalgus deformity is due to an imbalance between peroneal and tibialis posterior muscles. The resulting deformity is a plantarflexion of the calcaneus with an everted heel and forefoot abduction and pronation. There is reduced ROM with less than 10°of dorsiflexion, the weight bearing foot is pronated and there is bowstringing of the Achilles tendon.

Equinovarus deformity is found to result from unopposed action of tibialis anterior or posterior muscles on weak peroneal muscles in presence of an equinus[16].

The resulting deformity is a plantarflexion of the calcaneus with an inverted heel and forefoot adduction and supination. Benett *et al.*[17] found that in a group of children with spastic cerebral palsy who had surgery, equinovarus was the typical foot deformity in hemiplegia (38%) and

equinovalgus in diplegia and quadriplegia (37%). The deformities tended to be bilateral in children with diplegic and quadriplegic cerebral palsy.

Majority of this children were non ambulant and this together with the non-functional weight bearing status was thought to contribute to the deformities.

Other foot deformities seen in spastic CP include calcaneovalgus, which is associated with excessive dorsiflexion in about 16% of the feet[14], metatarsus adductus of the forefoot due to spasticity of small muscles of the foot, hallux valgus, pes planovalgus, cavus foot due to an imbalance between extrinsic and intrinsic muscles of the foot seen as a high medial arch and neurogenic club foot[11, 18-21].

A summary of these foot and ankle deformities is given in Appendix 9.

GRADING SEVERITY OF DISABILITY IN CEREBRAL PALSY

The Gross Motor Function Classification System (GMFCS), a tool of proven validity and reliability in clinical use, is used to grade severity of disability in CP[22]. While some overlap between the GMFCS and the pattern of cerebral palsy has been demonstrated, the GMFCS has been shown to be superior in prognostication of children with cerebral palsy[23].

The GMFCS is a 5-level grading system used for describing motor function in children with CP, and it is supplemented by illustrations for better understanding. It is based on the WHO-developed International Classification of Impairments, Disabilities and Handicaps (ICIDH, 1980) that defines functional limitation as limitation in performance at the level of the whole person[24]. It was developed in 1997, heavily based on the Gross Motor Function Measure (GMFM) that had been developed in 1989[25].

At development, its interrater variability (κ) was found to be 0.55 at 2 years and 0.75 between the ages of 2 – 12 years[24]. It provides an accurate description of gross motor prognosis in a child with CP. Originally, the GMFCS was only applicable up to the age of 12; this issue was addressed by the GMFCS Expanded and Revised (GMFCS-ER), that caters to children and adolescents up to 18 years of age[10]. The GMFCS-ER is useful for analysing and documenting the change in ambulatory status of the child over time, and gross motor function curves have been developed to compare the patient's to children of similar age. Using these curves, it has been shown that motor function peaks at approximately 5 years for GMFCS levels I and II, 8 years for level III, and 7 years for levels IV and V[10].

GMFCS at 12 years is highly predictive of adult gross motor function despite any interventions aimed at improving their gait and function, whereas the GMFM has been used to evaluate the outcome of physiotherapy in CP[10, 25].

The GMFCS has been found to be a good indicator of severity of CP compared to the use of limb distribution and type of motor impairment. Children with hemiplegia have been found to fall under class I, while children with bilateral syndromes have been found in all levels, III, IV and V Most children with spastic quadriplegic cerebral palsy fall under GMFCS class III, IV and V[22].

Further, it has been recommended as a guide in determining a patient's suitability for certain treatment modalities, GMFCS has been used for planning surgical correction in children with foot deformities. The first consideration is the child's gait function, high level ambulators in GMFCS I, II, III, attempts should be made to preserve mobile joints. These children have also been shown to have better clinical and radiological outcomes after surgery for foot and ankle

deformities compared to non ambulant children in GMFCS IV and V. GMFCS can also be used as a communication tool between caregivers and parents of the affected child[22, 26, 38,]

The GMFCS is illustrated in Appendix 3.

MANAGEMENT

Management of cerebral palsy is a multidisciplinary endeavour, involving developmental paediatricians, paediatric orthopaedists, paediatric neurologists, and nurses, physical, occupational and speech therapists, clinical psychologists and the family of the affected child. Interventions should be aimed at reducing and/or curtailing the progression of disability, prevention and treatment of comorbidities (respiratory infections, bronchopulmonary dysplasia, and bed sores), alleviating muscle spasms and the associated pain, providing parent education and family adjustment[3].

Treatment of foot and ankle deformities is aimed at obtaining a painless, plantigrade, 'shoeable' or braceable foot on which the patient can ambulate or sit appropriately on a wheelchair, this will positively affect gait and prevent chronic foot pain. It has been shown that the patients with the best prognosis are those who maintain ambulatory capability and the ability to self-feed[27].

Gait analysis is used in mapping out the child's motor disability at baseline as well as help plan for necessary interventions, such as osteotomies, gastrocnemius recession and myofascial lengthening. The outcome of various interventions can also be effectively gauged using gait analysis[28, 29]. The commonest gait disorders seen on gait analysis are stiff knee (88%), crouch gait (74%), excessive hip flexion (66%), intoeing (66%), and equinus (58%) [30].

Physiotherapy and occupational therapy are particularly important for the development of gross motor skills (walking, sitting upright, wheel chair mobility, amongst others) as well as fine motor skills (dressing, toileting, eating, bathing and writing)[3].

Valuable techniques in physiotherapy include speech therapy, conductive therapy, biofeedback and constraint-induced movement therapy[3, 31]. However this treatment modality does not correct spasticity permanently hence the need for pharmacological and surgical interventions.

Medical intervention is aimed at treatment of spasticity (baclofen, botulinum toxin, diazepam, tizanidine, dantrolene), drooling (antimuscarinic agents), dystonia (levodopa/carbidopa, trihexyphenidyl) and chorea (clonazepam, haloperidol, levetiracetam)[3, 23, 32]. The botulinum toxin (subtype A, BTX-A) has particularly found wide use in treatment of CP. It is injected intrafascially within a spastic muscle, with the aim of relieving spasticity and allowing for balanced application of force across a joint. This way, deformities are averted, pain is treated and better joint mobility is achieved. Spastic dynamic lesions such as equinus, equinovarus, equinovalgus, knee and hip flexion deformities may be treated this way. In addition, in more severe cases of spastic quadriplegia, BTX-A may be injected to the hip adductors in combination with adductor tenotomy or hip spica to improve perineal hygiene, positioning and orthotic tolerance[33]. Thus intervention reduces strain and stress of joints and results in pain relief.

Pain management is of particular importance in cerebral palsy. Pain reduces participation in daily activities in up to a third of ambulant patients, and impacts negatively on the quality of life. Sixty percent of CP patients and 14 – 73% of CP patients' caregivers report pain of some level, with the commonest sites being the lower limbs (82%), the upper limbs (19%), back (14%), abdomen (11%) and the head and neck region (10%).

The commonest causes of pain as identified by the physician are hip dislocation/subluxation (16%), dystonia (12%) and musculoskeletal deformity (11%)[34].

Medical management of pain includes analgesics, treatment of spasticity and treatment of musculoskeletal deformities. Because chemical intervention only results in temporally relief of pain, surgery is often performed to improve muscle balance and position of joints and limbs.

Surgical management is aimed at releasing of contractures (myofascial lengthening procedures such as tendocalcaneus elongation, gastrocnemius recession and tenotomy), prevention of loss of function through bracing, casting and orthotics, abolition of spasms (selective posterior rhizotomy) and remodelling of deformed structures through osteotomies and arthroplasties[12, 23]. The most commonly used orthotic is the ankle-foot orthotic (AFO), designed to hold the foot in optimal biomechanical position for better ambulation[3].

In conclusion, none of the studies has been able to determine the severity of the ankle and foot deformities in children with spastic cerebral palsy in terms of foot-thigh angles, foot bisector, R1 and R2 ratio and the size of the foot (length) as an indication of foot growth in these children.

JUSTIFICATION AND SIGNIFICANCE

This study is aimed at determining the commonest foot and ankle deformities in children with spastic CP in Kenya as seen at AIC CURE International Hospital in Kijabe, and to assess the severity of these deformities. This study will help in filling the knowledge gap as pertains to ankle and foot deformities prevalence and aid in decision making in terms of resource allocation for orthotics and personal tracing. It will also provide a platform for further research.

OBJECTIVES OF THE STUDY

BROAD OBJECTIVE

To determine the pattern of foot and ankle deformities in children with spastic cerebral palsy.

SPECIFIC OBJECTIVES

1. To determine the prevalence of foot/ankle deformities in spastic CP
2. To determine the severity of foot and ankle deformities using foot bisector, ankle ROM and R1-R2 difference.
3. To assess the association between GMFCS and the presence of callosity.
4. To correlate the ambulatory status and ankle range of motion

MATERIALS AND METHODS

It is a prospective observational study, which was carried out for a period of 6 months. The study was conducted at the AIC CURE International Children's Hospital outpatient clinic.

SAMPLING

Non-random convenience sample of patients who met the inclusion criteria were recruited from the AIC CURE hospital out-patient clinic.

Inclusion criteria:

1. Children with diagnosis of spastic CP
2. Age 2 to 15years

Exclusion criteria:

1. Previous surgical or non surgical intervention for foot deformities
2. Patients with non spastic cerebral palsy
3. Patient age below 2 years
4. Patients with pathological fractures
5. Patients with whom the guardian or care taker refuses to give consent for the study

SAMPLE SIZE ESTIMATION

The information at the record department of AIC CURE International children's hospital indicated that there were 74 children with ankle and foot deformities out of 625 children with cerebral palsy in 2010 (11.84%), 111 out of 654 in 2011 (16.97%), 76 out of 623 in 2012 (12.19%) and 76 out of 648 in 2013 (11.72%).Therefore an estimate of 13.18% (from the mean of the 4 values) was used for sample size determination.

The Fisher's formula given below for calculating sample size for proportion was used:

$$N = \frac{Z^2.P(1-P)}{\Delta^2}$$

Where:

Z is the reliability coefficient for a normal distribution, given a 95% confidence level (1.96),

P is the proportion estimate (13.18%),

Δ is the desired precision/margin of error (estimated at 5%)

Using the above variables, a sample size of **176** was acquired.

PROCEDURE

All patients who meet the study criteria were recruited from the outpatient department after an initial screening. Parents or guardians of eligible patients were approached for informed consent to participate in the study by the principle researcher (registrar in the Orthopaedic Surgery Department, University of Nairobi). Consenting parents or guardians were interviewed for demographic information.

Data was collected from the parent or guardian using a structured questionnaire (Appendix 1). Each child was classified into one of the following cerebral palsy subgroups; monoplegia, diplegia, hemiplegia, quadriplegia, or mixed..

Ambulatory status was assessed as follows: fully mobile (walk, run, in and out doors without any assistance), community ambulator (can move around with walking aids such as crutches, special walking frames etc) and non-ambulant. A physical examination was then conducted by a single observer to determine the type of deformity present. GMFCS was determined through history, observation of ambulatory capabilities of the child and recorded in any of the five classes.

Range of motion of the ankle in terms of ankle plantarflexion and dorsiflexion was recorded in degrees measured using a goniometer. R1 and R2 difference at the ankle joint was determined using a goniometer as follows, the patient was lying supine with the legs maintained in full flexion by the evaluator at the edge of the examination couch, and then the legs were released to drop and swing freely from the horizontal position. R2 is the passive range of motion measured during slow passive stretch and R1 is the angle of muscle reaction measured during fast passive stretch and occurs in a particular angle of catch. The difference was obtained from subtracting R1 from R2 (R2-R1), large and small differences between R2 and R1 indicates spasticity and muscle contracture respectively[39]. Further on the physical examination, lateralization of the deformity whether right or left for children with hemiplegia, spasticity of the foot and if the deformities are unilateral or bilateral was recorded. Foot bisector was determined by a line drawn from the heel (heel bisector line) and should pass through the second and third space in a normal foot.

Thigh foot angle is the angle between the heel bisector line and the line down the centre of the thigh while prone and knees flexed at 90 degrees, this was also measured and recorded.

Ambulant children were examined standing and walking and non-ambulant children were brought to standing by assistance and observed in the weight bearing position for the ankle and foot deformities.

DATA ANALYSIS AND PRESENTATION

For statistical data processing, the statistical software SPSS v.20 and MS Excel was used. Numerical data is represented using means and standard deviations. Analyses of variance and chi-square, t-test, and kruskal-wallis tests were used to assess the association between GMFCS and degree of movement and type of CP respectively. A confidence level of 95% was used, where a value of $p<0.05$ was considered statistically significant. Results are presented in form of tables and figures.

ETHICAL CONSIDERATIONS

The study proposal was presented to the Orthopaedic Department for approval then submitted to KNH/UON Ethics and Research Committee (KNH-UoN ERC) and AIC CURE International Children's Hospital – Kijabe Ethics and Research Committee who reviewed and approved it. The study did not cause any harm to participants and they were free not to participate in the study if they so wished.

The participants were explicitly informed on the purpose of the study, who is involved, and the benefits of the study. Participants did not receive any form of financial or material inducement. All data collected was treated with utmost confidentiality. The data was kept private in a locked file and any written result was used to discuss group findings and did not include information that would identify the individuals participating in the study, the information was only accessible to the principal investigator. Upon completion of the study, the hard copies of collected data were destroyed and soft copy of the same was deleted. All patients who participated gave an informed consent. Patients who did not consent received standard treatment.

LIMITATIONS AND DELIMITATIONS

The need for an orthopaedist during data collection was met by frequent consultations with the supervising consultant orthopaedic surgeon running the clinics.

VARIABLES

Variables investigated included foot size measurement, R1 and R2 difference, thigh foot angles and foot bisector and range of motion at the ankle, with illustrations of the same in the procedure and /or appendix.

RESULTS

One hundred and seventy six patients, 98(56%) male and 78(44%) females were recruited. All patients were aged between 2 and 15 years with a mean age of 7 years.

Commonest type of cerebral palsy was quadriplegia 83(47%), followed by diplegic 40(23%), hemiplegic 39(22%), triplegic 11 (6%) and mixed 3(2%). Spasticity was observed in all of the patients.

TABLE 1: CHARACTERISTICS OF THE STUDY PATIENTS

	Overall (all patients) N = 176
	n (%) IQR
Median age (yrs)	7 (4 – 10)
Mean age (yrs)	7 (3.6)
Sex	
Female:	78(44)
Male**:**	98(56)
Age group (yrs)	
2 - 5 years	61 (34)
6 - 9 years	68 (38)
10 - 13 years	33 (19)
14 – 15 years	14 (8)
Type of spastic cerebral palsy	
Diplegic	40 (23)
Hemiplegic	39 (22)
Quadriplegic	83 (47)
Mixed	3 (2)
Other-triplegic	11 (6)
Lateralizationfor hemiplegic cp	
Right:	27 (67)
Left:	12 (33)

Spasticity	
No:	0(0)
Yes:	176 (100)
Mean Range of motion in degrees	
Dorsiflexion	7.6 (6.8)
Plantarflexion	28.9 (12)
Median Range of motion	
Dorsiflexion	5 (1.8 -10)
Plantarflexion	30 (20- 35.8)
Foot Bisector	
1st toe &1/2 webspace	87 (49)
2/3 webspace	58 (33)
3rd toe&3/4th webspaces	30 (17)
4th toe and 4/5th web spaces	1 (0.6)
Median Thigh foot angle	4 (5 -6)
Mean Thigh foot angle	5.4
Median R1 – R2 ratio	5 (0.5 – 10)
Mean R1 – R2 ratio	6.3 (5.6)
Type of deformity	
Equinus:	68 (38)
Pes planovalgus::	54 (31)
Hallux Valgus:	5 (3)
Other:	49 (28)
Gait	
Plantigrade	96 (55)
Toe	73 (41)
Heel	7 (4)
Deformity	
Unilateral	49 (28)
Bilateral	127 (72)
Callosity	
Yes:	59 (34)
No:	117 (66)
GMFCS	
I	1 (0.6)
II	43 (24)
III	44 25)
IV	38 (22)
V	50 (28)

Ambulatory	
Fully mobile	47 (27)
Community ambulator	47 (27)
Non ambulant	82 (46)

The median age of the study patients was 7 years, with boys being more then the girls (56%). Quadriplegic was the common type of CP at (47%). Right lateralization was the most common among those with hemiplegic type of cerebral palsy (67%). All the children had spasticity (100%). The median range of motion in degrees for dorsiflexion & plantarflexion was 7.6 and 30 degrees respectively. Equinus was the most common type of deformity at 38%. Over half of the patients (55%) had plantigrade feet. Most patients (72%) had bilateral type of deformity. A majority of the patients (66%) had no callosity. Most of the patients were non ambulant (46%).

TABLE 2: TYPE OF CEREBRAL PALSY AND TYPE OF DEFORMITY

	Type of deformity N = 176				
	Equinus n = 68	**Pes planovalgus n = 54**	**Hallux Valgus n = 5**	**Other n = 49**	**P value**
Type of CP					
Diplegic	19 (48)	5(12)	1 (2)	15 (38)	<0.001
Hemiplegic	30 (77)	1 (3)	0 (0)	8 (20)	
Quadriplegic	14 (17)	45 (54)	4 (5)	20 (24)	
Mixed	2 (67)	0 (0)	0 (0)	1 (33)	
Other-triplegic	3 (39)	3 (27)	0 (0)	5 (45)	

Among the patients with diplegic, hemiplegic and mixed type of CP, the Equinus type of deformity was most common; 48%, 77% and 67% respectively. Among the quadriplegic cerebral palsy, pes planovalgus was the most common type of deformity at 54%.The difference in the types of deformities among the types of cerebral palsy was statistically significant $p < 0.001$.

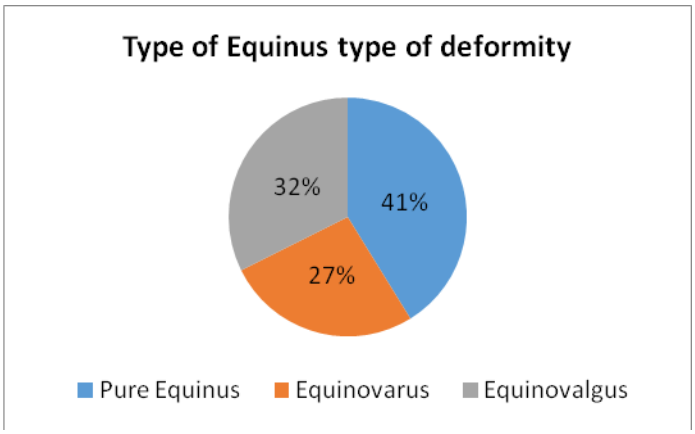
TABLE 3: OTHER TYPE OF DEFORMITIES

Type of deformity	frequency	%
Pes planus	21	43%
Calcaneovalgus	10	20%
Neurogenic talipes equinovarus	10	20%
Pes planovarus	7	14%
Cavovarus foot	1	2%

Pes planus (43%) was the most common among them

FIGURE 1: TYPE OF EQUINUS TYPE OF DEFORMITY

N=58



The pie chart above shows the types of equinus deformity. Pure Equinus was the most common type of deformity at 41%.

TABLE 4: TYPE OF SPASTIC CEREBRAL PALSY AND THE TYPE OF EQUINUS DEFORMITY

	Type of Deformity		
	Pure Equinus	**Equinovarus**	**Equinovalgus**
Diplegic	10 (25%)	3 (8%)	6 (15%)
Hemiplegic	12 (31%)	11(28%)	7 (18%)
Quadriplegic	3 (4%)	3 (4%)	8 (10%)
Mixed	2 (67%)	0 (0%)	0 (0%)
Other-triplegic	1 (9%)	1 (9%)	1 (9%)
Total	28	18	22

Among those with hemiplegic and mixed cerebral palsy majority had pure equinus deformity at 31% and 67% respectively.

FIGURE 2: LATERALIZATION IN HEMIPLEGIC CEREBRAL PALSY

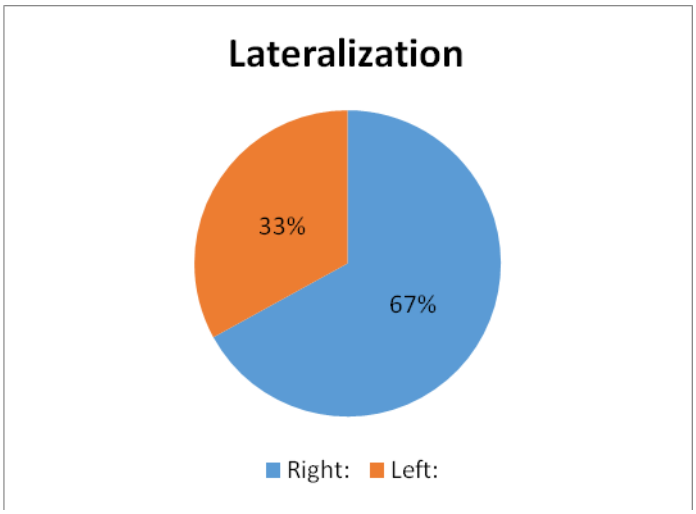
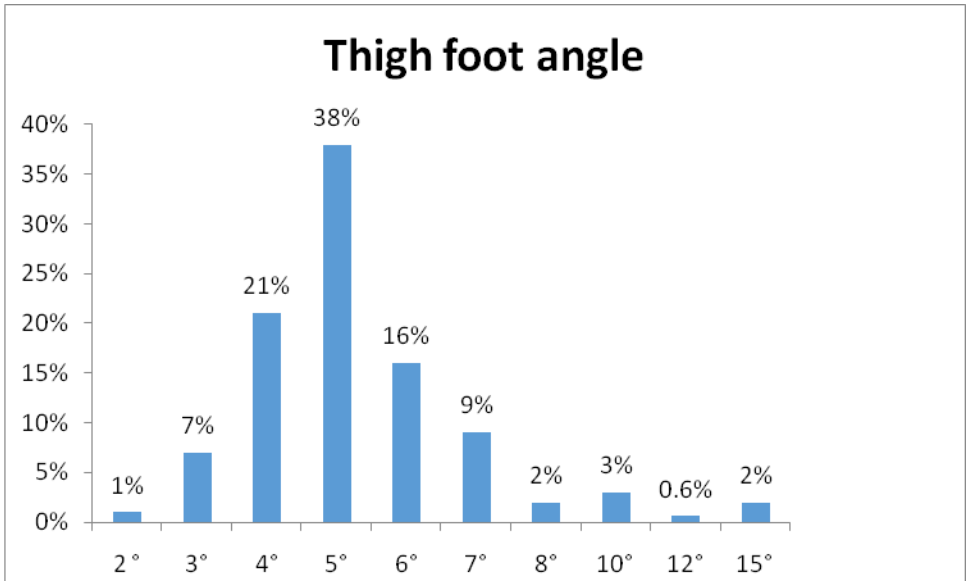


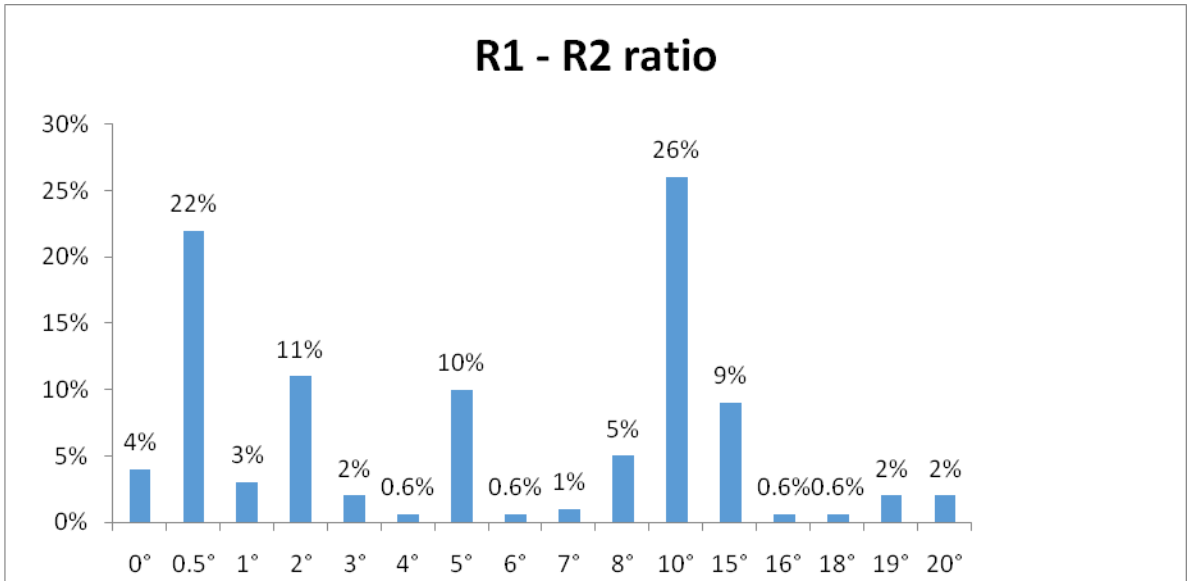
Chart 2 shows lateralization among the patient's with Hemiplegic Cerebral palsy. A majority had the lateralization on the right side (67%).

FIGURE 3: THIGH FOOT ANGLE



Graph 3 shows the distribution of the patients across the thigh foot angle degrees. The 5° angle had the most patients (38%).

FIGURE 4: R1-R2 RATIO



Graph 4 shows the distribution of the patients across the RI-R2 difference in degrees. The 10° angle had the most patients (26%).

FIGURE 5: R1-R2 RATIO PIE CHART

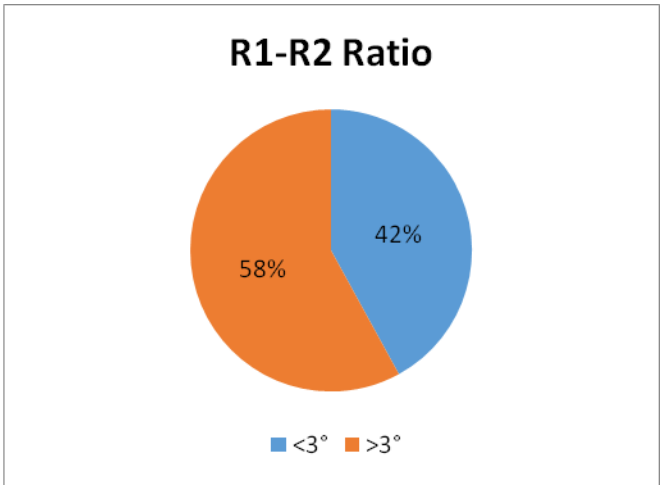


Chart 3 shows the % number of patients who had R1-R2 difference <=3° and those with >3°. A majority (58%) had R1-R2 difference >3°.

FIGURE 6: DORSIFLEXION

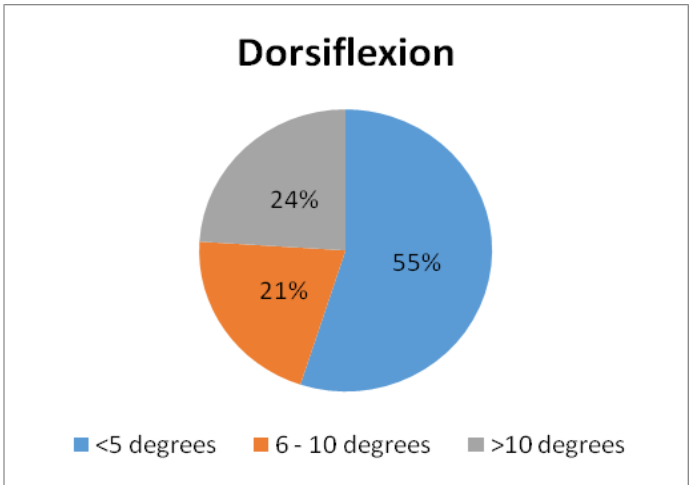


Chart 6 shows the categorization of the dorsiflexion and plantar flexion range of motions. A majority of the patients (55%) had <5 degrees in dorsiflexion while in plantar flexion a majority had between 21 – 50 degrees range of motions.

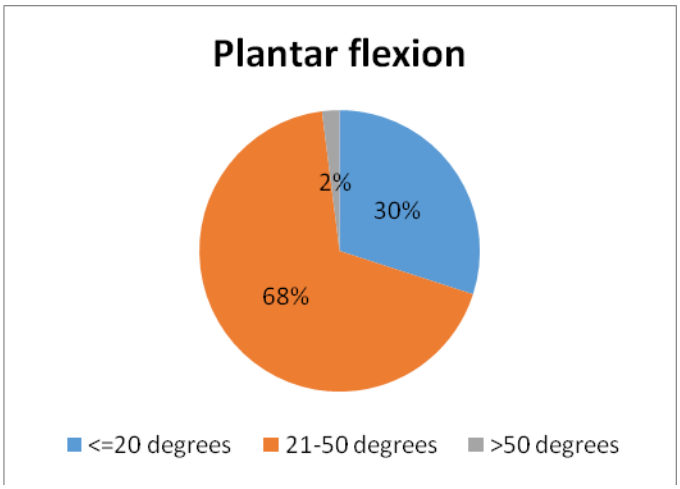

Plantar flexion
2%
30%
68%
<=20 degrees
21-50 degrees
>50 degrees

TABLE 5: GMFCS VS AMBULATORY STATUS

	Ambulatory status N = 176			
	Fully mobile n = 46	**Community ambulatory n = 47**	**Non Ambulant n = 83**	**P value**
GMFCS:				
I	1 (100)	0 (0)	0 (0)	
II	42 (98)	1 (2)	0 (0)	<0.001
III	3 (7)	41 (93)	0 (0)	
IV	0(0)	5 (13)	33 (87)	
V	0 (0)	0 (0)	50(98)	

Table 5 shows ambulatory status in the various GMFCS classifications.
Most patients with GMFCS I&II were fully mobile at 100% and 98% respectively. Most patients with GMFCSIII were community ambulators while those with GMFCS IV& V were non ambulant at 87% and 98% respectively.
There is a statistically significant difference in the patients ambulatory status in the various GMFCS classifications ($p<0.05$).

TABLE 6: CALLOSITY VS AMBULATORY STATUS

	Ambulatory status N = 176			
	Fully mobile n = 46	**Community ambulatory n = 47**	**Non Ambulant n = 83**	**P value**
Callosity				
Yes:	31 (53)	20 (34)	8 (13)	<0.001
No:	16 (14)	27 (23)	74 (63)	

Most of the patients who reported to be having callosity were fully mobile (53%) while among those who reported no callosity most of them were non ambulant (63%). There is a statistically significant difference in presence of callosity and between ambulatory and non ambulatory status of the patients ($p<0.001$).

TABLE 7: GMFCS AND CALLOSITY

	Callosity N = 176		
	Yes N=59	**No N=117**	**P value**
GMFCS:			
I	1 (100)	0 (0)	
II	29 (67)	14 (33)	<0.001
III	19 (43)	25 (57)	
IV	5(13)	33 (87)	
V	5 (10)	45 (90)	

The table 7 above shows callosity among the various GMFCS classifications. Most patients were in GMFCS I and the least in GMFCS V. The difference in the presence of callosity in the various GMFCS classes was statistically significant (P <0.001).

TABLE 8: RANGE OF MOTION VS AMBULATORY STATUS

	Ambulatory status N = 176			
	Fully mobile N=47	**Community ambulatory N=47**	**Non Ambulant N=82**	**P value**
Dorsiflexion				
<5 degrees	39 (83)	27 (57)	50 (60)	<0.001
6 – 10 degrees:	5(11)	9 (20)	16(20)	
>10 degree:	3 (6)	11 (23)	16(20)	
Plantarflexion				
<=20 degrees	6 (13)	17 (36)	29 (35)	0.039
21 - 50 degrees:	39 (83)	30 (64)	51 (62)	
>50 degree:	2 (4)	0 (0)	2 (3)	

Table 8 shows the ambulatory status of the patients in ranges in degrees of dorsiflexion and plantarflexion. There was a general reduction in the ankle range of motion.There is a statistically significant difference in the ambulatory status of the patient and the two types of range of motion (p<0.001)

TABLE 9: RANGE OF MOTION VS GAIT

	Gait N = 176			
	Plantigrade N=96	**Toe N=73**	**Heel N=7**	**P value**
Dorsiflexion				
<5 degrees	27 (28)	64 (67)	5 (5)	<0.001
6 – 10 degrees:	35 (88)	4 (10)	1 (2)	
>10 degree:	34 (85)	5 (13)	1 (2)	
Plantarflexion				
<=20 degrees	37 (71)	9 (17)	6 (13)	<0.001
21 - 50 degrees:	59 (49)	60 (50)	1 (1)	
>50 degree:	0 (0)	4 (100)	0 (0)	

Table 9 shows the Gait status of the patients in the three categories of dorsiflexion and plantarflexion. Most of the patients with <5degrees range of motion had a toe gait (67%) while those with 6 – 10 degrees and >10 degrees had a plantigrade gait at 88% and 85% respectively. Most of the patients with <20 degrees range of motion had a toe gait (71%) while those with 21-50 degrees had a toe gait at 50%. All patients with >50 degrees had a toes gait (100).

There is a statistically significant difference in the patient's Gait and the two types of range of motion ($p<0.001$)

TABLE 10: RANGE OF MOTION VS GMFCS CLASSIFICATION

	GMFCS classification N = 176					
	I n = 1	**II n = 43**	**III n = 44**	**IV n = 38**	**V n = 50**	**P value**
Doraflexion						
<5 degrees	1 (1)	37 (38)	25 (26)	15 (15)	18 (19)	<0.001
6 – 10 degrees:	0 (0)	3 (8)	9 (22)	8 (20)	20 (50)	
>10 degree:	0 (0)	3 (7)	10 (25)	15 (38)	12 (30)	
Piantoflexion						
<=20 degrees	0 (0)	6 (11)	15 (29)	13 (25)	18 (34)	0.346
21 - 50 degrees:	1 (1)	35 (29)	29 (24)	24 (20)	31 (26)	
>50 degree:	0 (0)	2 (50)	0 (0)	1 (25)	1 (25)	

Table 10 shows the GMFCS classification status of the patients in the three categories of dorsiflexion and plantarflexion.

A statistically significant difference in the GMFCS classification and the dorsiflexion range of motion was noted ($p<0.001$). However, this was not true with the plantarflexion category.

DISCUSSION

The main purpose of this study was to determine the pattern of foot and ankle deformities in spastic cerebral palsy. The study confirmed that foot and ankle deformities are the most common musculoskeletal problems seen among the children with spastic cerebral palsy. These deformities were found in 90% of children with spastic cerebral palsy in this study .This compares relatively well with other studies[1, 15, 38]. The severity and the pattern of this deformities is variable and unpredictable in children younger than five years, this is probably because of difference in the regions of brain injury as well as etiology of cerebral palsy. The main factor in the development of foot and ankle deformity in spastic cerebral palsy is muscle imbalance. Muscle control is abnormal and as a result leads to abnormal posture. Three most common foot and ankle deformities reported in literature are equinus, equinovalgus and pes planovalgus[14, 42]and this distribution is similar to the findings in this study. (Table 2 and figure 1).

Equinus represented majority of the deformity seen in our study at 38%, pure equinus without an element of varus or valgus was the most frequent variant at 41 %.(Table 4). This differs from other studies that have found equinovalgus deformity being most prevalent type.[11, 14, 15]

Equinus deformity results from spastic Achilles tendon or weakness of tibialis anterior tendon causing plantarflexion of the foot at the ankle resulting in toe walking or absent heel strike during gait which makes it difficult to keep the heal in the shoe. The deformity is commonly noticed at the beginning of standing and walking. The children with equinus gait have been shown to have longer than normal Achilles tendon and shorter than normal muscle bellies[38, 42]

Pure equinus was the most frequent deformity reported in children with hemiplegia (77%), diplegia (48%), and mixed type of CP (67%). This agrees with the study by Basset and Baker[15]. Most deformities were lateralized to the right (67%) in hemiplegia; left side lateralization was seen in 33%. (Table 1). This is similar to the findings by Kwau and Tidemann et al[44.] Equinovalgus was reported in 18% of the children with hemiplegia as opposed to 38% reported by Bennet et al[17]. In quadriplegic cerebral palsy it was reported in 10%. Equinus deformity creates difficulties in shoeability of the foot, causing uneven shoe wear and tear, results in tripping during gait due to poor foot clearance and instability as a result of a limited base of support afforded by the position of the toes. (Table 6)

Pes planovalgus is the most common deformity in children with bilateral lower extremity spaticity,[38,] it varies from mild flat foot to severe deformity making it difficult to wear shoes and walk. Several abnormalities contribute to the deformity; lateral displacement of the navicular exposing the talus head on the medial aspect of the midfoot. The deformity affects stance phase of gait in ambulant children. May be associated with contracture of gastrocnemeus that is usually masked by valgus heel which allows for a shorted path for the Achilles tendon.[43]

In this study pes planovalgus was the second most common deformity in CP and the most common deformity in children with quadriplegia at 54%. (Table 2). This is different from other studies that have found equinovalgus being the most common deformity in children with quadriplegia[11, 14]. This difference could possibly be due to different aetiologies of cerebral palsy, effect of physiotherapy and family care practices. Most of the children were non ambulant

(Table1), and nonfunctionally weight bearing, therefore child positioning and gravity probably lead to the development of the deformity. (Table 6, 11)

Hallux valgus commonly described to be an acquired deformity in cerebral palsy was seen most in quadriplegic cerebral palsy 5%, and in diplegia 2%. The feet with the hallus valgus were perceived by the patients as cosmetically unappealing and made shoe wear and orthotic use difficult.

Neurogenic talipes equinovarus is composed of several deformities such as equinus, cavus, hind-foot varus, supination and fore-foot adduction, this develops due to neurological disease such as cerebral palsy that leads to muscle imbalance. It was seen in 20% of all children with cerebral palsy mainly in older children with diplegic and hemiplegic type of CP. Other deformities seen in this study are cavovarus, pes planovarus, calcaneovalgus and pes planus.

In this study children with hemiplegic and diplegic cerebral palsy were in GMFCS II and III. Majority of diplegia were classified as GMFCS III (53%), despite the fact that the upper limbs were graded as normal. Presence of bilateral deformity in these children markedly impaired their gait necessitating the need for walking aid. 74% of children with hemiplegia were classified as GMFCS II, an indication that unilateral deformity impaired ambulatory ability to a lesser extent compared to bilateral deformity. These findings were the same as those found by Mandeleson A, and Lee Y et al[22]. Quadriplegic children had a GMFCS score of IV (29%) and V (60%). (Table 11). 83% were non ambulant. The feet in these children were flexible with ankle range of motion being more than 10 degrees of dorsiflexion and 21-50 degrees of plantarflexion.

Ambulant children in class II and III had more fixed (rigid feet) deformities with dorsiflexion of less than 5 degrees and planterflexion of 21-50 degrees. There was no correlation noted between

GMFCS and development of foot and ankle deformity; however presence of foot deformity impacted negatively on ambulation and motor function translating to a lower GMFCS level.(Tables 5 and 8).

The severity of the foot and ankle deformity is determined by measuring the range of motion at the ankle joint, use of heel bisector line to show the varus and valgus components of the deformity and R1-R2 difference to indicate the level of spasticity and differentiate between dynamic and fixed deformities. Valgus feet with heel bisector line passing through the 1st and 2nd toe web spaces were 49% and varus feet were 17%. In 23% of the feet the heel bisector line was passing between 2nd and 3rd toe web spaces, this was considered normal and was seen in those children who had equinus and pes planus deformities. Majority of the patients had a R1-R2 difference of 10 degrees at 26% with mean difference of 6.3 degrees.

Large and small differences between R1 and R2 were indicative of spasticity and muscle contractures respectively. (Figure VI). No other study has looked at these variables as a measure of severity of foot and ankle deformities and using this variables therefore, it was concluded that majority of patients in this study had moderate to severely deformed feet..

There is a direct correlation between range of motion at the ankle joint and gait. The normal gait cycle involves a period of weight bearing (stance) and an interval of self advancement (swing). Two periods of dorsiflexion and plantarflexion are experienced in each gait cycle. At the onset of stance the ankle has 90 degrees position, as the heel is loaded, the foot drops into 10 degrees of plantarflexion. The action reverses and gradually reaches 10 degrees of dorsiflexion.Therefore limited range of motion at the ankle will impair gait. In our study it was shown that most children who had less than 5 degrees of dorsiflexion with the foot in more than 20 degrees of

plantarflexion had tip toe gait (67%). Those who had an ankle range of motion between 10 degrees of dorsiflexion and 20-50 degrees of plantarflexion had plantigrade feet (85%). In foot and ankle deformity with reduced motion of the ankle, tip toe walking, presence of varus or valgus deviation affect the stance phase of gait and cause instability in stance due to limited contact of the foot with the surface.

Children with cerebral palsy are at risk of developing skin conditions and bunions due to the nature, care and treatment of their impairment. Callosities can develop in the pressure areas of the foot due to impaired gait, poor shoe fit and pressure from orthotics. In this study, callosity was meanly reported in children who were fully mobile at 53% and in 13% of non ambulant children. No callosity was reported in 63% of non ambulant patients. Callosity in non ambulant children could have been due to sustained pressure on the skin from orthotics and same position in prolonged periods of wheelchair use. Callosity was seen in association with severe foot deformity and was mostly found on the sole and tips of the toes and has been seen to complicate skin closure and wound healing following surgery.

Most of the parameters in this study are statistically significant, with p-value of less than 0.001, this means that the difference between all the variables compared and analysed are not by chance there is a real difference.

CONCLUSION

- ✓ The study demonstrates that 90% of children with spastic cerebral palsy will develop a dynamic or fixed deformity of foot and ankle. The most common deformity reported was equinus across all the types of cerebral palsy.
- ✓ Presence of Varus and Valgus foot demonstrated using foot bisector line, limited range of motion at the ankle and a small R1-R2 difference was associated with severe deformities of foot and ankle.
- ✓ Presence of bilateral deformity in ambulant children was associated with significant impairment of mobility.
- ✓ Skin condition (callosity) was mostly seen in ambulant children in GMFCS I, II, III, due to abnormal pressure on the skin along the bony prominences in presence of abnormal attitude of the foot.
- ✓ Range of motion of the ankle joint was shown to influence ambulation and gait. Fixed plantarflexion of the ankle was associated with equinus deformity resulting in tip toe walking.

RECOMMENDATIONS

1. Adequate padding and the right size of orthotics should be used to protect bony prominences and maintain a plantigrade foot to minimize development of callosity.

2. Establishment of cerebral palsy physical therapy units in various health institutions to improve rehabilitation and reduce the amount and severity of foot deformities associated with spasticity.

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APPENDIX

APPENDIX 1: QUESTIONNAIRE

PATTERN OF FOOT AND ANKLE DEFORMITIES

Serial Number …….. IP No …….

Gender:

M ☐ F ☐

AGE: ……..

DATE: ....……

Type of spastic cerebral palsy:

- ☐ Monoplegic
- ☐ Diplegic
- ☐ Hemiplegic
- ☐ Quadriplegic
- ☐ Mixed
- ☐ Other: ……..

Lateralization

- ☐ Right
- ☐ Left

Clinical examination of the ankle and feet:

1. Spasticity: Y ☐ N ☐
2. Range of motion: degrees ☐
3. Deformity: ☐
   - I. Foot bisector
   - II.Thigh foot angle
   - III.R1-R2 ratio
4. Type of deformity
   - ☐ Equinus
     - ☐ Pure equinus
     - ☐ Equinovarus
     - ☐ Equinovalgus
   - ☐ Cavus foot/toe clawing
   - ☐ Hallux varus
   - ☐ Hallux valgus
   - ☐ Other

☐ Pes planovalgus

5. Gait (toe/heel)
6. Deformity unilateral or bilateral
7. Foot size (heel to toe (tip of 2nd toe) length) ……. cm
8. Normal feet size in cm
9. Callosity

GMFCS classification:

☐ I ☐ IV

☐ II ☐ V

☐ III

Ambulatory status:

☐ Fully mobile

☐ Community ambulatory (with assistive devices)

☐ Non ambulant

APPENDIX 2: MEASUREMENT OF THE THIGH-FOOT ANGLE

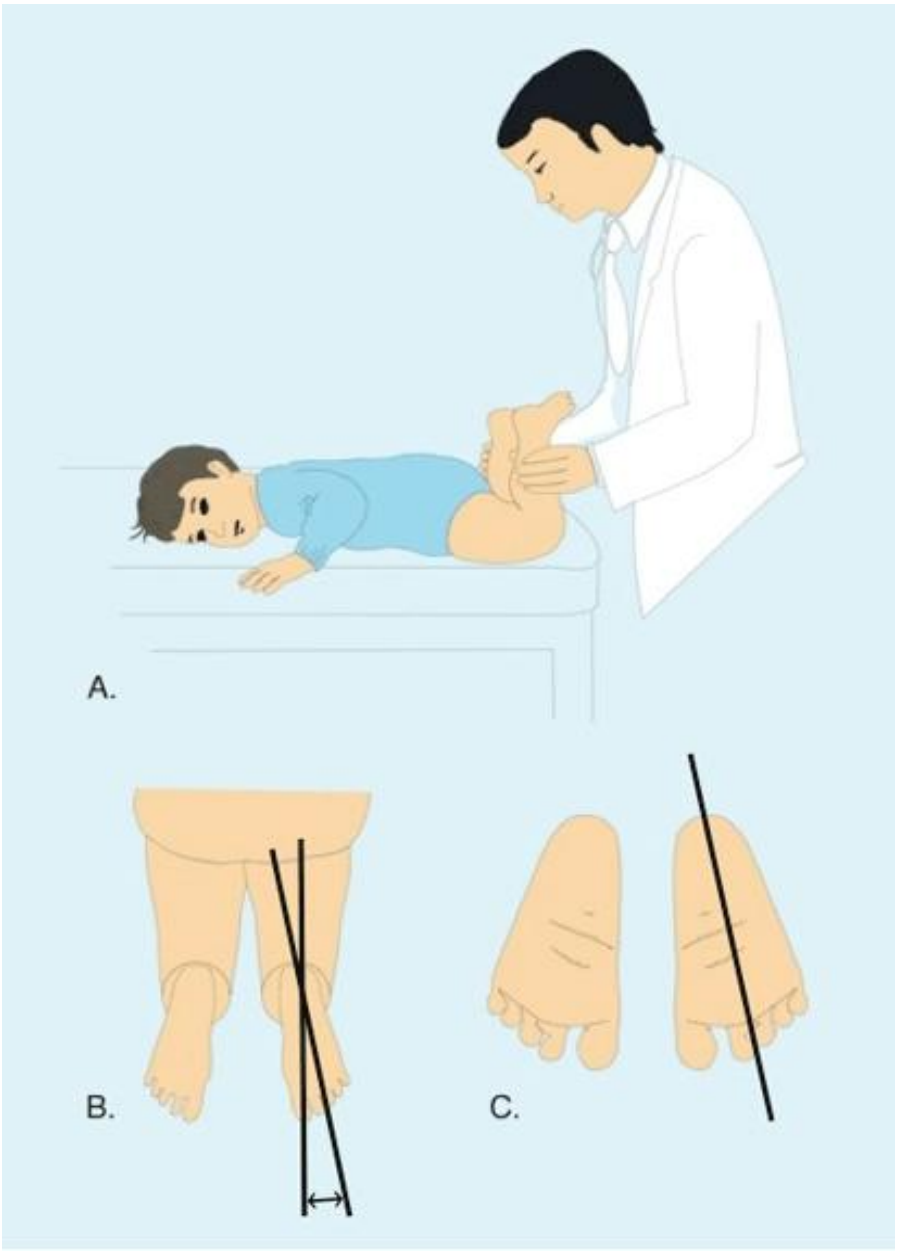
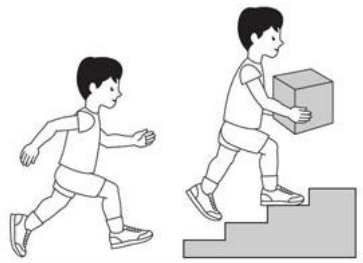


FIGURE 3: THIGH-FOOT ANGLE. A. POSITIONING OF THE BABY. B. THE THIGH-FOOT ANGLE IS THE ANGLE BETWEEN THE AXIS OF THE THIGH AND THAT OF THE HEEL-BISECTOR LINE. C. HEEL-BISECTOR LINE.

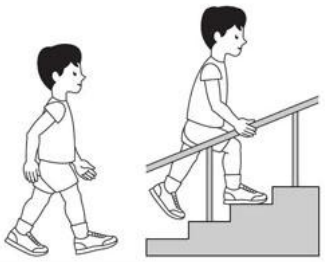
*Courtesy of bestpractice.bmj.com

APPENDIX 3: THE GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM[22]



GMFCS Level I

Children walk indoors and outdoors and climb stairs without limitation. Children perform gross motor skills including running and jumping, but speed, balance and co-ordination are impaired.

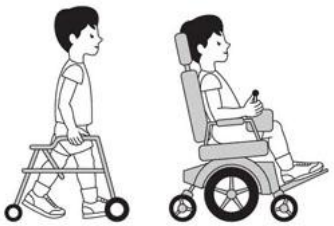


GMFCS Level II

Children walk indoors and outdoors and climb stairs holding onto a railing but experience limitations walking on uneven surfaces and inclines and walking in crowds or confined spaces.

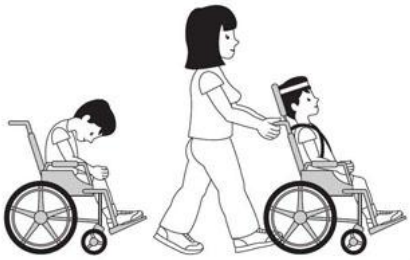
GMFCS Level III

Children walk indoors or outdoors on a level surface with an assistive mobility device. Children may climb stairs holding onto a railing. Children may propel a wheelchair manually or are transported when traveling for long distances or outdoors on uneven terrain.



GMFCS Level IV

Children may continue to walk for short distances on a walker or rely more on wheeled mobility at home and school and in the community.



GMFCS Level V

Physical impairment restricts voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Children have no means of independent mobility and are transported.

APPENDIX 4: CONSENT FORM

PATTERN OF ANKLE AND FOOT DEFORMITIES IN SPASTIC CEREBRAL PALSY.

Study Number

Hospital number

Research study

You are invited to participate in a research study on the pattern of ankle and foot deformities in spastic cerebral palsy at AIC CURE Children hospital Kijabe being conducted by Dr Caroline Kawira Gatobu, a postgraduate student in the department of orthopedic surgery ; University of Nairobi.

Purpose of the study

The purpose of this study is to determine the pattern of ankle and foot deformities seen in spastic cerebral palsy in AIC CURE Children hospital. The information gathered will be useful in both your patient's diagnosis, treatment and for other patients in the future who will present with similar complaints and require similar management.

Risks and benefits

There will be no harm or risk to your child by participating in the study.

Apart from taking a detailed history from you, a thorough physical examination of the child will be conducted as follows: assessment of the general condition of the child, examination of the back, the upper and lower limbs will be examined for range of motion of the joints, pain, muscle bulk and power, tendon reflexes, spasticity, deformity and limb length discrepancy.

Your child will not be denied medical care in case you refuse to participate in the study.

Confidentiality:

Information related to your child will be treated with strict confidence to the extent of the law. Your child's identity will be coded and will not be associated with any published results. The records of this study will be kept private in a locked file and any written result will discuss group findings and will not include information that will identify your child. Research records will be stored securely and only researcher and individuals responsible for research will have access to the records.

CONSENT FORM

I have read and fully understand the conditions for participation in the study. I sign it freely and voluntarily.

Signature/thumb print (parent/next of kin)

Date _____ _____

Telephone number (parent/next of kin)_____

Contacts: Feel free to ask questions now or at any other time. If you have any questions about this study, contact:

Dr Caroline Kawira Gatobu,

Phone no. **0729 673642**

Email: carolmanyara@yahoo.com.

If you have questions concerning the rights of human research participants, contact **The Chairperson, the AIC CURE Ethics and Research Committee** at **0736 215631**.

APPENDIX 5: ASSENT FORM

Pattern of ankle and foot deformities in spastic cerebral palsy.

Study Number

Hospital number

Research study

You are invited to participate in a research study on the pattern of ankle and foot deformities in spastic cerebral palsy at AIC CURE Children hospital Kijabe being conducted by Dr Caroline Kawira Gatobu, a postgraduate student in the department of orthopedic surgery ; University of Nairobi.

Purpose of the study:

The purpose of this study is to determine the pattern of ankle and foot deformities seen in spastic cerebral palsy in AIC CURE Children hospital.

The information gathered will be useful in both your patient's diagnosis, treatment and for other patients in the future who will present with similar complaints and require similar management.

Risks and benefits:

There will be no harm that will come to you if you agree to participate in the study. Apart from taking a detailed history from you, physical examination will be conducted on you as follows: Assessment of your general condition , examination of the back, the upper and lower limbs will be examined for range of motion of the joints, pain, muscle bulk and power, tendon reflexes, spasticity, deformity and limb length discrepancy.

Participation on the study is out of your own free will. You will not be denied medical care in case you refuse to participate in the study.

Confidentiality:

Information related to you will be treated with strict confidence to the extent provided by the law. Your identity will be coded (no names will be used) and will not be associated with any published results. The records of this study will be kept private in a locked file and any written result will discuss group findings and will not include information that will identify you. Research records will be stored securely and only researcher and individuals responsible for research will have access to the records.

Contacts:

You should feel free to ask questions now or at any time of the study.

If you have any questions about this study, you contact,

Dr Caroline Kawira Gatobu,

Phone no. 0729-673642,

Email: carolmanyara@yahoo.com.

If you have questions concerning the rights of human research participants, contact the **chairperson, the AIC CURE ethics and research committee at 0736215631**.

Minor's age:

The undersigned hereby give consent/assent for……to be recruited in the study entitled pattern of foot and ankle deformities in spastic cerebral palsy at AIC CURE Hospital Kijabe.

Signature/thumb print (parent/next of kin)

Date _____ _____

APPENDIX 6: FOMU YA KUSHIRIKI

MIFANO YA ULEMAVU WA MIGUU KWA WATOTO WALIO NA UGONJWA WA KUPOOZA UBONGO

Jina _____

Nambari ya hospitali _____

Nambari _____

Research study

Unakaribishwa kijiunga na utafiti kuhusu mifano ya ulemavu wa miguu kwa watoto walio na ugonjwa wa kupooza ubongo utakao fanyika katika hospitali ya watoto ya AIC CURE Kenya.

Utafiti huu utafanywa na Daktari Caroline Kawira Gatobu mwanafunzi katika kitengo cha utibabu wa mifupa chuo kikuu cha Nairobi.

Matokeo ya utafiti huu yataweza kuboresha matibabu kwa wagonjwa hao na wale wengine ambao watapata huu ugonjwa wa kupooza ubongo.

Hakutakua na athari yoyote kwa siha na mwili ambayo itatokana na kushiriki kwenye uchunguzi huu. Isipokua kuchukua historia kutoka kwako, mtoto atachunguzwa vifuavyo, kwanza mgonjwa ataangaliwa kama ako na shida yoyote ya mwili kwa jumla, alafu mgongo, mikono na miguu na ukubwa wa miguu kupimwa.

Kushiriki katika uchunguzi huu ni hiari na si lazima, na kutoshiriki kwako hakutaathiri matibabu utakayo pata kwa namna yoyote ile.

Habari kuhusu mtoto wako itahifadhiwa kulingana na sheria. Matokeo ya utafiti huu yatahifadhiwa na mjadala wowote kuhusu matokeo ya utafiti utafanywa kwa ujumla bila kutoa habari kumhusu mtoto wako. Kumbukumbu za utafiti nazo zitahifadhiwa ipasavyo.

Kwa ufafanuzi zaidi au suala lolote kuhusiana na uchunguzi huu, piga simu kwa Daktari Caroline Kawira Gatobu- mchunguzi mkuu, simu 0729673642 ama tuma barua pepe anwani: carolmanyara@yahoo.com.

Pia unaweza kuwasiliana na mwenye kiti wa kitengo cha uchunguzi, hospitali kuu ya AIC CURE KENYA,nambari ya simu ni 0736215631.

Mimi nilioweka sahihi hapo chini ninahakika nimemueleza mshiriki mambo yalio hapo juu, na amekubali kushiriki kwa hiari yake baada ya kuelewa maelezo.

Sahihi / kidole_____(mzazi / mwakilishi)

Tarehe _____

Nambari ya simu(mzazi /mwakilishi)_____

APPENDIX 7:BUDGET:

ITEMS	COST (KSh)
Research fees(KNH/ERC)	2,000
Stationary, printing, internet, and binding	10,000
Statistician	22,000
Correspondence supervisors and transport	7,000
Contingencies	5,000
Total	**46,000**

APPENDIX 8: STUDY SCHEDULE:

ACTIVITIES	**Nov 2014**	**Dec 2014 – Apr 2015**	**Apr – Oct 2015**	**Oct - Nov 2015**	**Nov 2015**
Literature review					
Proposal preparation and approval					
Data collection					
Data analysis and dissertation writing					
Data presentation					

APPENDIX 9: SUMMARY OF FOOT AND ANKLE DEFORMITIES IN CP

DEFORMITY	PATHOGENESIS	AFFECTED PART	BONE CHANGES	TREATMENT OPTIONS
Equinus[18]	Spasticity of triceps surae	Hindfoot; ankle and subtalar joints	Plantarflexion of calcaneus	Passive stretching, manipulation Bracing Splintage Triceps surae denervation Gastrocnemius recession Tendocalcaneus elongation
Equinovarus[18]	Overpull of tibialis posterior and/or tibialis anterior	Hindfoot; ankle and subtalar joints	Plantarflexion and inversion of calcaneus Adduction and supination of forefoot	Split posterior tibial tendon transfer Split anterior tibial tendon transfer Extrinsic toe flexor release Anterior transfer of toe flexors
Equinovalgus[18]	Spastic peroneus muscles	Hindfoot; ankle and subtalar joints	Plantarflexion and eversion of calcaneus Abduction and pronation of forefoot	Peroneal tendon lengthening Calcaneal osteotomies Peroneus brevis lengthening Subtalar arthrodesis
Calcaneus deformity[18]	Iatrogenic: overlengthening of triceps surae Spastic dorsiflexors	Hindfoot; ankle and subtalar joints	Progressive vertical orientation of calcaneus under talus, eventually resulting in rocker bottom deformity	Prevention of excessive lengthening of gastrocsoleus complex
Pes planus[20]	Progression of equinus deformity	Hindfoot and midfoot; subtalar joint, mid-tarsal joint	Calcaneal valgus Flat arch	Ankle-foot orthoses Botulinum toxin Gastrocnemius recession Tendocalcaneus elongation
Pes cavus[18]	Spasticity of intrinsic foot muscles	Hindfoot and mid foot	Dropped first metatarsal Claw toes ~Hindfoot varus	Soft tissue release of plantar structures Tendon lengthening Serial casting Triple arthrodesis
Intoeing[21, 37]	Internal hip rotation	Multiple	Multiple	Correct initial pathology: multi-

	Internal tibial torsion Pes varus Metatarsus adductus	Alteration of thigh-foot angle		level lower-extremity surgery, derotation femoral osteotomy