EFFICACY OF BIOMECHANICAL ANKLE PLATFORM SYSTEM AND A STRENGTHENING EXERCISE PROGRAMME ON FUNCTIONAL PERFORMANCE OF CHILDREN WITH CEREBRAL PALSY

By

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ABSTRACT

Cerebral Palsy (CP), the most common neuropaediatric disorder, is characterised by impaired Functional Performance (FP) which may be associated with reduced muscular strength and poor balance. Improving balance and strength in children with CP can therefore enhance their FP. Biomechanical Ankle Platform System (BAPS) and Strengthening Exercise Programme (SEP) are physiotherapy modalities that can be used to improve balance and strength respectively. There is limited evidence on the efficacy of these two modalities in enhancing FP among children therefore this study was designed to compare efficacy of BAPS and SEP on FP among children with CP.

Forty-four children with hemiplegic or diplegic CP were consecutively recruited into this quasi-experimental study. They were assigned into one of BAPS, SEP and Combined Training (CT) groups using a simple random assignment technique. Motor Function (MF), balance, and Walking Speed (WS) were measured as indices of FP at baseline using the Gross Motor Function Classification System (GMFCS), Berg Balance Scale (BBS) and Timed-Up and Go (TUG) respectively. The BAPS group performed perturbation exercise training involving lateral, antero-posterior, and diagonal shifts using a paediatric wobble board. The SEP group received bridging, side-stepping and wall slides exercise training while the CT group received a combination of BAPS and SEP. Progression was achieved by individualised increase in number of exercise bouts and decreased external support. All participants were treated using Bobath neurophysiotherapy technique. Training for each participant lasted 16 consecutive weeks; twice weekly for initial 8 weeks and then weekly for subsequent 8 weeks. Balance, MF and WS were re-evaluated at the 8^{th} and 16^{th} weeks

of training and six weeks after cessation of the training (22nd week). Data were analysed using descriptive statistics, Wilcoxon signed rank, linear model of repeated measure ANOVA and Kruskal-Wallis at p=0.05.

The mean age of participants was 7.7±2.8 years and they comprised 51.3% males; 53.8% hemiplegic; 46.2% diplegic CP children. The BBS scores in the BAPS group increased significantly by 15.8% from baseline to 8weeks, 25.3% at 16 weeks; and 25.8% at 22 weeks. Similar trends were observed for the SEP group which had 22% increase from baseline to 8 weeks, 43.4% at 16 weeks and 47% at 22nd week. Across-group significant difference was noted for the TUG only at baseline with CT group (30.9± 10.3) obtaining lower score than the BAPS (38.7± 8.8) and SEP (37.1 ± 8.1). The TUG scores increased significantly within the BAPS group from 38.7± 8.8 at baseline to 44.7 ± 8.3 at 8th; 48.5±5.9 at 16th and 48.7 ±5.9 at 22nd weeks. Similar trends were observed for the SEP at baseline (37.1±8.1), 8th (37.7±9.4), 16th (44.3± 8.9) and 22nd weeks (45.4± 8.5) and for the CT at baseline (30.9±10.3), 8th (44.0±6.8), 16th (44.3± 7.1) and 22nd weeks (45.3±6.8). At baseline, the CT had significantly higher GMFCS (4.0) than BAPS (4.3) and SEP (3.8) groups.

Biomechanical ankle platform system and strengthening exercise programme were both efficacious in improving functional performance of children with cerebral palsy.

Key words: Cerebral palsy, Biomechanical ankle platform system, Strengthening exercises

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CERTIFICATION

We certify that this work was carried out by Mrs Faderera Ajibola Adepoju of the Department of Physiotherapy, University of Ibadan under our supervision.

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TABLE OF CONTENTS

		Page
Title Page		i
Abstract		ii
Certification		iv
Acknowledgements		v
Table of Contents		vii
List of Tables		x
List of Figures		xi
List of Plates		xii
List of Appendices		xiii
CHAPTER ONE		
1.1	Introduction	1
1.2	Statement of the Problem	5
1.3	Aims of Study	6
1.4	Hypotheses	6
1.5	Delimitation	10
1.6	Limitations	11
1.7	Significance of Study	11
1.8	Operational Definition of Terms	12
CHAPTER TWO		
2.0	Literature Review	13
2.1	Cerebral Palsy	13
2.1.1	Introduction	13
2.1.2	Classification/Clinical Presentations of Cerebral Palsy	13
2.1.3.	Epidemiology of Cerebral Palsy	16
2.1.4	Aetiology of Cerebral Palsy	17

2.1.5 Pathophysiology of Cerebral Palsy 18
2.1.6 Clinical Manifestations in Cerebral Palsy 20
2.1.7 Associated Problems in Cerebral Palsy 21
2.1.8 Management of Cerebral Palsy 23
2.1.9 Rehabilitation Approaches in Management of Cerebral Palsy 25
2.2 Balance Dysfunctions in Cerebral Palsy 27
2.2.1. Strength training in the Management of Cerebral Palsy 29
2.2.2 Biomechanical Ankle Platform System (BAPS) Board for Training Balance in Cerebral palsy 31
2.2.3. The Gross Motor Function Classification System (GMFCS) 32
2.2.4 The "timed up and go" test for measuring walking speed 34
2.2.5 The Berg Balance Scale for assessing balance 35

CHAPTER THREE

3.0 Materials and Methods 38
3.1 Participants 38
3.2 Materials 38
3.2.1 Instruments 38
3.3 Methods 40
3.3.1 Research Design 40
3.3.2 Sampling Technique and Sample Size 40
3.3.3 Procedure for Data Collection 41
3.3.4. Venues 51
3.3.5 Analyses of Data 52

CHAPTER FOUR

4.0 Results and Discussion 54
4.1 Results 54

4.1.1. Physical and Clinical Characteristics of participants 54

4.1.2 Changes in balance scores within the three groups over 22 weeks 54

4.1.3 Changes in walking speed within the three groups over 22 weeks 54

4.1.4. Changes in GMFCS scores over 22 weeks 58

4.1.5 Comparison of balance scores across the three groups 62

4.1.6 Comparison of walking speed across the three groups 62

4.1.7 Comparison of GMFCS scores within and across the three groups 62

4.2 Hypotheses Testing 68

4.3 Discussion 80

4.3.1. Physical and Clinical Characteristics of participants 80

4.3.2 Changes in balance scores from baseline to 16 wks 81

4.3.3. Comparison of balance across the three exercise groups 82

4.3.4 Changes in walking speed of participants within group over 22 weeks 83

4.3.5 Walking speed of participants across the three groups 84

4.3.6 Trend of GMFCS levels in the three groups over 22 weeks 85

CHAPTER FIVE

5.0 Summary, Conclusions and Recommendations 86

5.1 Summary 86

5.2 Conclusions 88

5.3 Recommendations 88

REFERENCES 89

LIST OF TABLES

		Pages
2.1	Classification of cerebral palsy	16
2.2:	Aetiological factors in cerebral palsy	18
2.3	Studies on strength and Balance training in CP	36
4.1	Physical and Clinical Characteristics of participants	56
4.2	BBS Scores within the three groups	59
4.3	Walking speed scores within the three groups	61
4.4	BBS Scores for within and across group analysis (Using repeated measures and one way ANOVA)	63
4.5	Post hoc analysis for balance scores across the 3 groups	64
4.6	Walking speed scores across groups (using one way ANOVA and ANCOVA)	65
4.7	Comparison within group of walking speed (using paired t-test)	66
4.8	Within group comparison for GMFCS (using Friedman's ANOVA)	67
4.9	Across group comparison for GMFCS (Using Kruskal Wallis)	68
4.10	Pair-wise comparison over time for GMFCS (using Wilcoxon signed rank)	69

LIST OF FIGURES

		Pages
4.1	Subject attrition (drop out) over 22 weeks	55
4.2	Percentages of participants in the 3 exercise at commencement	57
4.3	Trend of improvement in GMFCS levels from baseline to 22 weeks	60

LIST OF PLATES

		Pages
3.1	Participant in starting position of the wall slide exercise	44
3.2	Participant performing wall slide exercise	45
3.3	Participant performing bridging exercise	47
3.4	Participant on side stepping exercise	48
3.5	Participant performing BAPS board perturbation	50

LIST OF APPENDICES

		Pages
I.	Sample Sizes for the Analysis of Variance for α = .05	98
II.	Modified Ashworth Scale	99
III.	Berg Balance Scale	100
IV.	Gross Motor Function Classification System For Cerebral Palsy (GMFCS)	106
V.	Data gathering form	110
VI.	Ethical Approval	111
VII.	Letter of Permission	112

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Cerebral palsy describes a group of disorders of posture and movement that occur as a result of non-progressive disturbances in the developing foetal or infant brain (Rosenbaum et al, 2007). It has also been described as a product of an insult to the immature brain at any time prior to birth and up to two years of age (Dimitrijevic and Jakubi, 2005; Alikor, 2007). Although the damage to the central nervous system is non-progressive, the clinical manifestations do change as the child grows and develops (Alikor, 2007). Chronic physical disabilities and other neurological deficits such as seizures, intellectual deficits result from this damage; while speech and language deficits could also co-exists alongside the motor and posture disorders.

Cerebral palsy (CP) is regarded as the most common cause of childhood physical disability with an incidence of 2 to 2.5 per 1000 live births in Europe; while 3.6 per 1000 live births was reported for America (Aneja 2004; Zeldin, 2007; Yeargin-Allsopp et al, 2008; Hurley et al, 2011). This paediatric disorder has substantial effects on function and health-related quality of life of both the patients and their caregivers respectively. A report by Hamzat and Mordi (2007) indicated that caring for children with CP had negative impact on the health of their caregivers. The estimated cost of care of 587,000 patients with cerebral palsy in the US in 2002 was 8.2 billion US$; while in Australia, the estimated cost was 1.47 billion US$ in 2007. In the same year 2007 in Australia, the cost of caring for CP accounted for 0.14% of the gross domestic product and the annual cost per person with CP in Australia exceeded 115,000 US$ (Koman et al 2004; Cerebral Palsy League of Queensland, 2009).

Hospital-based epidemiological studies on cerebral palsy have been reported in Nigeria. Izuora and Iloeje (1989) observed that cerebral palsy accounted for 16% of 965 cases seen at the Paediatric Neurology clinic of the University of Nigeria Teaching Hospital, Enugu between 1985 and 1987 while studies from Ibadan by Lagunju et al (2010) reported that CP accounted for 44.1% of new referrals to the Paediatric Neurology Clinic at the University College Hospital, Ibadan. The reason for the increased incidence in Ibadan over time could be due to increased awareness on the utilisation of hospital services which in turn has led to more patients reporting for medical attention. Severe perinatal asphyxia, bilirubin encephalopathy and post infectious brain damage were the most common aetiological factors in Nigeria (Wammanda et al, 2007; Ogunlesi et al, 2008; Lagunju and Okafor, 2009); while the strongest risk factors for cerebral palsy in Western Europe and America are prematurity and low birth weight (Haslam 2000; Zeldin 2007).

Cerebral palsy severely decreases voluntary motor control causing exhibition of muscular activity that is characterised by counteracting forces. These forces disturb equilibrium and affect the development of a child's capacity to explore his environment (Rosenbaum, 2003; Carlberg and Hadders-Algra, 2005). Barlett and Palisano (2000) identified the following motor impairments in children with cerebral palsy; delay in movement onset, poor timing of force generation, inability to maintain antigravity postural control, decreased speed of movement and increased co-contraction. Children with cerebral palsy also encounter problems during static upright standing in altered sensory environments and when rapid weight shifts are required either in gait initiation or in reaction to external perturbations (Woollacott and Shumway – Cook 2005; Donker et al, 2008). These postural deficits play a central role in the motor disorders seen in children with cerebral palsy who exhibit greater postural sway than typically developing "normal" children (Donker et al, 2008).

Balance skills form an integral part of gross motor abilities. Musculoskeletal impairments in cerebral palsy worsen as the child attempts to compensate for abnormalities during antigravity postural control (Bartlett and Palisano, 2000; Kembhavi et al, 2002; Olama and Thabit, 2012). Poor compensation of balance leads to difficulties with functional tasks involved in activities of daily living (Kembhavi et al, 2002). Balance dysfunction poses a great challenge in spastic diplegia and hemiplegic CP particularly in the performance of activities of daily living which require standing and walking (Law and Webb, 2005; Woollacott et al, 2005; Butner et al, 2007; Chen and Woollacott, 2007; Donker et al, 2008).

Management of cerebral palsy is multi-disciplinary with the paediatrician, physiotherapist, occupational therapist, speech and language therapist, special educator, developmental psychologist as well as the orthopaedic surgeon all playing vital roles in the optimisation of the child's overall development (Haslam, 2000). Various approaches of physiotherapy have been used in the habilitation of children with cerebral palsy; these include the earlier sensory integration, conducive education, Doman-Delacato/Patterning, neuro-developmental therapy, Rood approach, Hare approach, Eclectic approach and Vojta technique (Rosenbaum, 2003; Patel, 2005; Schuyler, 2006). Newer approaches include body weight support treadmill training, constraint-induced therapy, Adelhi technique and the use of strengthening exercises and robotics (Morton, 2005; Patel, 2005; Schuyler, 2006).

Physiotherapy interventions are usually aimed at assisting a child to perform tasks in a variety of environmental settings while maintaining a position against gravity (Barlett and Palisano, 2000). Movement from one place to another also forms part of the focus of intervention because it contributes to activities of daily living and play (Barlett and Palisano, 2000; Olama and Thabit, 2012). Inability to maintain antigravity postural control invariably leads to poor balance maintenance in children with CP. Inability to maintain antigravity

postural control occurs due to factors such as reduced contraction of agonist muscles, problems with adaptation of the degree of muscle contraction and this causes an excess of antagonists co-activation (Roncesvalles et al 2002; van der Heide and Hadders – Algra, 2005). These children therefore exhibit poor balance skills when compared with normally developing children in various sensory environments (Burtner et al 2007; Chen and Woollacott, 2007). Measures that improve mobility in children with CP could potentially result in substantial reduction of costs of health care (Olama and Thabit, 2012).

Efficacy of strengthening exercises in improving isometric and functional strength in the lower limbs, and invariably balance performance in children with CP, have been proven in studies (Dodd et al, 2003; Morton et al, 2005; Kelly and Darrah, 2005). The improvements in functional strength attained were sustained even after treatment was discontinued. Various forms of strengthening exercises employed by Physiotherapists in the management of children with CP include: task – specific exercises such as group circuit training, progressive resistance exercise training of different muscle groups and the use of free weights (Blundell et al 2003; Koman et al, 2004; Kelly and Darrah, 2005; Morton et al, 2005; Olama, 2011).

Biomechanical Ankle Platform System (BAPS), otherwise known as “Balance board” used to generate external perturbations in the antero-posterior and lateral directions is a commonly employed modality for balance training among patients with different clinical conditions in many Nigeria physiotherapy clinics. They are particularly used in rehabilitation of the lower limbs after musculoskeletal injuries. Efficacy of BAPS in facilitating equilibrium reactions in the rehabilitation of children with cerebral palsy have been reported (Ratliffe, 1998). There however appears to have been no significant efforts at further establishing its efficacy in enhancing balance and functional activity after CP.

1.2 Statement of the problem

Efficacy of strengthening exercises in improving balance performance and functional ambulation in children with spastic hemiplegic and diplegic cerebral palsy has been shown in previous studies (Blundell et al 2003; Morton et al, 2005). The Biomechanical Ankle Platform System (BAPS) is readily available and an easy-to-administer equipment commonly used in rehabilitation of the lower limbs after musculoskeletal injuries. However, despite its common utilisation for training balance in many physiotherapy clinics, evidence of published information on the efficacy of balance board in enhancing functional performance in cerebral palsy is scarce.

Establishment comparative efficacy of strengthening and balance board exercise programmes in children with CP was needful in order to show the efficacy of the BAPS. The following questions then arose:

i. What would be the efficacy of a 16-week strengthening exercise programme (SEP), balance board exercise programme (BAPS) and a combined strengthening exercises and balance board exercise programme (CT) in training balance among children with cerebral palsy?

ii. To what extent would the effect of these three exercise programmes (SEP, BAPS and CT) impact functional performance (FP as measured by walking speed, balance and motor function) in children with cerebral palsy at 8, 16 and 22 weeks?

1.3 Aims of Study

This study was aimed at:

i. Comparing the efficacy of a 16-week Strengthening Exercise Programme (SEP) and Biomechanical Ankle Platform System (BAPS) training on functional performance among children with cerebral palsy.

ii. Determining whether or not the effect on functional performance among children with CP will be sustained 6 weeks after cessation of the exercise training programme.

1.4 Hypotheses

1.4.1 Major Hypothesis

The following hypotheses were formulated for this study:

1. There would be no significant difference in the efficacy of 16-week Strengthening Exercise Programme (SEP), Biomechanical Ankle Platform System (BAPS) and Combined Therapy (CT) on functional performance (walking speed, balance and motor function) of children with CP.

1.4.2 Sub-hypotheses

1. There will be no significant difference in the baseline scores of the 'timed up and go' (TUG) of children with CP across the 3 groups.
2. There will be no significant difference in the baseline Berg Balance Scale (BBS) scores of children with CP across the 3 groups.
3. There will be no significant difference in the baseline Gross Motor Function Classification System (GMFCS) levels of children with CP across the 3 groups.
4. There will be no significant difference between the baseline and 8-week TUG scores of children with CP in the BAPS group.

5. There will be no significant difference between the baseline and 8-week TUG scores of children with CP in the SEP group.
6. There will be no significant difference between the baseline and 8-week TUG scores of children with CP in the CT group.
7. There will be no significant difference between the baseline and 8-week BBS scores of children with CP in the BAPS group.
8. There will be no significant difference between the baseline and 8-week BBS scores of children with CP in the SEP group.
9. There will be no significant difference between the baseline and 8-week BBS scores of children with CP in the CT group.
10. There will be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the BAPS group.
11. There will be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the SEP group.
12. There will be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the CT group.
13. There will be no significant difference between the baseline and 16-week TUG scores of children with CP in the BAPS group.
14. There will be no significant difference between the baseline and 16-week TUG scores of children with CP in the SEP group.
15. There will be no significant difference between the baseline and 16-week TUG scores of children with CP in the CT group.
16. There will be no significant difference between the baseline and 16-week BBS scores of children with CP across the BAPS group.

17. There will be no significant difference between the baseline and 16-week BBS scores of children with CP in the SEP group.
18. There will be no significant difference between the baseline and 16-week BBS scores of children with CP in the CT group.
19. There will be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the BAPS group.
20. There will be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the SEP group.
21. There will be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the CT group.
22. There will be no significant difference between the 8^{th} week and 16^{th} week TUG scores of children with CP in the BAPS group.
23. There will be no significant difference between the 8^{th} week and 16^{th} week TUG scores of children with CP in the SEP group.
24. There will be no significant difference between the 8^{th} week and 16^{th} week TUG scores of children with CP in the CT group.
25. There will be no significant difference between the 8^{th} week and 16^{th} week BBS scores of children with CP in the BAPS group.
26. There will be no significant difference between the 8^{th} week and 16^{th} week BBS scores of children with CP in the SEP group.
27. There will be no significant difference between the 8^{th} week and 16^{th} week BBS scores of children with CP in the CT group.
28. There will be no significant difference between the 8^{th} week and 16^{th} week GMFCS levels of children with CP in the BAPS group.

29. There will be no significant difference between the 8th week and 16th week GMFCS levels of children with CP in the SEP group.
30. There will be no significant difference between the 8th week and 16th week GMFCS levels of children with CP in the CT group.
31. There will be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the BAPS group.
32. There will be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the SEP group.
33. There will be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the CT group.
34. There will be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the BAPS group.
35. There will be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the SEP group.
36. There will be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the CT group.
37. There will be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the BAPS group.
38. There will be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the SEP group.
39. There will be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the CT group.
40. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the BAPS group.

41. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the SEP group.
42. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the CT group.
43. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the BAPS group.
44. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the SEP group.
45. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the CT group.
46. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS level of children with CP in the BAPS group.
47. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS level of children with CP in the SEP group.
48. There will be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS level of children with CP in the CT group.

1.5 Delimitations

This study was delimited to the following:

a) Participants:

i. Children with diagnosed diplegic and hemiplegic cerebral palsy; this was because these two topographic classifications are the ambulatory types of cerebral palsy commonly seen in Nigeria (Ogunlesi et al, 2008; Lagunju et al, 2010).

ii. Children who were aged between 4 and 12 years

iii. Children with cerebral palsy whose degree of spasticity was not more than grade 2 on the modified Ashworth scale (Bohannon and Smith, 1987).

iv. Children with cerebral palsy who could comprehend verbal instructions and whose Gross Motor Function Classification System (GMFCS) score was not greater than level 3 at the point of recruitment into the study.

1.6 Limitations

1. Some of the participants that commenced this study dropped out at various points in the study in spite of the incentives given in the form of free physiotherapy treatment and transport fare supplements.
2. Efforts were made to ensure that the subjects were blinded to the groups that they were assigned into, however interactions between participants could not be absolutely ruled out because some patients had their appointments on similar days.

1.7 Significance of the study

a) The outcome of this study has provided scientific evidence on comparative efficacy of strengthening exercise, balance board exercises and combination of the two procedures in training balance and enhancing motor function (improved walking speed) in children with cerebral palsy. The outcome of this study could therefore go a long way to enhance outcome of physiotherapy intervention aimed at treating balance and improving functional performance among children with cerebral palsy.

b) The Biomechanical Ankle Platform System of training has been proven to be efficacious in training balance and function in children with cerebral palsy.

1.8 Operational definition of terms

a) Ambulatory cerebral palsy in this study referred to children who had diplegic and hemiplegic cerebral palsy. The participants in this study could stand either supported or without support.

b) Biomechanical Ankle Platform System (BAPS) in this study referred to the locally fabricated wobble or balance board with a rocker base.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cerebral Palsy

2.1.1 Introduction

Cerebral palsy was first described by an orthopaedic surgeon named William Little in 1862 and was initially called Little's disease. It was described as a disorder that appeared to strike children in the first year of life; affected developmental skill progression and did not improve over time (Haslam 2000). Thereafter in 1897, Sigmund Freud suggested that CP may be due to abnormal development influencing the developing foetus (Zeldin, 2007). Cerebral palsy has been described as a group of disorders of posture and movement that occur as a result of non-progressive disturbances in the developing foetal or infant brain (Rosenbaum et al, 2007).

Cerebral palsy is primarily a disorder of posture and movement and has been referred to as "static encephalopathy" because of the non-progressive nature of the lesion. The brain is connected to different areas of the nervous system; a lack of function in the originally damaged areas may interfere with the proper functioning of the undamaged areas of the brain (Haslam, 2000; Koman et al, 2004; Sankar and Mundkur, 2005; Martin and Kessler, 2007; Rosenbaum et al, 2007). The damage usually affects most parts of the brain, with other neurological problems, emotional disorders, feeding problems possibly co-existing alongside cerebral palsy (Aneja, 2004; Ogunlesi et al, 2008; Lagunju and Okafor, 2009; Lagunju et al, 2010).

2.1.2 Classification / Clinical Presentations of Cerebral Palsy

Cerebral palsy had been classified using various criteria; these include physiologic, topographic, aetiologic and functional parameters (Rosenbaum, 2003; Zeldin 2007). The

European classification of CP is based on the predominating motor impairments and characteristics which include; spastic, ataxic and dyskinetic (Zeldin, 2007).

Spasticity in CP is due to intraventricular haemorrhages in the cerebrum. Hypertonicity is mostly seen in antigravity muscles with the affected body parts demonstrating increased deep tendon reflexes, hypertonicity, muscle weakness and tremors (Krigger, 2006; Martin and Kessler, 2007). It is the most common clinical feature and is seen in 70-80% of cerebral palsy cases (Krigger, 2006).

Ataxic CP arises from damage to the cerebellum; it is the rarest form of cerebral palsy and is seen in 5-10% of cases. Loss of coordination and low postural tone make movement jerky and irregular. Patient with ataxic CP stand with a wide base of support as a compensatory mechanism for poor static postural control (Krigger, 2006; Martin and Kessler, 2007).

Athetosis is the most common dyskinetic syndrome resulting from damage to the basal ganglia. Flunctuations of muscle tone are often observed and these make voluntary movements difficult. Exhibition of slow, writhing involuntary movements are seen in the extremities when the patient attempts voluntary movement (Krigger, 2006; Martin and Kessler, 2007).

Another method of classifying CP is based on physiologic motor impairments and this is divided CP into pyramidal (spastic) and extrapyramidal (non-spastic). Lagunju et al (2010) reported that spastic CP accounted for 83.5%, dyskinetic CP accounted for 6.5% and hypotonic CP constituted 2.4% of cerebral palsy cases seen in Ibadan, Nigeria. Wammanda et al, (2007) while classifying CP in Zaria, Northern Nigeria reported that hypotonic CP accounted for 19.1%, mixed 4.8% while spastic CP accounted for over 70%.. Ogunlesi et al, (2008) reported that spastic CP accounted for 80.4%, hypotonic 12.0%, extrapyramidal 4.3% and mixed type 3.3% of cerebral palsy cases seen in Sagamu, Nigeria.

Another classification is based on topographical manifestations of the limb/limbs involved which include:

a. Monoplegia: this topographic form of CP involves paralysis of only one extremity (Koman et al, 2004; Stokes, 2005). There was paucity of evidence on this subtype because it is not commonly seen in the clinics.

b. Diplegia: this is a common form of spastic CP involving the paralysis of all the four limbs and trunk; the lower limbs are usually more affected. It constitutes about 30-40% of spastic cerebral palsy and 6 - 13.5% of spastic CP seen in Nigeria (Ogunlesi et al, 2008; Peters et al, 2008); although Wammanda et al (2007) had reported a prevalence of 20.6% in Zaria. It is commonly found as a consequence of preterm, low birth weight (Stokes, 2005; Zeldin, 2007).

c. Hemiplegia: this form involves paralysis of the muscles of the upper and lower limbs on one side of the body and constitutes about 20-30% of spastic CP and 11-20.3% of CP seen in Nigeria (Koman et al 2004; Stokes, 2005; Zeldin, 2007, Ogunlesi et al, 2008; Peters et al, 2008).

d. Quadriplegia: this form of CP involves paralysis of all the four limbs, the upper limbs being more severely affected than the lower limbs and constitutes 10-15% of spastic CP (Stokes, 2005; Zeldin 2007). It accounted for 66.2% of CP cases in Sagamu (Ogunlesi et al, 2008).

Classification by Zeldin et al, 2007 showing the physiologic, topographic, aetiologic and functional sub types are shown in table 2.1 below:

Table 2.1: Classification of cerebral palsy (Zeldin et al, 2007)

Physiologic/European classification of motor impairment	Topographic	Aetiologic	Function
Spastic	Monoplegia	Prenatal	Class I: no activity limitation
Ataxic	Diplegia	Perinatal	Class II: slight to moderate limitation
Dyskinetic	Triplegia		Class III: moderate to great limitation
Dystotonic	Hemiplegia	Postnatal	Class IV: No useful physical activity
Choreo-athetotic	Quadriplegia		

2.1.3 **Epidemiology of Cerebral Palsy**

The prevalence of cerebral palsy (CP) in Europe is 2 to 2.5 per 1000 live births and recent epidemiological statistics in the United States reported incidence as 3.6 per 1000 live births with males more affected than females (Yeargin-Allsopp et al 2008; Hurley et al, 2011). There is a higher prevalence of CP in premature and twin births in developed countries (Rosenbaum, 2003; Zeldin et al 2007). In the developing world, estimates of CP ranging from 1.5 to 5.6 cases per 1000 live birth have been reported. However, it is possible that these figures may be underestimated due to poor health access and inconsistent diagnostic criteria (Stanley et al, 2000).

Nottidge and Okogbo (1991) reported that 16.2% of new referrals to the paediatric neurology clinics of the University College Hospital, Ibadan over a three-year period was due to cerebral palsy. Lagunju and Okafor (2009) in Ibadan and Belonwu et al (2009) in Kano reported that cerebral palsy accounted for 44.1% and 42.4% respectively of all new paediatric neurological cases. Cerebral palsy accounted for 50.3% of paediatric neurology clinics seen at Sagamu (Ogunlesi et al, 2008).

Records from the Physiotherapy clinics at the Oni Memorial Children Hospital (OMCH), Ibadan and the Physiotherapy Department of UCH showed that 72 new cases and 63 new cases respectively were seen between November 2011 and April 2012 (Oni Memorial Children's Hospital Medical Records Registers, 2012; Physiotherapy Department, UCH Medical Records Register, 2012). The marked difference in the number of cases seen at the centres in Ibadan could be attributable to the lower fees paid in OMCH as well as the ease of seeing the physiotherapist compared with the UCH.

2.1.4 **Aetiology of Cerebral Palsy**

The aetiology of cerebral palsy is diverse and multifactorial (Sankar and Mundkur, 2005). While prematurity and low birth weight had been reported as the strongest aetiological factors in Europe and North America (Haslam, 2000); the most important factors in developing countries such as Nigeria are: perinatal asphyxia, bilirubin encephalopathy, prematurity and post infectious brain damage (Alikor, 2007; Ogunlesi et al, 2008; Belonwu et al 2009; Lagunju and Okafor, 2009). Aetiological factors of cerebral palsy as seen in Sagamu have been presented as: birth asphyxia 57.65, bilirubin encephalopathy 36.9% and CNS infections 21.7% (Ogunlesi et al, 2008). Lagunju and Okafor (2009) reviewed aetiological factors of CP cases seen in Ibadan over a three- year period; severe perinatal asphyxia accounted for 42.2%, bilirubin encephalopathy accounted for 23.4% while intracranial infections accounted for 15.8%.

The aetiological factors of CP range from prenatal events such as hypoxia, genetic disorders, intra-uterine infections ; perinatal insults such as birth asphyxia, prematurity, instrumental delivery, to postnatal events such as seizures, hyperbilirubinaemia and head trauma (Jacobson and Hagberg, 2004; Zeldin, 2007). These are presented in table 2.2 below.

Table 2.2: Aetiological factors in cerebral palsy (Zeldin et al 2007)

Prenatal	Perinatal	Postnatal
Hypoxia	Asphyxia	Seizures within 48 hours of birth
Genetic disorders	Premature birth <32 weeks or >2500g	Cerebral infarction
Metabolic disorders	Blood incompatibility Infection	Hyperbilirubinaemia
Multiple gestation	Abnormal foetal presentation	Sepsis
Intrauterine infections	Placental abruption	Respiratory distress syndrome
Thrombophilic disorders	Instrument delivery	Meningitis
Teratogenic exposure		Intraventricular haemorrhage
Chorioamnionitis		Shaken baby syndrome
Maternal fever		Head injury.
Exposure to toxins		
Malformation of brain structures		
Intra uterine growth restriction		
Abdominal trauma		
Vascular insults		

2.1.5 **Pathophysiology of cerebral palsy**

Different pathological processes may give rise to the same clinical manifestations and maturity of the brain at the time of injury has been linked to the type of lesion (Haslam, 2000; Alikor, 2007). Damage occurring before or during the birth process is termed "congenital" while damage after birth is termed "acquired". Insults before the 20th week of gestation result in brain malformation; while insults between 26 and 30 weeks of gestation cause damage to the white matter in the periventricular areas. Cortical and basal ganglia damage are seen more in term babies with insults due mainly to perinatal events (Alikor, 2007).

The pathophysiologic basis of prematurity is based on the physical stress on the premature infants as well as the immaturity of the brain and cerebral vasculature which are significant risk factors for CP in the premature infant. Before term, distribution of foetal cerebral circulation results in the tendency for hypoperfusion in the periventricular white matter, therefore hypoperfusion in this region may result in germinal matrix haemorrhage or periventricular leukomalacia (PVL) (Koman et al, 2004; Zeldin et al, 2007) . Between the 26th and 34th week of gestation, the periventricular white matter around the lateral ventricles are most susceptible to injuries and because these areas carry the rubrospinal and corticospinal fibres; injury may result in spastic diplegia. Periventricular leukomalacia, thought to be due to ischaemia to the internal capsule in premature infants, is generally symmetrical though asymmetric injury may result in one side being more affected than the other which may then appear to be a spastic hemiplegia though it is best described as asymmetric spastic diplegia.

Injury to the brain before the 20th week of gestation may result in neuronal migration deficits while injuries between 34-40th week can result in focal and multifocal deficits. At term, vascular injuries to the brain often affect the distribution of the middle cerebral artery with resulting spastic hemiplegia CP. The brain is also susceptible to hypoperfusion at term affecting mostly the cortex which may result in spastic quadriplegic CP. However, when the basal ganglia are affected, it results in extrapyramidal or dyskinetic CP (Koman et al, 2004; Zeldin et al, 2007).

2.1.6 **Clinical Manifestations in Cerebral palsy**

Postural problems play a central role in the motor dysfunctions seen in children with CP; postural control has been studied in two ways which are: compensatory or feed-back control and anticipatory or feed-forward control (Carlberg and Hadders-Algra, 2005). Clinical

manifestations in cerebral palsy is characterised by impaired muscle tone, delayed motor development and decreased functional abilities. Manifestations of damage to the central nervous system depend on the developmental age of the child at the time of injury; severity and extent of the injury (Krigger, 2006). The major problems seen in cerebral palsy are:

(a) Abnormalities of motor control that present as fluctuations in muscle tone which is characterised by generalised hypotonia in infancy and spasticity later in life. Involuntary movements and postures are commonly seen in the patients with severe reduction in selective motor control (Fernandez-Alvarez and Aicardi, 2001; Carlberg and Hadders- Algra, 2005).

(b) Persistence of primitive reflexes: in a typically developing child, primitive reflexes observed in infancy are inhibited and integrated into voluntary movements as the central nervous system matures. However in a child with cerebral palsy, primitive reflexes tend to be retained thereby causing movement abnormalities that could persist into adulthood. Examples include the asymmetric tonic neck reflex, tonic labyrinthine reflex and positive supporting reactions (Fernandez-Alvarez and Aicardi, 2001; Martin and Kessler, 2007).

2.1.7 **Associated problems in Cerebral palsy**

In addition to motor deficits, other neurocognitive and sensory deficits are seen in children with cerebral palsy (Aneja, 2004; Koman et al, 2004; Anttila et al, 2008; Ogunlesi et al, 2008; Lagunju et al, 2010). These associated deficits were observed in 88.8% of CP cases seen in Ibadan and as many as 51.5% of the patients had multiple deficits (Lagunju et al, 2010); also 90.2% of cases seen in Sagamu had associated problems. These associated problems seen in children with cerebral palsy include:

a. Mental retardation: Usually expressed as learning disabilities are associated with cerebral involvements commonly seen in wide spread lesions and occur in up to 60% of CP cases (Aneja, 2004; Koman et al, 2004; Patel, 2005). Ogunlesi et al (2008) reported that 24% of CP cases seen in Sagamu had mental subnormality. Lagunju et al (2010) reported that 83.3% had cognitive impairments. It was commoner in children with spastic quadriplegia (Aneja, 2004).

b. Seizures occur in 35-40% of cases and it is commoner in cerebral palsy types with postnatal aetiology (Aneja, 2004; Koman et al, 2004). It is the most common co-morbidity seen in Nigeria; Lagunju et al (2010) reported that 40.3% had epileptic seizures while Ogunlesi et al (2008) reported 46.7%, and that it was commoner in with microcephaly children who had suffered from asphyxia at birth.

c. Sensory deficits: These present as abnormalities of proprioception, stereognosis and tactile stimulation. Poor organisation of sensory stimulation occurs and this leads to poor organisation of movement; hemiplegic CP patients particularly manifest these as 97% had abnormal stereognosis, 90% had diminished two-point discrimination and 46% had diminished propriocetion (Aneja, 2004; Koman et al 2004; Patel, 2005).

d. Visual problems associated with cerebral palsy present as strabismus, amblyopia, nystagmus, optic atrophy, retrolental fibroplasia and refractive errors. Squints may account for 30% of visual impairment. These visual problems impact negatively on reading and writing; 20% are from errors of refraction and cortical damage (Aneja, 2004; Koman et al, 2004). Ogunlesi et al (2008) reported that 25% of cases seen in Sagamu had visual impairments while 32% of cases seen in Ibadan had visual challenges (Lagunju et al, 2010).

e. Speech and language disorders occur in over 50% of cases, it could occur either as dysarthria or as dyspraxia or due to hearing loss which could be conductive or sensorineural (Aneja, 2004; Koman et al, 2004). Speech disorders were seen in 43.5% and 24.8% of cases seen in Sagamu and Ibadan respectively (Ogunlesi et al, 2008; Lagunju et al, 2010). Hearing impairments occur more commonly in CP due to very low birth weight, neonatal meningitis and kernicterus and 33.3% of cases in Ibadan had these deficits (Lagunju et al, 2010).

f. Oral-motor disorders could arise from difficulties with the coordination of oral musculature and this could lead to feeding difficulties and swallowing dysfunctions which could later result in nutritional problems that affect physical growth; this was reported in 29% of cases seen in Ibadan (Lagunju et al, 2010). Poor oral-motor control could also lead to respiratory problems due to aspiration of food (Stanley et al, 2000; Aneja, 2004; Zeldin, 2007).

g. Behavioural disorders: Poor motor control and communication difficulties could lead to frustration and depression in the children with CP (Rosenbaum, 2003; Wammanda et al, 2007) and has been reported in 61% of cases (Aneja, 2004). Ogunlesi et al (2008) reported that 6.5% of cases seen had behavioural challenges.

2.1.8 **Management of Cerebral palsy**

The management of cerebral palsy starts with appropriate diagnosis and this incorporates a detailed history taking, physical examination, and ancillary investigations (Koman et al, 2004). Cerebral palsy is usually recognised early in life when a child fails to reach motor milestones at the appropriate chronological age; exhibits abnormal muscle tone in unusual postures (Aneja, 2004; Sankar and Mundkur, 2005; Krigger, 2006). Diagnosis is almost impossible under four months of age and even in mild cases it might not be possible until after eight months. (Sankar and Mundkur, 2005). Although detailed history taking, physical examination and neurological evaluation all give rise to the diagnosis; neuroimaging with the use of magnetic resonance imaging (MRI) has been found to be the most useful diagnostic tool (Sankar and Mundkur, 2005). Several assessment instruments are available to quantify and monitor developmental milestones; and to assess the quality of life of patients and their caregivers. These include: Child- Health Questionnaire, Pediatric Evaluation of Disability Inventory (PEDI) and Functional Independence Measure for children (WeeFIM). Surveillance for associated disabilities could also aid in thoroughly assessing and diagnosing cerebral palsy (Krigger, 2006).

Conventional treatment approaches target the functional challenges faced by patients suffering from cerebral palsy. A modern team approach focuses on total patient development and goals of therapies aim at enhancing patient and caregiver interaction while providing family support (Krigger, 2006). The World Health Organisation (WHO) emphasises function in cerebral palsy; it is therefore necessary to shift treatment focus from attaining normal function towards the achievement of functional abilities that will facilitate independence. Interventions in the management of cerebral palsy should therefore aim at promoting function and increasing the child's developmental capabilities towards independence (Rosenbaum, 2003). Clinicians need to constantly ask themselves questions such as what can

we do in childhood, or what should we not do to maximise mobility and independence in adulthood (Damiano et al, 2009). Best clinical outcomes result from early and intensive management (Krigger, 2006).

Medical interventions in CP are targeted at the sequelae of the non-progressive lesions and basic understanding of neurophysiology is required (Damiano et al, 2009). Pharmacologic and surgical interventions are usually employed. The pharmacologic agents could be directed at structures within the CNS, peripheral nerves, neuromuscular junctions or directly at the muscle; they could be administered orally, intramuscularly and intrathecally (Koman et al, 2004; Damiano et al, 2009). Spasticity is a major problem in CP which is managed through parenterally administered agents that are used to produce selective denervation of muscles and nerves. They include baclofen, botulinum toxins, phenyl alcohol. Gamma amino-butyric acid (GABA) antagonists, alpha 2-adrenergic agonists are administered orally in the treatment of spasticity. Seizure which is another commonly seen problem in CP could be controlled with the use of anticonvulsants such as carbamazepine, phenobarbitol and phenytoin; though the side effects could be severe (Koman et al 2004; Damiano et al, 2009).

The surgical management includes orthopaedic and neuro-surgery. Orthopaedic surgical procedures commonly carried out include: arthrodesis, osteotomy, tendon transfer and musculotendinous or tendon lengthening. Arthrodesis involves fusion of joints; this is used to put a joint in an optimal position. Arthrodesis is used to treat scoliosis in children with CP.

Osteotomy is carried out when multiple deformities prevent or limit ambulation and also cause pain as well. Osteotomies are also used to align the foot when there are multiple deformities. Tendon transfer in CP involves taking a spastic muscle which is causing deformity and repositioning it to perform another function. For example when the knee is stiff, transfer of rectus femoris to the hamstrings has been shown to improve swing phase in

gait cycle. Musculotendinous or tendon lengthening involves lengthening the tendon in a Z-type pattern at the musculotendinous junction or incising through the fascia. This is commonly done when there is a contracture (Damiano et al, 2009).

Neurosurgical procedures include: selective dorsal rhizotomy and CNS stimulation (Koman et al 2004; Damiano et al, 2009). Dorsal rhizotomy is performed to manage spasticity; it involves stimulation and transection of selective posterior rootlets or transection of a specific portion of rootlets. CNS stimulation is done electrically with a view of reducing excessive tone (Koman et al, 2004).

2.1.9 **Rehabilitation Approaches in Management of Cerebral Palsy**

Various approaches and schools of thought in managing cerebral palsy have been developed in Europe and America over the past 60 years.

1. Doman-Delacato system is sometimes called patterning. It was developed from theories originally expounded by Temple Fay that movement sequences paralleled evolutionary movements and that a child with brain damage could begin to learn appropriate patterns of movement similar to those of amphibians and reptiles. Doman and Delacato therefore propounded that highly systematic movement and sensory input can promote sensory and motor integration in undamaged brain cells (Ratliffe, 1998).
2. Conductive education approach was developed by Peto in Hungary in 1945. It was based on the premise that a child's daily activities can be integrated in a unified approach that combines treatment, education, self-help skills and social skills. Practice in social skills, functional skills, language, cognitive skills and motor skills are all integrated into the structure of the day by the conductor who uses group activities to reach individual goals (Ratliffe, 1998).

3. Rood approach was devised by Margaret Rood on the premise that motor patterns can be modified through sensory stimuli. The focus was on normalising tone after which the child can bear weight through the affected extremity; and can begin to move through the developmental sequences of movement. Repetition of movement was emphasised and techniques such as slow stroking, fast brushing, ice, joint compression techniques were used to either facilitate or inhibit tone.
4. Sensory integration approach was developed in the 1970s by Jean Ayres, who observed that children with neurological disorders had difficulties with other tasks other than motor coordination. They had difficulties with behavior, attention and visual perception which were not being addressed with traditional therapy. Techniques used in sensory integration include; deep pressure, vibration, compression, traction (Ratliffe, 1998).
5. Neurodevelopmental therapy (NDT): It was developed by Bertha and Karl Bobath in the 1940s in England as a result of years of treatment of patients with neurological disorders, particularly children with cerebral palsy (Ratliffe, 1988). The NDT is not a method but rather, a flexible approach to the multiple problems of the individual child with CP. There are no general patterns of exercises for all children but treatment is based on individual patient's specific needs; the approach uses assessment, treatment planning, facilitation against gravity and transition of movements into functional skills, incorporating patterns of movement which are aimed at improving coordination in posture and movement as well as normalising postural tone (Ratliffe, 1998).

The key principles in NDT are the inhibition of abnormal postural patterns and facilitation of normal motor patterns. Treatment is primarily directed towards inhibiting the patterns of abnormal reflex activity and facilitating normal patterns of movement through techniques of

handling; and the key points of control may be proximal or distal body parts. Examples are the head, should girdle, trunk, pelvis, knees and calcaneus. These points are frequently changed in order to avoid dependency on the physiotherapist and to promote control by the child (Ratliffe, 1998; Butler and Darrah, 2001).

Researches had favoured the systems model of motor control over the hierarchical model upon which the NDT is premised. The systems model incorporates other components which are non-neural into habilitation; psychological components and environmental contexts are examples (Butler and Darrah, 2001). Butler and Darrah (2001) in conjuction with the American Academy for Cerebral Palsy and Developmental Medicine reviewed evidences available on the use of NDT in children with CP; levels of evidence available were rather weak in substantiating the effectiveness of NDT. However, parents whose wards had been exposed to NDT and had seen dramatic results are convinced that it is the best approach to habilitate children with cerebral palsy (Rosenbaum, 2003).

2.2 **Balance Dysfunctions in Cerebral Palsy**

Balance refers to the process by which one controls the body's centre of mass with respect to the base of support whether it is stationary or moving (Blackburn and Voight, 2001). Maintaining, achieving or restoring a state of balance during any posture or activity is referred to as postural control and the strategies involved could be predictive or reactive; involving either a fixed support or a change in support response (Pollock et al, 2000). Mechanisms governing postural control and orientation in three dimensional space are largely reflex in character and they depend on afferent inputs from body systems such as visual, vestibular, somatosensory and musculoskeletal (Ganong, 2005; Kisner and Colby, 2007). Balance control is important for competence in the performance of most functional skills and helping children with CP recover from unexpected balance disturbances which

could be due to slips or self-induced instability (Woollacott and Shumway-Cook, 2005; Olama and Thabit, 2012).

In the elderly, declines in all sensory systems and stages of information processing accompany aging. Anticipatory postural adjustments mechanisms are impaired and their responses to perturbations are characterised by slower-onset of force generation, limitations in balance abilities and the use of hip strategy in balance control (Edwards, 2002; Kisner and Colby, 2007).

Postural problems play a central role in the motor dysfunctions seen in children with CP; such that the performance of daily activities is markedly affected by postural deficits (Carlberg and Hadders-Algra, 2005). Predominance of primitive, spinally controlled muscle response patterns over centrally integrated and coordinated movement patterns seen in CP is partly due to poor myelination of the descending cerebral and brainstem neurons as well as reduction in number and connection of neurons in higher centres like motor cortex, basal ganglia, cerebellum and brainstem (Olama, 2011; Olama and Thabit, 2012). Impaired balance, gait disturbances and frequent falls are common problems seen in CP and they are due to reduction in muscle strength, range of motion, motor coordination, sensory organisation and abnormal muscle tone (Stackhouse et al, 2007; Olama, 2011).

In studying pathophysiology of cerebral palsy, impaired postural control have been shown to have negative effects on balance maintenance (Bartlett and Palisano , 2000; Van der Heide and Hadders- Algra, 2005; Woollacott and Shumway- Cook , 2005; Damiano et al, 2010; Tomita et al, 2011). The following impairments were identified:

1. Delay in movement onset: this is due to delay in onset latencies of muscles in response to external perturbations.

2. Poor force production: due to abnormal velocity dependent electromyographic recruitment.
3. Poor antigravity postural control due to changes in the mechanical properties of the muscle- tendon system.
4. Decreased speed of movement: due to inability to modulate postural muscle activity with changes in the degree of external perturbation.
5. Loss of selectivity in neuromuscular output which leads to proximal- distal co-activation and then increased co-contraction of agonists and antagonists.

All these impairments lead to inability of the patient to maintain adequate balance in functional postures such as sitting, standing and walking. Musculoskeletal impairments that result from compensations, while moving against gravity, cause balance dysfunctions; and the latter had been commonly reported in the ambulatory types of cerebral palsy which are diplegia and hemiplegia (Law and Webb, 2005; Woollacott et al 2005). Van der Heide and Hadders-Algra (2005) opined that therapy for children with ambulatory types of CP should focus on balance exercises in which the children practise varying degrees of balance control during self-initiated movements rather than focusing on the reduction of muscle co-activation.

2.2.1 **Strength Training in the Management of Cerebral Palsy**

Progressive strength training leads to increased muscle strength and improved function in children with cerebral palsy (Scholtes et al, 2008; Olama, 2011). It is recommended in promotion fitness and increase in patients' participation in various recreational and occupational activities (Koman et al 2004; Kelly and Darrah, 2005). Damiano and Abel (1998) engaged 11 patients with cerebral palsy (6 had diplegia while 5 had hemiplegia) in a

6-week strength training programme and reported effectiveness of the protocol in terms of the significant strength gained and higher gait velocity recorded after the training.

Dodd et al (2002) reviewed studies on the efficacy of various methods of progressive resistance exercise programmes for people with cerebral palsy and noted that gross motor function such as sitting, standing, walking and stairs climbing improved after varying sessions of strength training. Dodd et al (2003) in another study involved 21 children who had cerebral palsy and were aged between 8 and 18 years in a strength- training randomised control trial for six weeks. The subjects performed repeated practice of step-up, toe raises and squatting activities against the resistance of a weighted back pack. Improvements were observed in the muscle strength and walking speed of the participants. Blundell et al (2003) studied 8 children with cerebral palsy (7 with diplegia and 1 with ataxic quadriplegia) on a 4-week task-specific strength training conducted as group circuit training. After treatment, isometric and functional strength improved by 47% and 150% respectively and the patients were able to walk faster with longer strides. The improvements were found sustained when reevaluated 8 weeks after treatment. Morton et al (2005) studied 8 children with hypertonic cerebral palsy aged between 6 and 12 years in a 6-week progressive, free-weight, strengthening programme. Muscle strength was observed to increase with quadriceps and hamstring strength moving towards normal, muscle tone decreased, while walking speed and step rate increased. The improvements were sustained at follow up after 4 weeks and no adverse effects accompanied the positive outcome in strength and function.

Kelly and Darrah (2005) reviewed studies that evaluate the effects of progressive resistance exercise on muscle strength and motor function in children with cerebral palsy. Studies reviewed utilised resistance that included free weights, isokinetic and isometric exercises; and the targets were muscles of the trunk, hips, knees and the ankles. Evidences showed that

the progressive resistance exercise programmes which lasted between 4 and 10 weeks resulted in improved muscle strength, improved walking speed, improved wheel chair endurance and improved scores of perceived physical appearance.

Taylor et al (2005) in a summary of systematic reviews on Progressive Resistance Exercise (PRE) reported that PRE had been proven to be effective in various aspects of Physiotherapy ranging from Cardiopulmonary, Orthopaedics, Neurology as well as Geriatrics. For optimal results, strength training must be invidualised; intensity must be progressively increased in order to stimulate increase in strength and progression should be based on individual's level of strength (Taylor et al, 2005; Scholtes et al, 2008; Olama, 2011).

2.2.2 **Biomechanical Ankle Platform System (BAPS) for training balance in cerebral palsy**

Balance training had been carried out using equipment such as force platform, application of postural stress and the use of movable platforms to generate antero-posterior perturbations (Roncesvalle et al, 2002; Woollacott et al, 2005; Woollacott and Shumway – Cook 2005). These equipment (force platform, posturography) are however expensive (costing as much as 2,950 US$), cumbersome and not readily available to researchers and clinicians in third world countries like Nigeria.

The BAPS board commonly called balance board has been widely used in training balance in a variety of conditions and its efficacy has also been established (Kisner and Colby, 2007). It is a form of closed chain exercise equipment which uses the body weight as resistance; with the feet positioned on the board, the patient shifts his weight laterally and anteroposteriorly while attempting to control the ankle and maintain balance (Kisner and Colby, 2007).

Closed –chain exercise refers to movement that occurs in a closed kinematic chain where the body moves over a fixed distal segment i.e a closed chain movement occurs in a weight bearing posture when the feet are planted on the ground. These exercises load muscles, bones, joints and non-contractile soft tissues thereby stimulating joint mechanoreceptors, muscle contraction; improving muscle strength, power, endurance as well as balance, coordination and agility (Kisner and Colby, 2007). Closed-chain exercises are usually performed in functional postures with some degrees of weight bearing and it could involve concentric, eccentric or isometric muscle action. Mechano receptors in and around the joints are stimulated and this in turn stimulate muscle contraction and invariably joint stability (Kisner and Colby, 2007).

Daleiden (1990) observed that in order to achieve long term improvements of standing balance during ambulation and other activities of daily living there is need for repetition of postural adjustments such as rocking, tipping and pushing. The BAPS provides the movements by rocking thereby shifting the weight of the patient from side to side and front to back (Kisner and Colby, 2007). Ratliffe (1998) reported that the balance board is useful in facilitating equilibrium reactions in children with cerebral palsy. Bobath (1999) also suggested that the use of active rocking or repetitive weight shifts backwards and forwards while balancing in sitting, quadruped and upright postures can be used to facilitate balance reactions and improve mobility in neurological cases particularly stroke. In spite of its wide usage in the clinic, there is a dearth of literature on studies that utilised the balance board in training balance in children with cerebral palsy.

2.2.3 **The Gross Motor Function Classification System (GMFCS)**

The GMFCS is a method of classifying children with cerebral palsy and was developed using the Delphi consensus method (Palisano et al, 2000). The Gross Motor Function Classification

System (GMFCS) was devised by Palisano et al (2000) and is used to classify the level of gross motor function in children with cerebral palsy. It is based on self-initiated movement with particular emphasis on sitting (truncal control) and walking. A classification is made by determining which of the five levels best correspond to the child's abilities and limitations in gross motor function in home, school and community settings (Palisano et al, 2000). It is a reliable and valid system that classifies children with CP on the basis of major age appropriate gross motor activities that they can typically accomplish with particular emphasis on functional mobility (Hanna et al, 2008). The focus of GMFCS is on determining which level best represents the child's present abilities and limitation in motor function. Distinctions between the levels of motor function (GMFCS levels) are based on functional limitations, the need for assistive mobility devices or wheeled mobility and to a lesser extent, the quality of movement. The GMFCS has been cited in hundreds of publications and its usage increases internationally every year (Wood and Rosenbaum, 2000; Morris and Barlett 2004). The GMFCS has been clearly established as the principal classification system of functional ability for children with CP and it has been translated into more than three international languages (Morris and Barlett, 2004; Hanna et al, 2008).

The five levels of GMFCS are ordinal and they represent meaningful distinctions in motor function; with level I meaning children are able to move without restrictions but with limitations in advanced skills while children on level V have severe movement restrictions (Palisano et al 2000). Inter rater reliability value (generalisability quotient {G}) obtained was 0.93. Inter rater agreement (kappa) values were 0.55 and 0.75 for children less than two years and children aged two to twelve years respectively (Palisano et al 2000). Content validity of GMFCS was established through nominal group and Delphi survey consensus. Construct validity is supported by a pearson correlation coefficient of -0.91 between GMFCS levels and GMFCS scores (Palisano et al, 2007).

2.2.4 **The 'Timed Up and Go' test for measuring walking speed**

Delay in movement onset and decreased speed of movement are major impairments seen in children with CP (Carlberg and Hadders-Algra,2005; Donker et al, 2008)..

The 'timed up and go' (TUG) test is a quick and practical test which was devised by Podsiadlo and Richardson (1991) for the assessment of basic or functional mobility in adults. It correlates well with gait speed, balance, functional levels and ability to go out and has been used widely in clinical practice to assess functional mobility and balance among adults (Williams et al, 2005).

In validating the test among children, it was modified to incorporate 2 new techniques of a defined task of touching a wall and the use of a chair without armrest (Williams et al, 2005). It was found to be reliable and valid in normal and physically challenged young individuals. Test-retest value for normal children (ICC) was 0.99; within session reliability was 0.98; while the mean time was 5.9 seconds (Williams et al 2005). For children with cerebral palsy, test-retest value (ICC) was 0.83 and within session reliability was 0.89. The mean time taken for the test in children with spastic hemiplegia was 8.4 seconds while it was 10.1 seconds for those with spastic diplegia (Williams et al 2005). In TUG, lower scores indicate faster speed and better functional abilities (Williams et al, 2005).

2.2.5 **The Berg Balance Scale for assessing balance**

This is a 14-item scale originally designed to assess balance in the elderly and neurologically-impaired adult population in a clinical setting (Berg 1989). It involves evaluation of performance in fourteen different activities common in everyday life, indicating ability to maintain sitting and standing positions of increasing difficulty.

The BBS is a simple tool which requires little training and minimal equipment. The items on the scale are performed within a specified time frame and then scored on a five-point ordinal scale from 0 to 4. The maximum obtainable score is 56; a higher score indicates better balance abilities. The test re-test within rater ICC was 0.97 and between rater ICC was 0.98; the internal consistency using the Cronbach's alpha was 0.96. Its application takes about twenty minutes and readily available equipment such as step, stop watch, ruler and chair are required (Berg, 1989). The BBS has also been utilised among post stroke subjects in Ibadan, Nigeria and its validity and reliability was established (Hamzat and Fashoyin, 2007).

The BBS had been validated in general paediatric population and among children with cerebral palsy and it has been found to be valid and reliable with ICC inter rater reliability of 0.96; ICC for intra rater reliability of 0.98 reported (Kembhavi et al 2002; Asgari et al 2007; Gan et al 2008).

Kembhavi et al (2002) evaluated the use of BBS to assess balance abilities of children with 36 hemiplegic and diplegic CP. Berg Balance Scale was able to distinguish balance abilities among children with CP.

Gan et al (2008) examined the validity and reliability of BBS, it was found to be positively correlated with Gross Motor Function Measure (GMFM) score, walking speed and 10-second sit-to-stand test.

Table 2.3: STUDIES ON STRENGTH AND BALANCE TRAINING IN CEREBRAL PALSY

Serial no	Authors	Duration of study	Sample size and age	Findings
1	Olama and Thabit, 2012	Six months (treadmill/ PRE)	30 (8-10 years)	Improved balance
2	Olama, 2011	Six months (vibration/ suspension)	30 (12-15years)	Improved balance performance
3	Damiano 2009	Eight weeks (PRE)	Eight (5-17 years)	Improved walking function and alignment of body parts.
4	Morton et al, 2005	Six weeks (PRE)	Eight (6-12years)	Increased muscle strength, walking speed and step rate.
5	Scholtes et al, 2008	Twelve weeks	Fifty-one (6-13 years)	Positive training effects
6	Verschuren et al 2007	Eight months	Eighty-six (7-18 years)	Improved aerobic capacity,

				muscle strength, agility and quality of life.
7	Woollacott and Shumway-Cook, 2005	Five days/ 100pertubations daily by force platform	Six (average 9yrs, 4 mths)	Improved / faster balance recovery. Reduced muscle co-activation
8	Eagleton et al, 2004	Six weeks strengthening programme	Seven (12-20 years)	Improved cadence, gait velocity, step length,
9	Blundell et al, 2003	Four weeks of group circuit training	Eight children (4-8years)	Improved isometric and functional strength which was sustained 8 weeks post cessation.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Participants

Forty-four children (23 males and 21 females) aged 4 to 12 years diagnosed by a paediatrician and assessed by a physiotherapist as having diplegic and hemiplegic cerebral palsy were recruited into this study. They satisfied the following inclusion criteria (a) degree of spasticity not higher than of 2 on the modified Ashworth scale, (b) possession of ability to comprehend instructions and to communicate verbally, (c) co-morbid conditions such as epilepsy, mental retardation did not interfere with a and b earlier stated.

3.2 Materials

3.2.1 Instruments

Data gathering form: This form (appendix v) was used to record the information on age, sex, topography of CP, causative factors of CP, modified Ashworth scale scores, GMFCS scores, BBS scores and TUG scores.

Modified Ashworth Scale (MAS): This is a 6-point ordinal scale devised by Bohannon and Smith (1987); it was used to assess muscle spasticity in the participants (Bohannon and Smith, 1987). Inter rater reliability was 0.84 while intra rater reliability was 0.83 for MAS (Bohannon and Smith, 1987) (Appendix ii).

Biomechanical Ankle Platform System (BAPS) board or balance board; which was locally fabricated at the carpentry workshop, Physiotherapy Department, UCH was used to facilitate close chain exercises of the lower limbs. The BAPS had a rocker base which facilitated the weight shifts in different directions (plate 5).

Berg Balance Scale (BBS) was used to assess balance in the participants (Berg, et al, 1989). The BBS consists of 14 items and the performance is scored on a 5-point scale from 0-4 with the maximum score of 56 points. It has been found to be valid and reliable with ICC inter

rater reliability of 0.96; ICC for intra rater reliability of 0.98 reported in the paediatric population (Asgari et al, 2007; Gan et al, 2008) (Appendix 3).

Gross Motor Function Classification System (GMFCS) was used to classify motor function in the participants (Palisano et al, 2000). GMFCS consists of five ordinal levels and each level describes the child's present abilities and limitations in motor function. Inter rater reliability value (generalisability quotient {G}) obtained was 0.93. Inter rater agreement (kappa) values were 0.55 and 0.75 for children less than two years and children aged two to twelve years respectively (Palisano et al 2000). Content validity of GMFCS was established through nominal group and Delphi survey consensus. Construct validity is supported by a pearson correlation coefficient of -0.91 between GMFCS levels and GMFCS scores (Palisano et al, 2007) (Appendix 4).

Digital stop watch (Sports-timer, UK) calibrated in seconds was used for timing the timed up and go test and BBS.

Plastic metre rule: a transparent metre rule (2.5cm by 30cm) was used for reaching forward in standing task on the BBS.

Chairs: Two chairs (one with armrest) were used for the transfer activity. The dimensions for the seat height are specified as follows (European Standards EN-1729)

Age (years)	Chair height (mm)
4-6	310
6-8	350
8-11	380
11-14	460

A wall used as landmark was three meters away from the point where the chair was positioned.

Land measuring tape (crocodile brand, made in China) calibrated in centimeters from zero to 3,500 centimetres was used to measure a point three metres away from the wall and the chair was put at that point.

Wooden stool: a wooden block of 10cm height, 25cm width was used for the stool steeping task on the BBS.

Sand bags of various sizes (0.5kg, 1kg, 1.5kg) were used in progression of the wall slide exercise.

Stair case with steps of height 17cm and width 29.5cm was used for the side stepping exercise.

3.3 Methods

3.3.1 Research design

The study utilised quasi-experimental research design. This study involved experimental manipulation of participants and there was a control group but the participants were purposively recruited. The researcher did not have total control over all other activities that the participants were engaged in during the exercise training period.

3.3.2 Sampling technique

The participants were recruited using purposive sampling technique.

Sample size

The sample size was determined using the Cohen table (appendix 1):

Alpha level = 0.05,

Degree of freedom (u) =k-1 where k is the number of groups (3). Therefore U=2,

Power of the test (w) =0.80

Effect size =0.70

The calculated sample size for each group was 8 participants. Participants were assigned into in to the three exercise groups using simple random assignment technique. Recruitment above the calculated sample size (24) was done in order to cater for subject attrition. Forty-four (44) participants were recruited into this study from various clinics and rehabilitation homes after they duly signed the informed consent, 39 participants however commenced the exercise training; 31 participants completed eight weeks of training; 26 participants completed 16 weeks and 22 participants completed 22 weeks.

3.3.3 **Procedure for data collection**

Ethical approval was obtained from the University of Ibadan/University College Hospital Ethics Committee before the commencement of the study (appendix vi). Permission to involve the children was sought and obtained from the management of the various hospitals, clinics and rehabilitation homes involved in this study (appendix vii). Informed consent was taken by proxy from the carers of the children.

Two research assistants, who are qualified physiotherapists, were recruited for this study. One research assistant did the baseline assessment and assignment to groups; the researcher administered the treatments, while the second research assistant carried out the assessments fortnightly.

Pre Training Assessment:

At baseline, functional levels of the participants which ranged between levels I and III were recorded using the GMFCS; BBS scores and modified timed up go (TUG) scores were also recorded at the commencement of the study. Motor function level (GMFCS) of the participant was not greater than level 3 for ages 4 to 12 which was the inclusion criterion for the study, and participants were ambulant.

Assessment of walking speed

The modified 'timed up to go' test (TUG) for children was carried out using the outline of Williams et al (2005) as follows:

A chair was positioned three meters away from a wall such that it was stable and did not shift when the participant moved from sitting to standing. The participant sat on the chair with his feet flat on the floor and the knees at 90 degrees. The procedure was demonstrated by the research assistant who assisted in taking the baseline assessments. On instruction, the participant stood up and walked the 3 metres at his regular pace to wall, touched a drawing on the wall; and then walked back to the chair and sat down. Timing which was carried out by the second research assistant started when the participant stood up and this was stopped when the participant sat down again on the chair after covering six meter (to and from the chair). This ensured that only the movement time was measured. Three trials were carried out and the average score of the trials was used for data analysis (Williams et al, 2005).

Assessment of balance

For the Berg Balance Scale, each of the 14 tasks was demonstrated one after the other. The tasks include: sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing with eyes closed, standing with feet together, reaching forward, retrieving objects from floor, turning to look behind, turning 360 degrees, placing alternate foot on stool, tandem stance and one leg stance. When performing each task, the participant maintained each position and performance was graded on a 5-point scale as specified in the BBS manual (appendix iii). Points were deducted when any of the following happened:

a) The time or distance requirements were not met.

b) The subject' performance warranted supervision.

c) The subject touched an external support or received assistance from the assessor.

The score of the items were summed up and recorded for each patient at baseline and on subsequent re-assessments. The highest score obtainable was 56; a higher score indicated better balance ability.

Participants were treated twice weekly for consecutive eight weeks, and once in a week for subsequent 8weeks. In addition to the exercise protocol for each group, all the participants were treated by the researcher using the neurodevelopmental treatment approach. Reevaluation was carried out at weeks 2, 4, 6, 8, 10, 12, 14, 16 and on completion of the 16 weeks of exercise training, all participants were followed up for another six weeks and the assessments were taken weekly during the follow-up period.

Exercise Training

Group 1: Strengthening Exercise Group: the major muscle groups of the lower limbs had been reported to contribute tremendously to closed chain exercises involving the lower limbs. The hip flexors and extensors, knee extensors and flexors were targeted through the following exercises: bridging, wall slides, side stepping (Kisner and Colby, 2007; Bundonis, 2007). The exercises are described as follows:

A.) **Wall slides:** In standing position, each of the participants rested his back against the wall; with both feet firmly on the floor (plate 1). He then slid the back down the wall by flexing the hips and knees with both feet planted on the floor and about shoulder width apart (plate 2). Sliding up the wall by extending the hips and knees was done consecutively for ten repetitions; this equaled one bout. Five bouts of the exercise were carried out and progression was introduced when the participant could perform more than five bouts. Progression was introduced in form of arm motions and further progression was done by asking participants to hold weights of 0.5kg, 1kg and 2kg as required.

Plate 1: Participant in starting position for the wall slide exercise

Plate 2: Participant performing wall slide exercise

B) Bridging: With each participant in crook lying, the upper back and both feet were pressed into the mat while the pelvis was elevated (plate 3). The position was sustained for ten seconds and a minimum of three bouts were carried out per session. Progression was introduced when the participant could perform bridging with one leg.

C). **Side stepping:** Each participant stood with his side facing the staircase, and then stepped up the first step transferring his body weight on the supporting leg. Ten repetitions were carried out in each bout and three bouts were carried at each exercise session. Progression was introduced when the participant was able to perform five bouts for each session and this was done by increasing the number of steps (Plate 4).

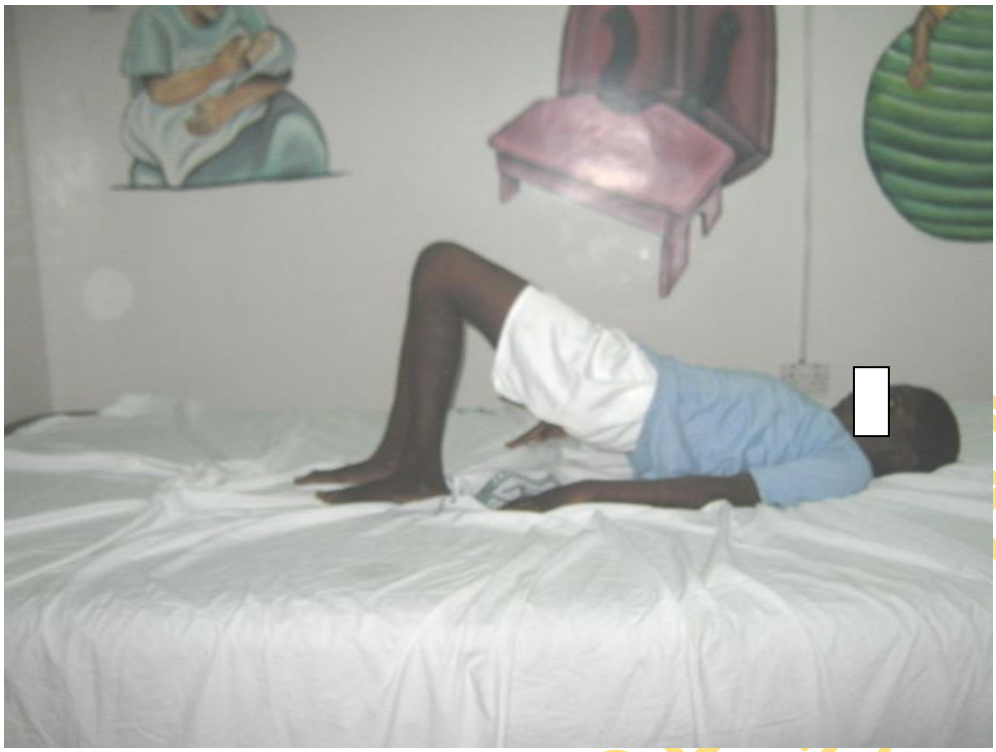

Plate 3: Participant performing bridging exercise

Plate 4: Participant on the side stepping exercise

Group 2: Biomechanical Ankle Platform System Group:

Starting position:

In sitting position, the participant learnt to control the direction of motion of the board this was done to familiarise himself with the directions of movement. In standing position with the balance board placed on the floor, he stood with both feet on the balance board and began with single plane weight shifting forward and backward side to side (plate 5). When necessary, participant supported himself with both hands on a solid object and then progressed by not supporting with hands. Further progression occurred by placing the feet in a diagonal plane and then shifting the weight forward and backward, then side to side. The highest form of progression occurred when the participant could perform one-legged activities. Perturbations of the balance board were carried out by each participant on his/ her individual tolerance; however the participants were encouraged to do as much as possible but not less than three bouts with each made up of ten repetitions (Kisner and Colby, 2007).

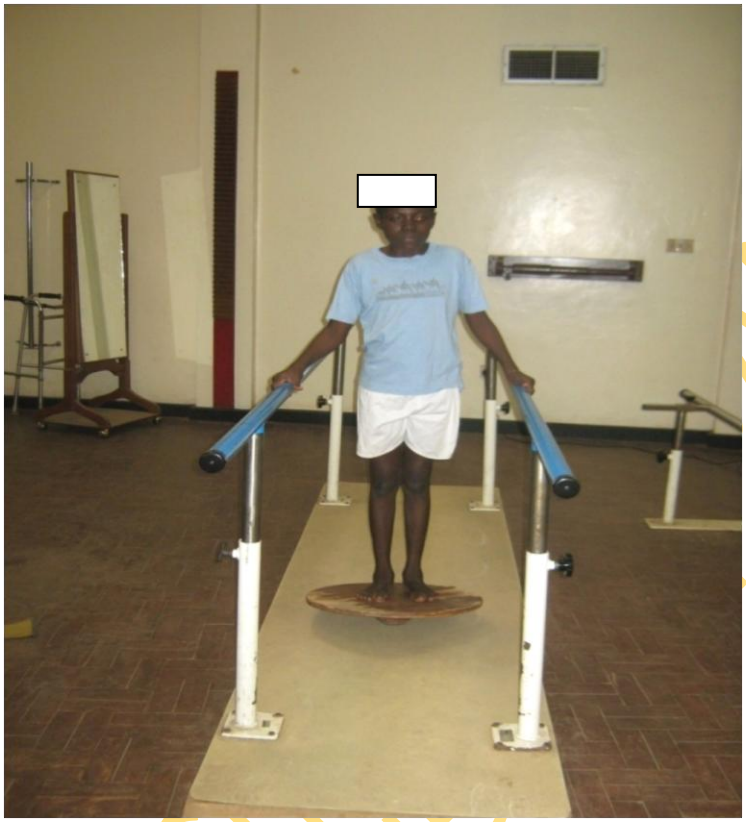

Plate 5: Participant on the Biomechanical Ankle Platform System for perturbation exercise

Group 3: Combination Therapy Group:

This group received both balance board and strengthening exercise training programme as outline above. To prevent data setting, the sequence in which the participants performed exercises was randomised such that they started with any of the two sets of exercises. Any participant who missed out consecutively thrice was excluded from the study.

Treatment Schedule

Appointments were scheduled such that participants were seen twice weekly from baseline to week 8 and once in a week from weeks 9 to 16. Treatment ceased after 16 weeks but the participants' assessments were carried out once weekly until week 22. Clinic appointments of twice weekly were usually given to children with CP, this was the rationale for the twice weekly appointment from baseline to 8 weeks. The once weekly appointment between weeks 9 and 16 was to determine if the improvements gained at 8 weeks could be maintained even with less frequent hospital appointments. Cerebral palsy is the most common cause of chronic disability in childhood and the caregiver burden is quite enormous; less frequent hospital visits with emphasis on home programmes could be of tremendous value in enhancing the financial and psychological well being of caregivers of children with CP.

3.3.4 Venues

Participants were recruited from the Paediatric Neurology Clinics of the University College Hospital and Oni Memorial Children's Hospital, both in Ibadan.

Treatment was carried out at the following centres:

a) Physiotherapy Department, University College Hospital, Ibadan.

b) Physiotherapy Department, Oni Memorial Children's Hospital, Ring road, Ibadan.

c) Exercise room of Servants of Charity Rehabilitation Centre, Yemetu Alaadorin, Agala G.R.A.

d) Exercise room of W.O. Lawal Centre for the Handicapped (WOLACH), Lawal Street, Lister area, Ring road. Ibadan.

3.3.5 Analyses of data

Statistical Package for Social Sciences (SPSS) version 15 was used for the data analyses.

1. Descriptive statistic of mean, standard deviation and percentages were used to present physical and clinical characteristics such as age, sex, type of cerebral palsy, GMFCS level, timed up and go test scores, BBS scores.
2. Wilcoxon signed rank test was used to compare the GMFCS scores between baseline and week 8 across the three groups.
3. Wilcoxon signed rank test was used to compare the GMFCS scores between week 8 and week 16 across the three groups.
4. Wilcoxon signed rank test was used to compare the GMFCS scores between week 16 and week 22.
5. Kruskal-Wallis test was used to compare the GMFCS scores across the three groups (BAPS, SEP and CT) at baseline, 8 weeks, 16 weeks and 22 weeks.
6. Repeated measures ANOVA were used to evaluate the BBS scores across the three groups.
7. Repeated measures ANOVA were used to evaluate the TUG scores across the three groups.
8. Paired t-test was used to compare walking speed within the groups at different pairs of time intervals.

9. Analysis of co-variance (ANCOVA) was used to evaluate the TUG scores across three groups; the co-variate was the type of cerebral palsy.

10. Friedman's analysis of variance (ANOVA) was used to evaluate GMFCS scores within three groups.

11. Bonferroni adjustments were done to show the post hoc analysis for the BBS scores. The level of significance (α) was set at 0.05.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1. Physical and Clinical Characteristics of participants

Forty four (44) children with CP were recruited into the study, 39 (88.6%) commenced and completed 8 weeks; 31 (70.5%) completed 12 weeks; 26 (59.1%) completed 16 weeks and 25 (56.8%) completed 22 weeks. Attrition of the participants over the study period is presented in figure 4.1. The mean age of the participants was 7.7 ± 2.8 years; physical and clinical characteristics such as gender, topography of CP and modified Ashworth scale grading are shown in table 4.1.

Figure 4.2 shows the percentages of participants in the three exercise groups at the commencement of the study, BAPS group had the highest number.

4.1.2 **Changes in balance scores within the three groups over 22 weeks**

Results shown on table 4.2 reported a significant increase in balance scores within the three groups from baseline through 16 weeks; Berg Balance Scale scores progressively increased from week 2, significant improvements were observed from week 8 until week 16 after which it reached a plateau. Balance scores in each of the three groups did not deteriorate during the follow up period; slight improvements were observed and the combination therapy group showed the greatest improvements out of the three groups.

4.1.3 **Changes in walking speed within the three groups over 22 weeks**

Walking speed of participants within the three groups was significantly different at baseline and the disparity continued until the eight week. Within the three groups, walking speed improved significantly from week 2 through 16 week. An increase in walking speed of participants was also observed 6 weeks after formal exercise training ceased (table 4.3). There was no deterioration in the walking speed of the participants over the follow up period.

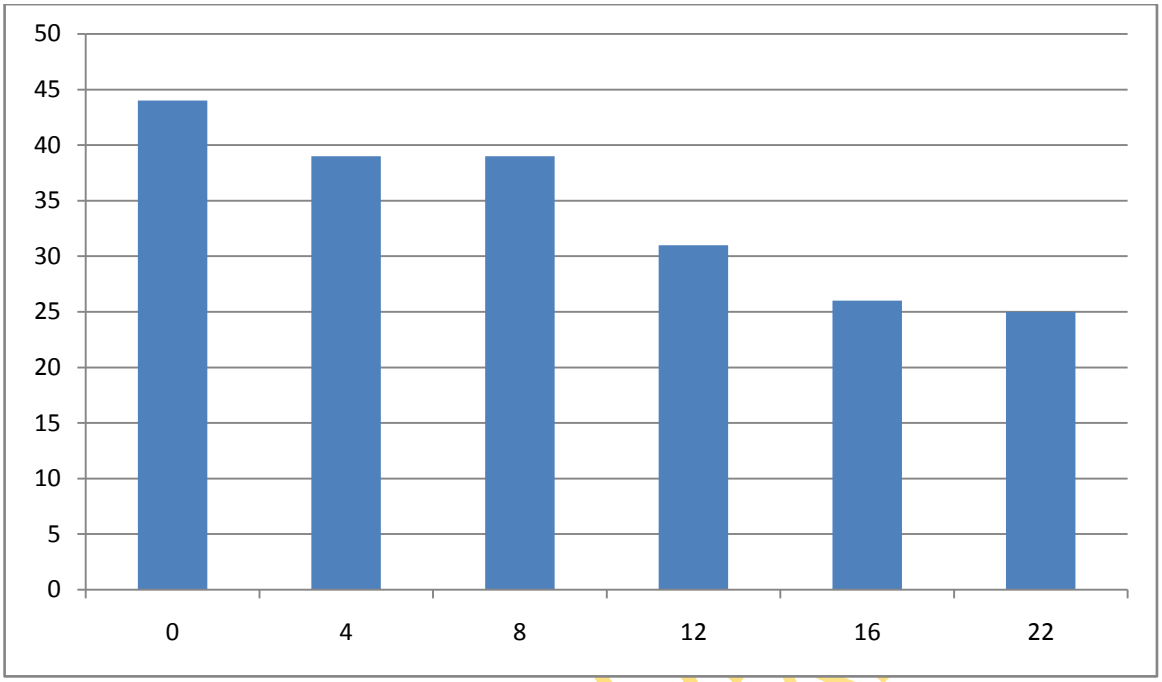

Figure 4.1: Subject attrition (drop out) over 22 weeks

Table 4.1.: **Physical and Clinical Characteristics of participants**

Variable	N	ẍ ± S.D	Percentage (%)
AGE (Yrs)	39	7.7 ± 2.8yrs	
Minimum 4 yrs			
Maximum 12 yrs			
SEX			
Male	20		51.3
Female	19		48.7
ASHWORTH SCALE			
0	11		28.2
1	14		35.9
1+	2		5.1
2	12		30.8
TOPOGRAPHY			
Diplegic	18		46.2
Hemiplegic	21		53.8

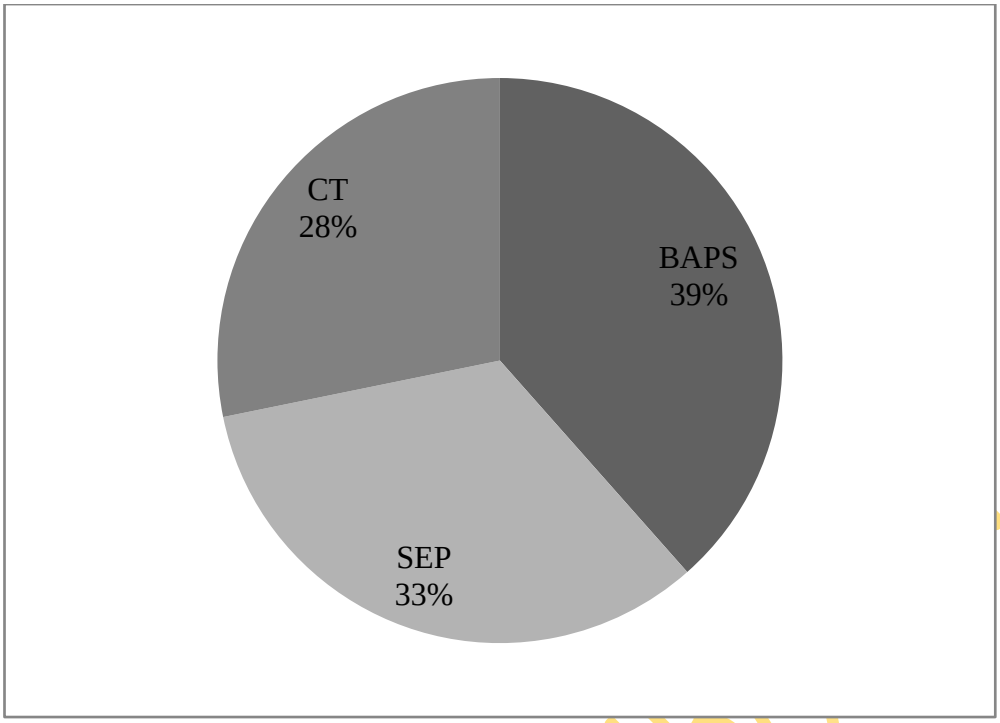

Figure 4.2: **Percentage Distribution of the Participants in the 3 Exercise Groups at the Commencement of the Study**

KEY:

BAPS: Biomechanical Ankle Platform System group (15 participants)

SEP: Strengthening Exercise Programme group (13 participants)

CT: Combination therapy group (11 participants)

4.1.4. **Changes in Gross Motor Function Classification System levels over 22 weeks**

At baseline, 28.2% (11 participants) were at level 1, 53.8% (22 participants) were at level II and 17.9% (6 participants) were at level III. Percentages of participants' GMFCS levels at 8 weeks were 28.2% (11 participants) for level I, 64.1% (25 participants) for level II and 7.7% (3 participants) for level III. At 16 weeks with 26 participants, 46.2% (12 participants) were at level I and 53.8% (14 participants) were at level II. Follow up at 22 weeks with 25 participants, showed 60% (15 participants) were at level I and 40% (10 participants) at level II (see figure 4.3).

Table 4.2. **Berg Balance Scale scores within the three groups (N=25)**

Time (wks)	**BAPS**	**CT**	**SEP**
	ẍ ± S.D	**ẍ ± S.D**	**ẍ ± S.D**
0	38.7 ± 8.8	30.9 ± 10.3	37.1 ± 8.1
2	38.7 ± 8.8	30.9 ± 10.3	37.1 ± 8.1
4	40.7 ± 8.4	32.7 ± 10.5	39.1 ± 7.6
6	42.7±8.1	35.4 ±9.7	41.1 ± 7.1
8	45.0±8.3	37.7 ± 9.4	44.0 ± 6.8
10	45.2 ± 8.1	41.3 ± 9.0	43.3 ± 6.3
12	46.0 ±7.6	42.2 ± 8.9	44.4 ± 6.4
14	46.9 ± 7.7	43.6 ± 8.6	43.3 ± 7.0
16	48.5 ± 5.9	44.3 ± 8.9	44.3 ± 7.1
22	48.7 ± 5.9	45.4 ± 8.5	45.3 ± 6.8
F-VALUE	298.88	135.66	295.53
P-VALUE	0.00*	0.00*	0.00*

***indicates statistically significant at P<0.05**

KEY:

BAPS: Biomechanical ankle platform system group

SEP: Strengthening exercise group

CT: Combined therapy group

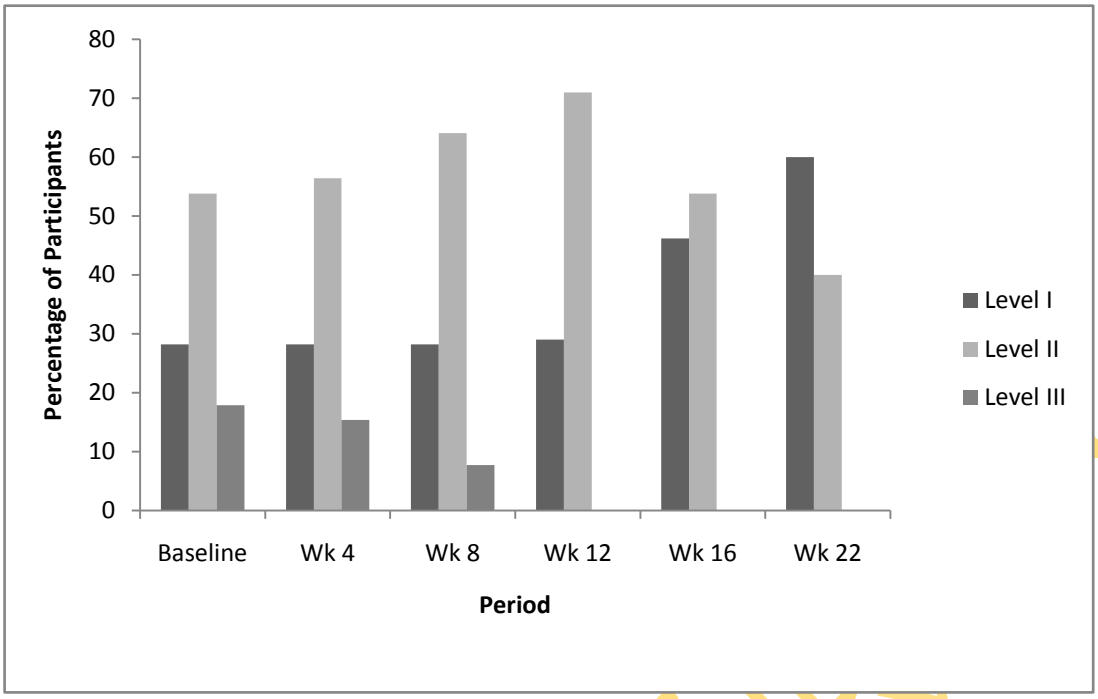

Figure 4.3: Trend of improvement (%) in GMFCS levels from baseline to 22 weeks

Table 4.3: **Walking speed scores within the three groups over 22 weeks (N= 25)**

Time (wks)	**BAPS**	**CT**	**SEP**
	ẍ ± S.D	**ẍ ± S.D**	**ẍ ± S.D**
0	0.50 ± 0.1	0.43± 0.1	0.46± 0.1
2	0.50± 0.1	0.43± 0.1	0.46± 0.1
4	0.51± 0.1	0.43± 0.1	0.46± 0.1
6	0.52± 0.1	0.44± 0.1	0.47± 0.1
8	0.52± 0.1	0.45± 0.1	0.50± 0.1
10	0.53± 0.1	0.47± 0.1	0.50± 0.1
12	0.53± 0.1	0.47± 0.1	0.51± 0.1
14	0.54± 0.1	0.48± 0.1	0.52± 0.1
16	0.54± 0.1	0.48± 0.1	0.53± 0.1
22	0.55± 0.1	0.49± 0.1	0.55± 0.1
ANOVA	579.31	477.94	629.65
P-LEVEL	0.00*	0.00*	0.00*

*indicates statistically significant at P <0.05

KEY:

BAPS: Biomechanical ankle platform system group

SEP: Strengthening exercise programme group

CT: Combined therapy group

4.1.5 **Comparison of balance scores across the three groups**

The comparison of the balance scores within each of the groups showed there was a significant increase over the time period studied. (Table 4.4). However, there was no significant difference in the balance scores across the three groups (Table 4.4). Post hoc analysis showed balance scores were significantly different over the study period except at weeks 14 and 16 where there was no significant difference (Table 4.5)

4.1.6 **Comparison of walking speed across the three groups**

Across group comparison using one-way ANOVA showed that there was significant difference in the three groups at baseline; adjustments were then made using ANCOVA and the co-variate was the type of cerebral palsy. Children with diplegic CP were slower than their hemiplegic counterparts. At 8 weeks walking speed was still significantly different across the 3 groups; however by the 16^{th} and 22^{nd} weeks, the 3 groups were not significantly different. The combination therapy (CT) group had the lowest walking speed because it had the least number of participants (Table 4.6). Table 4.7 showed the pair wise comparisons of the walking speed at various time intervals; walking speed scores between baseline and 8 weeks, 8 and 16 weeks; 16 and 22 weeks were significantly different.

4.1.7 **Comparison of GMFCS scores within and across the three groups**

Within group comparison of GMFCS for BAPS and SEP groups showed that there were significant differences in motor function levels of participants from baseline to 16 weeks and the differences were sustained at 22 weeks. There was an exception in the SEP group where the within group difference was not statistically significant (table 4.8). Across groups comparison showed that the 3 groups were not significantly different from one another (Table 4.9) at the various time intervals studied.

Table 4.4: **Berg Balance Scale scores for within and across group analyses (Using repeated measures and One way ANOVA respectively)**

Groups	**Baseline** $\ddot{x} \pm$ **S.D**	**8th week** $\ddot{x} \pm$ **S.D**	**16th week** $\ddot{x} \pm$ **S.D**	**22nd week** $\ddot{x} \pm$ **S.D**	**F-value**	**p-value**
BAPS	38.7 ± 8.8	44.8 ± 8.3	48 .5 ± 5.9	48.7 ± 5.9	18.31	0.001*
CT	37.1 ± 8.1	44.0 ± 6.8	44.3 ± 7.1	45.3 ± 6.8	77.16	0.00*
SEP	30.9 ± 10.3	37.7 ± 9.4	44.3 ± 8.9	45.4 ± 8.5	15.29	0.03*
F-value	2.48	2.53	1.014	0.716		
P-value	0.09	0.10	0.38	0.50		

KEY:

BAPS: Biomechanical Ankle Platform System group

SEP: Strengthening Exercise Programme group

CT: Combination therapy group

*denotes significance at $p<0.05$

Table 4.5: **Post Hoc Analysis for Balance Scores Across the 3 Groups over the study period**

Time (wks)	0	2	4	6	8	10	12	14	16	22wks
0										
2										
4	*	*								
6	*	*	*							
8	*	*	*	*						
10	*	*	*	*	*					
12	*	*	*	*	*	*				
14	*	*	*	*	*	*	*			
16	*	*	*	*	*	*	*			
22	*	*	*	*	*	*	*	*	*	

- Denotes significantly different pairs of weeks

Table 4.6: **Walking speed scores across groups using one way ANOVA**

Groups	Baseline **ẍ ± S.D**	8th week **ẍ ± S.D**	16th week **ẍ ± S.D**	22nd **ẍ ± S.D**
BAPS	0.50 ± 0.1	0.52± 0.1	0.50± 0.1	0.60± 0.1
CT	0.40 ± 0.1	0.50± 0.1	0.50± 0.1	0.50± 0.1
SEP	0.50± 0.1	0.50± 0.1	0.50± 0.1	0.60± 0.1
f-value	4.47	4.68	2.145	2.247
P value	0.018*	0.016*	0.141	0.129

* statistical significance at $p < 0.05$

Table 4.7: **Comparison within group of walking speed (using paired t-test)**

Time (wks)	**Groups**		
	BAPS	**SEP**	**CT**
	ẍ ± S.D	**ẍ ± S.D**	**ẍ ± S.D**
Baseline	0.50±0.07	0.48±0.05	0.44±0.06
8 wks	0.52±0.07	0.50±0.05	0.46±0.06
t-value	2.47	4.51	6.81
p-value	0.03*	0.01*	0.00*
8wks	0.52±0.07	0.50±0.05	0.46±0.06
16wks	0.54±0.07	0.53±0.05	0.48±0.06
t-value	6.45	6.55	10.49
p-value	0.01*	0.01*	0.00*
16 wks	0.54±0.07	0.53±0.05	0.48±0.06
22wks	0.55±0.08	0.50±0.07	0.55±0.05
t-value	4.47	3.35	4.44
p-value	0.01*	0.03*	0.03*

Table 4.8: Within group comparison for Gross Motor Function Classification System using Friedman's ANOVA

Time (wks)	BAPS	CT	SEP
Baseline	4.00	4.31	3.83
Week 8	4.00	3.94	3.83
Week 16	2.91	3.19	3.25
Week 22	2.91	2.44	3.75
F value	10.20	9.75	4.71
P value	0.02*	0.02*	0.19

*denotes significant p-value

KEY:

BAPS: Biomechanical Ankle Platform System group

SEP: Strengthening Exercise Programme group

CT: Combination therapy group

Table 4.9: **Across group comparison for Gross Motor Function Classification System (Using Kruskal Wallis)**

Time (wks)	BAPS	CT	SEP	F value	P value
Baseline	4.00	4.31	3.83	6.23	0.08
Week 8	3.73	3.56	3.83	5.26	0.07
Week 16	2.91	3.19	3.25	5.23	0.07
Week 22	2.91	2.44	3.75	1.27	0.53

KEY:

BAPS: Biomechanical Ankle Platform System group

SEP: Strengthening Exercise Programme group

CT: Combination therapy group

Table 4.10: **Pair wise comparison of motor function levels over the study period (using Wilcoxon signed rank)**

Time Group	**BAPS**		**CT**		**SEP**	
	W	**P**	**W**	**P**	**W**	**P**
Baseline & 8 weeks	1.00	0.317	1.73	0.083	0.00	1.00
8 weeks & 16weeks	1.73	0.08	1.00	0.317	1.00	0.317
16 weeks & 22 weeks	0.00	1.00	1.41	0.15	1.00	0.317

KEY:

W: wilcoxon value

*: significance at $p < 0.05$

BAPS: Biomechanical ankle platform system group

SEP: Strengthening exercise programme group

CT: Combined therapy group

4.2 Hypotheses Testing

Sub-hypothesis 1

There would be no significant difference in the baseline scores of the 'timed up and go' (TUG) of children with CP across the 3 exercise groups.

Since p value is greater than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 2

There will be no significant difference in the baseline Berg Balance Scale (BBS) scores of children with CP across the 3 exercise groups.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 3

There would be no significant difference in the baseline Gross Motor Function Classification System (GMFCS) levels of children with CP across the 3 exercise groups.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 4

There would be no significant difference between the baseline and 8-week TUG scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 5

There would be no significant difference between the baseline and 8-week TUG scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 6

There will be no significant difference between the baseline and 8-week TUG scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 7

There would be no significant difference between the baseline and 8-week BBS scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 8

There would be no significant difference between the baseline and 8-week BBS scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 9

There would be no significant difference between the baseline and 8-week BBS scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 10

There would be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the BAPS group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted**.

Sub-hypothesis 11

There would be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the SEP group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 12

There would be no significant difference between the baseline and 8-week GMFCS levels of children with CP in the CT group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 13

There would be no significant difference between the baseline and 16-week TUG scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 14

There would be no significant difference between the baseline and 16-week TUG scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 15

There would be no significant difference between the baseline and 16-week TUG scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 16

There would be no significant difference between the baseline and 16-week BBS scores of children with CP across the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 17

There would be no significant difference between the baseline and 16-week BBS scores of children with CP across the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 18

There would be no significant difference between the baseline and 16-week BBS scores of children with CP across the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 19

There would be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 20

There would be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 21

There would be no significant difference between the baseline and 16-week GMFCS levels of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 22

There would be no significant difference between the 8th week and 16th week TUG scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 23

There would be no significant difference between the 8th week and 16th week TUG scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 24

There would be no significant difference between the 8th week and 16th week TUG scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 25

There would be no significant difference between the 8th week and 16th week BBS scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 26

There would be no significant difference between the 8th week and 16th week BBS scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 27

There would be no significant difference between the 8th week and 16th week BBS scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 28

There would be no significant difference between the 8th week and 16th week GMFCS levels of children with CP in the BAPS group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 29

There would be no significant difference between the 8th week and 16th week GMFCS levels of children with CP in the SEP group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 30

There would be no significant difference between the 8th week and 16th week GMFCS levels of children with CP in the CT group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 31

There would be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 32

There would be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 33

There would be no significant difference between the 16th week and 22nd week TUG scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 34

There would be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 35

There would be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 36

There would be no significant difference between the 16th week and 22nd week BBS scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 37

There would be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the BAPS group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 38

There would be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 39

There would be no significant difference between the 16th week and 22nd week GMFCS levels of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Accepted**.

Sub-hypothesis 40

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 41

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 42

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week TUG scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 43

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the BAPS group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 44

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the SEP group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted**.

Sub-hypothesis 45

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week BBS scores of children with CP in the CT group.

Since p value is less than 0.05, the hypothesis is hereby **Failed to be Accepted.**

Sub-hypothesis 46

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS levels of children with CP in the BAPS group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 47

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS levels of children with CP in the SEP group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

Sub-hypothesis 48

There would be no significant difference in the baseline, 8th week, 16th week and 22nd week GMFCS levels of children with CP in the CT group.

Since p value is greater than 0.05, the hypothesis is hereby **Accepted.**

4.3 Discussion

4.3.1. Physical and Clinical Characteristics of participants

Results showed that there were more male participants in this study. This is a natural trend of prevalence of cerebral palsy; studies have shown that genetics particularly the male sex is a risk factor for CP (Wammanda et al, 2007, Lagunju and Okafor, 2009; Lagunju et al, 2010). Wammanda et al (2007) suggested however that a male child would most likely be more favoured to be brought for medical attention and that this might have also contributed to the higher incidence in males (Segels, 2000; Alikor, 2007). Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency has been reported to be commoner in males; G6PD plays an important role in maintaining the integrity of the red cell membrane. Ingestion of compounds such as sulphonamides, nalidixic acid acetylsalicylates could lead to haemolysis which is an important cause of hyperbilirubinaemia and potential kernicterus which could lead to cerebral palsy (Segels, 2000). Topographical distribution of the participants in this study showed that hemiplegic CP was commoner than diplegic; this observation may be a pointer to the relative prevalence of these 2 subtypes as already noted by Peters et al (2008) who reported that diplegic CP accounted for 6-10% while hemiplegic CP accounted for 11-20% of the cases seen in a Nigeria hospital. Various levels of spasticity were observed in the participants, 71.8% of them were spastic. This corroborated previous studies by Wammanda et al (2007); Ogunlesi et al (2008) and Lagunju et al (2010) were spastic cerebral palsy was shown to be the most predominant physiologic classification in various parts of Nigeria. Krigger (2006) and Martin and Kessler (2007) also reported that spastic physiologic classification accounted for 70-80% of CP cases seen worldwide.

4.3.2 **Changes in Balance Scores from Baseline to 16 Weeks**

Balance performance of the participants improved steadily and significantly between baseline and sixteen weeks; the improvements recorded were also sustained six weeks post-cessation of exercises. This could be attributed to the effects of neuroplasticity which underlies all forms of skill learning. Neuroplasticity is the ability of the nervous system to respond to intrinsic and extrinsic stimuli by reorganising its structure, function and connections (Edwards, 2002; Martin and Kessler, 2007). Plasticity of the nervous system is necessary for learning and memory; parts of the brain concerned with motor function (motor cortex, basal ganglia and cerebellum) and even the spinal cord have been shown to mediate learning and memory of motor skills (Edwards, 2002; Stokes, 2005; Kisner and Colby, 2007; Martin and Kessler, 2007). The findings of this present study corroborated previous study of Woollacott and Shumway-Cook (2005) who observed that postural control and invariably balance improved following sessions of reactive balance training in children with CP. Woollacott et al (2005) also reported that following perturbations on a moveable force platform, balance control as well as the muscle responses improved under electromyography. They advocated that the possible neural mechanisms that underlie these neuromuscular responses include: improved proprioceptive sensitivity in leg muscles; enhanced synaptic efficacy within the primary motor cortex pathways and higher levels of adaptations at the level of cerebellum and association cortex.

Improvements in functional performance observed in the participants in this study could have been due to learning adaptations which was the outcome of repetition of tasks; and practice is fundamental to motor learning (Edwards, 2002; Stokes, 2005; Kisner and Colby, 2007; Woollacott and Shumway-Cook, 2005).

4.3.3 **Comparison of balance across the three exercise groups**

Balance control is important for competence in the performance of most functional skills; helping children recover from self-induced or unexpected balance disturbances that could occur when limits of stability are perturbed (Olama and Thabit, 2012). Poor compensation of balance in children with CP leads to difficulties in performing functional tasks that are involved in activities of daily living (Kembhavi et al, 2002; Donker et al, 2008).

Similarities were observed among the balance scores of the three groups at baseline, 8, 16 and 22 weeks. For the baseline observation of similarities in balance function, this could be attributed to the similarities in the physical and clinical characteristics of the participants who assigned into the exercise groups through the simple random assignment technique.

This partly corroborated the study by Olama (2011) who reported that endurance exercise and treadmill training both resulted in increased muscle strength and functional performance of children with hemiplegic cerebral palsy; the group that received treadmill training however had significantly improved functional performance when compared with the other group that received conventional exercise therapy. Olama and Thabit (2012) while comparing the effects of vibration and suspension training on hemiplegic CP children reported that though participants were similar in pre treatment scores, they differed significantly on the indices of stability measured post treatment. This is in variance with the outcome of this study which showed that though participants in the three groups had improved functional indices; the comparison of the three exercise groups was not significantly different throughout the study period. There is a dearth of literature on studies that compared efficacy of two models of intervention in children with CP, most studies seen had single group designs (Dodd et al, 2002; Eagleton et al, 2004;Woollacott and Shumway-Cook, 2005; Woollacott et al, 2005; Scholtes et al, 2008; Damiano et al, 2009).

4.3.4. **Changes in walking speed of participants within the groups over 22 weeks**

Cerebral palsy is the most prevalent physical disability in childhood (Rosenbaum, 2003; Damiano et al, 2009); children with cerebral palsy experience difficulties walking independently, negotiating stairs, running and navigating on uneven surfaces (Barlett and Palisano, 2000; Ketelaar et al, 2001). Maintaining a position against gravity and moving from one place to another are focuses of intervention because of their impact on activities of daily living and play of children with cerebral palsy (Bartlett and Palisano, 2000; Rosenbaum, 2003). Independent ambulation is therefore a major functional goal in ambulatory types of CP because it has been associated with employability, economic status and social integration (Barlett and Palisano, 2000). Children with ambulatory types of CP are known to walk with low walking speed and abnormal kinetics; improving walking speed is thus an important intervention in this group of patients. Use of Biomechanical Ankle Platform System (BAPS), Strengthening Exercise Programme (SEP) led to significant improvements in walking speed of children with cerebral palsy; combination of these two exercise trainings led to the most significant improvements in walking speed. The group that received combination therapy had the greatest improvements in their walking speed. This could be explained by the fact that each of the two treatment protocols administered produced significant improvement, therefore combining them as a treatment for a group provided combined advantage and improvement.

Previous studies have also reported improvements in gait characteristics such as the gait velocity, cadence, step length and stride length of children with CP as a result of exercise training (Blundell et al 2003; Eagleton et al 2004; Kelly and Darrah, 2005; Damiano et al, 2009).

4.3.5 **Walking speed of participants across the three groups.**

Ambulation status is clearly related to the type and severity of cerebral palsy (Damiano et al, 2009). Differences observed in walking speed of the participants at baseline could be attributed to the topographical differences seen in the ambulatory types of CP. Diplegic participants are slower than their hemiplegic counterparts because they have motor affectations in both lower limbs. Comparison of baseline scores across the three exercise groups showed significant differences; this could be attributed to the heterogenous nature of the participants. Exercise training led to improved functional performance in all participants in spite of their topographic distribution. A significant improvement was recorded in the walking speed of the participants across the groups over the study period. This could be attributed to gains in muscle strength and improved balance strategies which resulted from exercise training (Kisner and Colby, 2007). This is in line with previous studies who observed improvements in gait characteristics of children with CP following exercise training (Blundell et al 2003; Dodd et al 2003; Eagleton et al 2004; Olama, 2011; Olama and Thabit, 2012).

Sustenance of improvements up to follow up period was probably due to the effects of neuroplasticity refers to the ability of cells to undergo alterations in their forms and functions in response to significant changes in their environment. Neuroplasticity takes various forms which include: recruitment of latent synapses, synaptic potentiation, recovery of synaptic function and axonal sprouting (Edwards, 2002; Martin and Kessler, 2007).

4.3.6 **Trend of Gross Motor Function Classification System levels in the three groups over 22 weeks**

The Gross Motor Function Classification System is a standardised system that measures severity of movement in children with CP (Hanna et al, 2008). Children on level I walk without restrictions but are limited in advanced motor skills such as running; those on level II experience limitations walking outdoors though they ambulate independently. Children on level III walk with assistive devices and experience limitations walking outdoors in the community. Children on level IV are either transported or they use powered mobility outdoors. Self mobility is severely limited in level V and maintenance of antigravity postural control is extremely difficult (Rosenbaum, 2003).

Participants in this study could stand and walk independently or with assistive devices i.e they were on levels I- III. This study showed that the functional performance (as measured by balance, walking speed and motor function) of participants improved throughout the exercise training period such that by the 16th week of exercise training, there was no participant on level III. Follow up period showed sustenance of improvements as well as further improvements. These implied better participation and community reintegration of the participants which is a major focus of the World Health Organisation (WHO); and invariably leading to a reduction in caregiver burden (Wood and Rosenbaum, 2000; Rosenbaum, 2003; Morris and Bartlett, 2004; Palisano et al, 2007; Palisano et al, 2009).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Cerebral palsy (CP) describes a group of disorders that affect the development of movement and posture, causing activity limitations; and are attributable to non-progressive lesions that occurred in the developing foetal or infant brain. Functional performance (FP) could be severely impaired in children with CP and this may be associated with reduced muscular strength and poor balance. Biomechanical ankle platform system (BAPS) and strengthening exercises (SEP) are physiotherapy modalities used in training balance and strength respectively. Progressive strength training has been shown to lead to increased muscle strength and improved function in children with cerebral palsy (Scholtes et al, 2008; Olama, 2011), and therefore advocated to promote fitness and increase the patients' participation in various recreational and occupational activities (Koman et al 2004; Kelly and Darrah, 2005).

The BAPS board commonly called balance board has been widely used in training balance in a variety of conditions and its efficacy has also been established (Kisner and Colby, 2007). It is a form of closed chain exercise equipment which uses the body weight as resistance; with the feet positioned on the board, the patient shifts his weight laterally and anteroposteriorly while attempting to control the ankle and maintain balance (Kisner and Colby, 2007).

Closed –chain exercise refers to movement that occurs in a closed kinematic chain where the body moves over a fixed distal segment i.e a closed chain movement occurs in a weight bearing posture when the feet are planted on the ground. These exercises load muscles, bones, joints and non-contractile soft tissues thereby stimulating joint mechanoreceptors, muscle contraction; improving muscle strength, power, endurance as well as balance,

coordination and agility (Kisner and Colby, 2007). There is a dearth of evidence on the efficacy of these two modalities in enhancing functional performance in children with diplegic and hemiplegic CP. Hence the need for this study which was carried out to investigate the comparative efficacy of the BAPS and SEP models on functional performance of children with CP.

Forty-four children with hemiplegic or diplegic CP were purposively recruited into this quasi-experimental study. They were assigned into one of BAPS, SEP and Combined Training (CT) groups using a simple random assignment technique. Motor Function (MF), balance, and Walking Speed (WS) were measured as indices of FP at baseline using the Gross Motor Function Classification System (GMFCS), Berg Balance Scale (BBS) and Timed-Up and Go (TUG) respectively. The BAPS group performed perturbation exercise training involving lateral, antero-posterior, and diagonal shifts using a wobble board. The SEP group received bridging, side-stepping and wall slides exercise training while the CT group received a combination of BAPS and SEP. Progression was achieved by individualised increase in number of exercise bouts and decreased external support. All participants were treated using Bobath neurophysiotherapy technique.

Training for each participant lasted 16 consecutive weeks; twice weekly for initial 8 weeks and then weekly for subsequent 8 weeks. Balance, MF and WS were re- evaluated at the 8^{th} and 16^{th} weeks of training and six weeks after cessation of the training (22^{nd} week). Data obtained were analysed using descriptive statistics, linear model of repeated measure ANOVA, Wilcoxon signed rank test and Kruskal Wallis test with level of significance set at $\alpha = 0.05$.

The result of this study showed that functional performance (as measured by walking speed, balance and motor function ability) of children with CP improved significant within the three groups over the study period. No significant difference was however observed in the across group analysis of balance, walking speed and motor function ability.

5.2 Conclusions

Based on the findings of this study, it was concluded that:

1. Functional performance in terms of balance, walking speed and motor function ability of children with CP improved significantly following the Biomechanical Ankle platform System (BAPS),Strengthening Exercise Programme (SEP) training protocols; and the improvements were sustained even after six weeks.
2. Biomechanical ankle platform system compared effectively with strengthening exercises in enhancing functional performance of children with CP.

5.3 Recommendations

1. Biomechanical ankle platform system and strengthening exercises could be used by physiotherapists in enhancing the functional performance of children with CP.
2. Physiotherapy clinic visits for children with CP does not need to be frequent, emphasis should be placed on ensuring that caregivers of these children are taught the home programmes for the children.

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Appendix 1: Sample sizes for the analysis of variance for α = .05 (Cohen, 1988)

Power	.05	.10	.15	.20	.25	.30	35	.40	.50
df_b = 1									
.70	1235	310	138	78	50	35	26	20	13
.80	1571	393	175	99	64	45	33	26	17
.90	2102	526	234	132	85	59	44	34	22
df_b = 2									
.70	1028	258	115	65	42	29	22	17	11
.80	1286	322	144	81	52	36	27	21	14
.90	1682	421	188	106	68	48	35	27	18
df_b = 3									
.70	881	221	99	56	36	25	19	15	10
.80	1096	274	123	69	45	31	23	18	12
.90	1415	354	188	89	58	40	30	23	15
df_b = 4									
.70	776	195	87	49	32	22	17	13	9
.80	956	240	107	61	39	27	20	16	10
.90	1231	309	138	78	50	35	26	20	13
df_b = 5									
.70	698	175	78	44	29	20	15	12	8
.80	856	215	96	54	35	25	18	14	9
.90	1098	275	123	69	45	31	23	18	12
df_b = 6									
.70	638	160	72	41	26	18	14	11	7
.80	780	195	87	50	32	22	17	13	9
.90	995	250	112	63	41	29	21	16	11
df_b = 8									
.70	548	138	61	35	23	16	12	9	6
.80	669	168	75	42	27	19	14	11	8
.90	848	213	95	54	35	24	18	14	9
df_b = 10									
.70	488	123	55	31	20	14	11	8	6
.80	591	148	66	38	24	17	13	10	7
.90	747	187	84	48	31	22	16	13	8

Appendix II

Modified Ashworth Scale (Bohannon and Smith, 1987)

0 - No increase in muscle tone.

1 - Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the flexion or extension.

1+- Slight increase in muscle tone manifested by a catch followed by minimal resistance through the remainder of the ROM but the affected part(s) / is (are) easily moved.

2 - More marked increased in muscle tone through most of the range motion but the affected part is easily moved.

3 - Considerable increase in muscle tone, passive movement is difficult.

4 - Affected part is rigid in flexion or extension.

APPENDIX III

BERG BALANCE SCALE (Berg et al, 1989)

Name:_____

Date:_____

Location:_____

Rater:_____

ITEM DESCRIPTION	SCORE (0-4)
Sitting to standing	_____
Standing unsupported	_____
Sitting unsupported	_____
Standing to sitting	_____
Transfers	_____
Standing with eyes closed	_____
Standing with feet together	_____
Reaching forward with outstretched arm	_____
Retrieving object from floor	_____
Turning to look behind	_____
turning 360 degree	_____
Placing alternate foot on stool	_____
Standing with one foot in front	_____
Standing on one foot	_____

Total_____

GENERAL INSTRUCTIONS

Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- The time of distance requirements are not met
- The subjects performance warrants supervision
- The subject touches an external support or receives assistance from the Examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5 and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item 12.

SITTING TO STANDING

INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED

INSTRUCTIONS: please stand for two minute without holding on.
( ) 4 able to stand safely for two minutes
( ) 3 able to stand two minute with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported
If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported.
Proceed to item # 4

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL

INSTRUCTIONS: please sit with arms folded for two minutes.
( ) 4 able to sit safely and securely for two minutes
( ) 3 able to sit two minute under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING

INSTRUCTIONS: Please sit down
( ) 4 sits safely with minimal use of hands
( ) 3 control descent by using hand
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but as uncontrolled descent
( ) 0 need assist to sit

TRANSFERS

INSTRUCTIONS: Arrange chair's for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrest. You may use two chairs (one with or without armrests) or a bed and a chair.

( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED

INSTRUCTIONS: Please close your eye and stand still for 10 seconds

( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds but stay safely
( ) 1 unable to keep eye closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER

INSTRUCTIONS: Please your feet together and stand without holding on to support

( ) 4 able to place feet together independently and stand 1 minutes safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold feet for 30 seconds
( ) 1 need help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING

INSTRUCTION: lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingerprint when arm is at 90 degree. Finger should not touch the ruler while reaching forward. The recorded measure is the distance reached while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.

( ) 4 can reach forward confidently 25cm (10 inches)
( ) 3 can reach forward 12cm (5inches)
( ) 2 can reach forward 5cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION

INSTRUCTION: pick up the shoe/ slipper, which is placed in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2 -5cm (1-2 inches) from slipper and keeps balance independently.
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try need assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING

INSTRUCTIONS: turn to look directly behind you over toward the left shoulder; repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better turn
( ) 4 looks behind from both sides and weight shift well
( ) 3 looks behind one sides only other side shows less weight shift
( ) 2 turn sideways only but maintain balance
( ) 1 needs supervision when turning
( ) 0 needs assistance to keep from losing balance or falling

TURNING 360 DEGREES

INSTRUCTIONS: turn completely around in a full circle, pause and then turn a full circle in the other direction
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able turn 360 degree safely one side only four seconds or less
( ) 2 able to turn 360 degree safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED

INSTRUCTIONS: place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and can reach forward complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aids with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 need assistance to keep from falling/ unable to try

STANDING UNSUPPORTED WITH ONE FOOT IN FRONT

INTSRUCTIONS: (DEMONSTRATE TO SUBJECT) place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot (to score three points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width).

( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG

INSTRUCTIONS: stand on one leg as you can without holding on to a support.

( ) 4 able to lift leg independently and hold >10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold >3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remain standing independently.
( ) 0 unable to try of needs assist to prevent fail

TOTAL SCORE (MAXIMUM = 56)

APPENDIX IV

Gross Motor Function Classification System for Cerebral Palsy (GMFCS)

Before 2nd birthday

Level 1 Infant move in and out of sitting and floor, sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding on to furniture. Infants walk between 18 months 2years of age without the need for any assistive mobility device.

Level 2 Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding on the furniture.

Level 3 Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.

Level 4 Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.

Level 5 Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk posture in prone and sitting. Infants require adult assistance to roll

Between 2nd and 4th birthday

Level 1 Children floor sit with both hands free to manipulate objects. Movement in and out of floor, sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device

Level 2 Children floor sit but may have difficulty with balance when both hands are free to manipulate object. Movements in and out of sitting are performed without adult assistance.

Level 3 Children maintain floor sitting often by ‘’w’’- sitting (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self mobility. Children may

pull to stand on a stable surface and cruise short distance children may walk short distance indoors using an assistive mobility device and adult assistance for steering and turning.

Level 4 Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children may achieve self –mobility using a power wheel chair.

Level 5 Physical impairments restrict voluntary control of movement and ability to maintain antigravity head and trunk postures. All areas of motor functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At level 5, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Between 4th and 6th birthday

Level 1 Children get into and out of, and sit in a chair without the need for hands support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.

Level 2 Children sit in a chair with both hands free to manipulate objects. Children move the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for any assistive mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding on to a railing but are unable to run or jump.

Level 3 Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or up with their arms. Children walk with an assistive mobility device on level surfaces and climb stair with assistance from an adult. Children frequently are transported when travelling for long distance or outdoor on an even terrain.

Level 4 Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of the chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and an adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self –mobility using a power wheelchair.

Level 5 Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk posture. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At level 5, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Between the 6th and 12th birthday

Level 1 Children walk indoors and outdoors, climb stairs without limitations. Children perform gross motor skills including running and jumping but speed, balance and coordination are reduced.

Level 2 Children walk indoors and outdoors, and climb stairs holding unto a railway but experience limitations walking on uneven surfaces and inclines, and walking in crowd or confined spaces. Children have at best only minimal ability to perform gross motor skills such as running and jumping

Level 3 Children walk indoors or outdoors on a level surface with an assistive mobility device Children may climb stairs holding onto a railing depending on upper limb function, children propel a wheel chair manually or are transported when travelling for long distances or outdoors on uneven terrain

Level 4 Children may maintain levels of function achieved before age 6 or rely more on wheeled mobility at home, school, and in the community. Children may achieve self mobility using a powered wheel chair.

Level 5 Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk posture. All areas of motor function are limited. Functional limitation in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At level 5, children have no means of independent mobility and are transported. Some children achieved self - mobility using a power wheel chair with extensive adaptation.

APPENDIX IV: DATA GATHERING FORM

Serial no	Age	Sex	CP type	Cause of CP	Modified Ashworth scores	GMFCS levels	BBS scores	TUG scores

INSTITUTE FOR ADVANCED MEDICAL RESEARCH AND TRAINING (IMRAT)
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UI/UCH EC Registration Number: **NHREC/05/01/2008a**

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Comparative Efficacy of Strength and Balance Training on Functional Performance of Children with Cerebral Palsy

UI/UCH Ethics Committee assigned number: UI/EC/09/0083

Name of Principal Investigator: Faderera A. Adepoju

Address of Principal Investigator: Department of Physiotherapy
College of Medicine, University of Ibadan

Date of receipt of valid application: 18/06/2009

Date of meeting when final determination of research was made: **N/A**

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and *given full approval by the UI/UCH Ethics Committee.*

This approval dates from 05/10/2009 to 04/10/2010. If there is delay in starting the research, please inform the UI/UCH Ethics Committee so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. *All informed consent forms used in this study must carry the UI/UCH EC assigned number and duration of UI/UCH EC approval of the study.* In multiyear research, endeavour to submit your annual report to the UI/UCH EC early in order to obtain renewal of your approval and avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the UI/UCH EC. *No changes are permitted in the research without prior approval by the* UI/UCH EC *except in circumstances outlined in the Code. The* UI/UCH EC *reserves the right to conduct compliance visit to your research site without previous notification.*

UI/UCH EC
05 OCT 2009
APPROVED
COLLEGE OF MEDICINE U.I.

Dr. A. A. Adenipekun,
Chairman, Medical Advisory Committee,
University College Hospital, Ibadan, Nigeria
Vice- Chairman, UI/UCH Ethics Committee
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DEPARTMENT OF PHYSIOTHERAPY

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5/5/2011

The Head of Department,
Department of Paediatrics,
University College Hospital,
Ibadan.

Dear Ma,

RE: MRS FADERERA A ADEPOJU

I write to introduce Mrs Faderera Adepoju, a Physiotherapist who is currently enrolled as a Ph.D Neurophysiotherapy degree student in Department of Physiotherapy, College of Medicine, University of Ibadan. In partial fulfilment of requirements for her Ph.D degree, she is carrying out a research work titled:**"Comparative efficacy of two models of balance training in children with cerebral palsy"**. The study is being carried out under my supervision.

She is recruiting children with cerebral palsy who are aged between 4 and 12 years and have diplegic or hemiplegic presentation. We would like to recruit these patients from the Paediatric neurology clinic of your department.

We look forward to a favourable response.

Thank you for your anticipated cooperation.

Yours faithfully,

5/5/2011

Dr T.K. Hamzat
Project Supervisor