ORIGINAL RESEARCH ARTICLE

EFFECTS OF ISOKINETIC (CLOSED KINETIC CHAIN) STRENGTHENING EXERCISES ON CROUCH GAIT IN CHILDREN WITH SPASTIC DIPLEGIA (AGE GROUP – 6 TO 14 YEARS).

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ABSTRACT

Background: Hip extensors, knee extensors and plantar flexors are major contributors to supporting body weight during crouch gait. Therefore strengthening these muscles could potentially improve an individual's ability to walk in more upright posture. Isokinetic resistance is the excellent and safe type of training to increase strength and speed of movement in reciprocal movement patterns. Therefore this study is proposed to explore the use of isokinetic strengthening exercises as a therapeutic option to improve gait in children with spastic diplegia. Aim: To find out the effects of isokinetic (closed kinetic chain) strengthening exercises on crouch gait in children with spastic diplegia(Age group 6 to 14 years) Materials and methods: Thirty children with GMFC levels I & II, after allocating in two groups, underwent three dimensional gait analysis before and after six weeks of training & experimental group was reassessed at tenth week follow up. Both the groups underwent conventional therapy (thrice/week). Experimental group underwent additional isokinetic strengthening (thrice/ week).Statistical analysis: Paired and unpaired t test was used for intra and inter group analysis respectively. Results: After training, kinematic parameters of the gait (flexion angles of hip, knee and ankle at initial contact, mid stance and terminal stance) were reduced statistically significantly in experimental group ($p<0.001$) & the changes were retained at follow up. On comparison between two groups, the experimental group showed significant change in parameters ($p<0.05$).Conclusion: Isokinetic (Closed kinetic Chain) strengthening exercises along with conventional therapy are effective in reducing crouch gait in children with spastic diplegia.

Key words: Crouch gait, Isokinetic strengthening, Spastic diplegia, Kinematic parameters of gait.

Introduction

Spastic diplegia is the most prevalent form of Cerebral Palsy (CP).[1] Children with CP frequently walk with excessive hip, knee flexion and ankle dorsiflexion during stance phase. This movement abnormality called Crouch Gait, is problematic because it increases patello-femoral force[2], impedes toe clearance and increases the energy requirement of walking[3]. It can lead to altered patello-femoral joint mechanics, bone deformities[4], chronic knee pain[5] & walking limitation[6] if crouch is not corrected.

Weakness in individual with crouch gait could compromise their ability to generate the muscle forces required to produce an upright gait pattern. Muscles such as hip extensors, knee extensors and plantar flexors are major contributors to supporting body weight during crouch[7] gait therefore strengthening these muscles could potentially improve an individual's ability to walk in more upright posture.[8]

Strength training programs for preadolescents and adolescents can be safe if proper resistance training techniques and safety precautions are followed[9]. It has been found that Isokinetic resistance is the excellent and safe type of training to increase both strength and speed of movement in reciprocal movement patterns.[10] Less studies had been done in children with CP to see the effect of isokinetic strengthening by using closed kinetic chain exercises of lower extremities.

Therefore, this study is proposed to find out the effects of isokinetic (closed kinetic chain) strengthening exercises on crouch gait in children with spastic diplegia.

Materials & Methods:

This is Prospective interventional study comparing two types of interventions with study duration of ten weeks.

Participant's characteristics: Thirty children with spastic diplegia were selected for the study. Inclusion criteria consisted of children with spastic diplegia in age group of 6 to 14 years, GMFC level I & II, having > 10 degrees of knee flexion at initial contact & spasticity in lower limbs less than or equal to 2 by Modified Ashworth Scale. Children with Orthopaedic surgical intervention, Selective Dorsal Rhizotomy, Anti-spastic injection to lower extremity within one year prior to the study, Any musculoskeletal & neurological disorders other than CP, Contractures & deformities of Hip, Knee, ankle & Un-medicated epileptic patients were excluded from the study.

Outcome measures:

Kinematic parameters of the gait: Sagittal plane flexion angles of bilateral hips knees and ankles at Initial contact, Mid stance and Terminal stance of gait cycle.

Materials used: Biodex strength trainer system 4 pro, BTS Bio engineering computerized Gait and Motion analysis lab.

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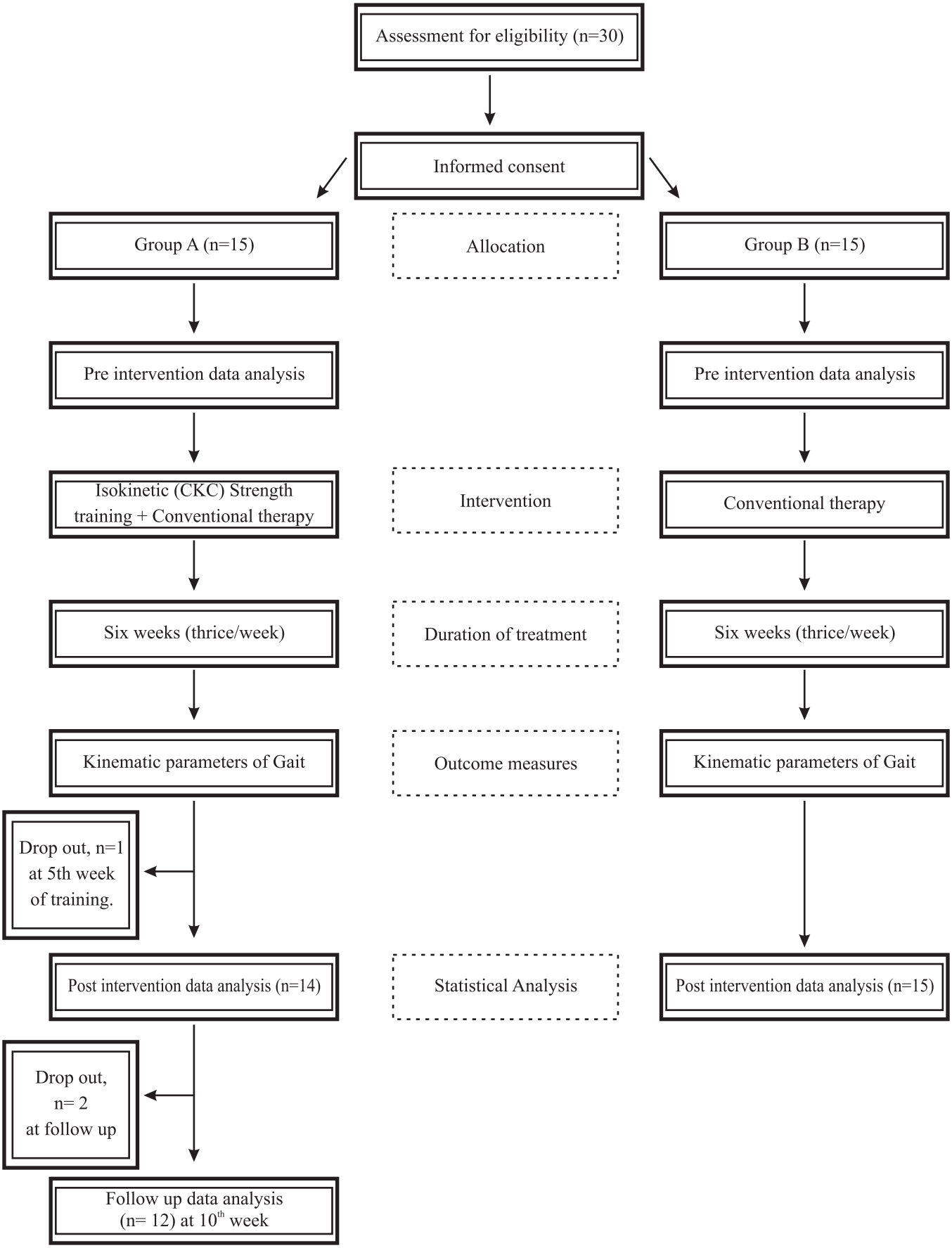
FLOW CHART


Assessment for eligibility (n=30)
Informed consent
Group A (n=15)
Allocation
Group B (n=15)
Pre intervention data analysis
Pre intervention data analysis
Isokinetic (CKC) Strength training + Conventional therapy
Intervention
Conventional therapy
Six weeks (thrice/week)
Duration of treatment
Six weeks (thrice/week)
Kinematic parameters of Gait
Outcome measures
Kinematic parameters of Gait
Drop out, n=1 at 5th week of training.
Post intervention data analysis (n=14)
Statistical Analysis
Post intervention data analysis (n=15)
Drop out, n= 2 at follow up
Follow up data analysis (n= 12) at 10th week

Procedure: Study was commenced after approval from institutional ethics committee. The selected 30 subjects were explained about the nature & implication of the study and written informed consent and ascent were taken from parents and children respectively. Thirty subjects were assigned to two groups viz. Group A (n= 15) and Group B (n=15) alternately by convenience sampling method. Assessment of each individual's kinematic parameters was done before & after six weeks of training. Group A was reassessed at tenth week follow up.

Biodex strength trainer system 4 pro was used for training on closed chain mode. Subject was positioned in seating position with seatback tilted to 85^0. Starting position for exercise was kept as below[11]:

- Hip : 90^0
- Knee : 90^0
- Ankle: Near neutral.

The Gait lab system was calibrated with axes wand and plate sequences to define the capture volume for the study and appropriate files of standing and walking of the subjects were prepared and saved in the 'SMART CAPTURE' software. After clinical examination, subjects were prepared for the study. The subjects were instructed to use minimal clothing for accurate placement of markers and for uninterrupted capturing procedure. As per Davis protocol[12] 16 reflective markers with strikers were stuck on anatomical reference points on the body. Subjects were made to walk barefoot on ten meter walk way at his self selected comfortable speed in North-South direction, each time started from pre defined point so that subject placed only one foot on each force plates during walking acquisition. Three-four trials were carried out before final walking acquisition and the file was saved. After successful completion of standing and walking acquisition, subjects were freed from the markers.

Then SMART TRACKER and SMART ANALYSER software were utilized to calculate the kinematic parameters.

Training protocol

As per study design, Group A as well as Group B received conventional physiotherapy treatment thrice a week for six weeks either at the institute or as advised at home, which is as follows:

- Cryotherapy followed by stretching exercise,
- Exercises to improve voluntary control of bilateral lower limbs, and
- Functional mobility exercises

Parents were also taught home exercise program.

Group A received additional sessions of strength training thrice a week for consecutive six weeks which were performed on alternate days in the institute.

Strength training

Participants were trained for isokinetic strengthening for three times per week for total of six weeks on Biodex S4 Pro dynamometer. Each session began with a ten minutes warm up consisting of Walking at self selected speed and stretching. Following the warm up, each participant performed three-five sub maximal efforts followed by six sets of five maximum effort contractions.

Group A performed strengthening exercises as per following protocol[13]:

Repetitions: Five repetitions per set.

Total Sets: Six

1. First week (first three sessions) -
   - Six sets of five concentric repetitions were performed at 30 deg/sec

2. Second week to sixth week (session 4-18) –
   - Set one was performed at 30deg/sec
   - Set two at 60 deg/sec
   - Set three at 60 deg/sec
   - Set four at 75 deg/sec
   - Set five at 90 deg/sec
   - Set six at 120 deg/sec.

Thus all participants completed six sets of five repetitions. One minute of rest was given between sets to allow the muscle to recover.

Isokinetic mode was used to enable strengthening throughout participants Range of motion which was set by ROM stops between most extended position of leg in seating position (away from the body) and with hip and knee flexed to 90 degrees with ankle in near neutral position (towards the body). During training all received biofeedback from computer display based on an individually determined target.

The target value was determined initially from 80% of their maximum concentric strength at 30deg/s and increased weekly to match the highest torque value achieved in the previous week. Participants were encouraged to meet or exceed the target on each repetition.

Exercise schedule compliance forms were given to the subjects/ parents of both the groups to be filled up. It contained exercise schedule as advised on all dates (i.e strength training and regular physiotherapy treatment on alternate days). They were asked to tick mark if exercises were done and '×' when not done. Compliance to the exercise program was checked and the filled up forms submitted to the evaluator at the end of six weeks. Reassessment of kinematic parameters was done after six weeks and at follow up i.e. four weeks after the cessation of isokinetic strengthening exercises.

After completing six weeks of isokinetic strength training, subjects were instructed to continue regular physiotherapeutic exercises at home. The diary was maintained to check the regular sessions of exercises being done at home. Subjects were called after four weeks for follow up and reassessment of kinematic parameters were done

Statistical analysis:

Analysis of data for this study was done using software GraphPad Instat version 3.1. The results were considered significant at p value <0.05 & confidence interval (CI) at 95%. Using normality test (KS), it was found that Kinematic parameters of gait in both groups followed normal distribution pattern. Hence parametric test was used for analysis. Within group analysis of pre& post test and follow up was done using paired t-test. Comparison of mean difference of post and pre intervention scores between two groups was done using unpaired t-test.

Results

Analysis of the baseline data revealed that both groups are similar at baseline ($p>0.05$).

After six weeks of training,

1. There is significant change in mean scores of flexion angles of bilateral hips-knees-ankles at initial contact of gait

cycle in Group A ($p<0.001$); no significant change in Group B ($p>0.05$).

2. There is significant change in mean scores of flexion angles of bilateral hips-knees-ankles at mid stance of gait cycle in Group A ($p<0.01$); no significant change in Group B ($p>0.05$).

3. There is significant change in mean scores of flexion angles of bilateral hips-knees-ankles at terminal stance of gait cycle in Group A ($p<0.01$); no significant change in Group B ($p>0.05$).

On comparison of mean difference (post intervention- pre intervention scores) between two groups, there was significant change in Group A. ($p<0.05$)

Post intervention v/s follow up shows no statistically significant change in Group A at initial contact, mid stance and terminal stance of gait cycle. ($p>0.05$)

Discussion

This study was conducted to explore the use of isokinetic strengthening exercises of lower extremities as a potential therapeutic option to improve crouch gait in children with spastic diplegia. A total number of thirty children (mean age 10.533 ± 2.825 years in each group) with spastic diplegia participated in the study. They were divided into two groups. From experimental group, there was a drop out of one subject at fifth week of strength training. Therefore findings and analysis has been presented for Group A (experimental group) and Group B (control group), with 14 and 15 subjects respectively.

In experimental group, two patients did not report for follow up. So comparison between post intervention and follow up was done having 14 and 12 subjects respectively.

Comparison of bilateral hips, knees and ankles were done in three different events in stance phase. The flexion angles of hip, knee and ankle joints were measured at initial contact (i.e at 0% of gait cycle), at mid stance (10 to 30 % of gait cycle) and at terminal stance phase (31 to 50 % of gait cycle) of gait cycle.

From the results, it is evident that after six weeks of training, there is significant difference in the mean flexion angles of bilateral hips, knees and ankles at initial contact, mid stance & terminal stance in Group A.

On comparison of effects of training between the two groups, the mean difference of flexion angles of bilateral hips-knees-ankles at initial contact, mid stance and terminal stance differed statistically significantly in Group A, indicating that six weeks of isokinetic (closed chain) strength training along with conventional physiotherapy was more effective in reducing the crouch gait.

On comparison of post training v/s follow up, the reduction in flexion angles of bilateral hips, knees and ankles at initial contact, mid stance and terminal stance were retained at tenth week follow up even after stopping isokinetic strengthening intervention.

The abnormal gait parameters in both groups before treatment application may be attributed to many factors such as spasticity, muscle weakness and co-contraction of both agonist and antagonist muscle groups during walking activity. This is supported by previous studies[14,15] who reported that, CP disrupts the ratio of excitatory and inhibitory impulses from afferent nerves, resulting in co-contraction of the agonist and antagonist muscle groups at the same moment. Weakness of quadriceps and hip extensor muscles was shown to be a factor in crouch gait and contribute to the walking impairment.[16]

Arnold As et al (2005)[17] examined the muscle actions during single limb stance and showed that the gluteus maximus, vasti, and soleus make substantial contributions to hip and knee extension during normal gait. Per unit force, the gluteus maximus had greater potential than the vasti to accelerate the knee toward extension. These data suggested that weak hip extensors, knee extensors, or ankle plantar flexors may contribute to crouch gait, and strengthening these muscles-particularly gluteus maximus--may improve hip and knee extension.

The present study used closed kinetic chain isokinetic leg press exercise which mostly targeted the hip and knee extensors; however closed kinetic chain exercise executed in seated leg press exercise would have recruited the ankle plantar flexors; the together effect of which may have contributed to improve the flexion angles of all three joints at initial contact and maximum extension at mid stance and terminal stance of gait in the current study.

The observed improvement in the experimental group can be attributed to the effect of isokinetic (closed kinetic chain) strengthening intervention through neural adaptation which may have regulated the ratio between excitatory and inhibitory impulses and resulted in decreasing the co-contraction of both agonist and antagonist group of muscles.

The results of the present study is supported by Diane L Damiano,et.al[18] who reported improvement in the degree of crouch at initial floor contact at the freely selected speed and an increase in stride length at free and fast speeds in children with spastic diplegia after undergoing strengthening of bilateral quadriceps femoris muscle for six weeks. The authors concluded that the greater quadriceps femoris muscle force enabled this muscle group to counteract the hamstring muscles as they acted to decelerate the thigh in later swing.

Unger et al(2006)19's study is in agreement with the present study which showed that there is statistically significant improvement in crouch gait (sum of hip/knee/ankle at mid stance) in strength training group as compared to control group and concluded that strength training program targeting multiple muscle groups can lead to improved degree of crouch gait.

As given in the study of Margaret Mockford et al (2008)[20], Bobath suggested that weakness may partly be attributed to tactile or proprioceptive sensory deficits. The present study included Closed chain strength training which may have helped enhancing sensory inputs by stimulating the proprioceptors in weight bearing tissues which may improve the motor recruitment.

Table1: Comparison of mean flexion angles of bilateral Hips-Knees-Ankles at Initial Contact, Mid Stance & Terminal Stance pre and post intervention in Group A.

Group A		Initial contact		Mid stance		Terminal stance	
		Mean(SD)	P value & Significance	Mean(SD)	P value & Significance	Mean(SD)	P value & Significance
Rt hip	Pre	46.36(10.14)	<0.0001	29.16(11.23)	0.0022	14.57(11.45)	0.0096
	Post	35.33(13.53)	**E.S**	19.95(12.34)	**V.S**	6.03(9.58)	**V.S**
Lt hip	Pre	48.65(10.75)	<0.0001	33.49(12.89)	0.0001	21.40(10.70)	< 0.00013
	Post	36.50(10.64)	**E.S**	19.95(12.08)	**E.S**	6.58(11.26)	**E.S**
Rt knee	Pre	39.55(11.94)	<0.0001	32.60(11.36)	0.0010	30.87(10.81)	0.0016
	Post	26.98(15.66)	**E.S**	21.62(16.42)	**E.S**	21.04(17.04)	**V.S**
Lt knee	Pre	38.14(15.09)	<0.0001	31.79(15.49)	0.0002	30.17(15.79)	0.0003
	Post	25.64(15.82)	**E.S**	19.39(18.52)	**E.S**	16.65(19.21)	**E.S**
Rt ankle	Pre	11.40(6.92)	0.0009	15.69(5.77)	0.0001	18.49(7.18)	0.0003
	Post	8.45(5.90)	**E.S**	11.80(5.16)	**E.S**	13.72(5.97)	**E.S**
Lt ankle	Pre	12.84(5.74)	0.0007	16.28(6.31)	0.0007	19.04(6.59)	0.0001
	Post	7.05(6.29)	**E.S**	9.62(5.30)	**E.S**	12.39(6.89)	**E.S**

E.S= extremely significant, V.S= Very Significant, SD= standard deviation, Rt= Right, Lt= Left.

Table2. Comparison of mean flexion angles of bilateral Hips-Knees-Ankles at Initial Contact, Mid Stance & Terminal Stance pre and post intervention in Group B.

Group B		Initial contact		Mid stance		Terminal stance	
		Mean(SD)	P value & Significance	Mean(SD)	P value & Significance	Mean(SD)	P value & Significance
Rt hip	Pre	41.65(9.68)	0.3813	23.56(12.19)	0.4533	10.26(12.55)	0.8208
	Post	40.88(10.22)	**N.S**	22.53(11.45)	**N.S**	9.90(11.53)	**N.S**
Lt hip	Pre	46.10(15.20)	0.9132	28.86(13.58)	0.5638	14.93(12.48)	0.6338
	Post	45.86(11.70)	**N.S**	28.05(12.70)	**N.S**	13.90(13.10)	**N.S**
Rt knee	Pre	37.46(8.40)	0.1574	30.02(12.43)	0.7923	29.30(14.45)	0.3466
	Post	35.24(10.17)	**N.S**	29.60(12.93)	**N.S**	27.78(14.02)	**N.S**
Lt knee	Pre	35.77(13.38)	0.0908	29.81(11.00)	0.2832	30.71(11.87)	0.8128
	Post	33.36(10.82)	**N.S**	28.46(12.53)	**N.S**	30.27(12.82)	**N.S**
Rt ankle	Pre	9.36(5.78)	0.2802	12.53(5.16)	0.7357	15.59(6.07)	0.6484
	Post	8.44(6.19)	**N.S**	12.14(7.07)	**N.S**	14.90(7.97)	**N.S**
Lt ankle	Pre	10.09(4.63)	0.3119	13.52(4.24)	0.5616	16.56(3.17)	0.3498
	Post	8.81(5.22)	**N.S**	13.00(4.48)	**N.S**	15.96(3.49)	**N.S**

N.S= Not Significant, SD= Standard Deviation, Rt= Right, Lt= Left.

Table 3: Comparison of mean difference (post training- pre training) of flexion angles of bilateral Hips-Knees-Ankles at Initial Contact, Mid Stance, Terminal Stance between Group A & Group B.

Group A		Initial contact		Mid stance		Terminal stance	
		Mean(SD)	P value & Significance	Mean(SD)	P value & Significance	Mean(SD)	P value & Significance
Rt hip	A	11.03(6.06)	<0.0001	9.20(9.07)	0.0056	8.20(10.81)	0.0218
	B	0.75(3.28)	**E.S**	1.02(5.15)	**V.S**	0.36(6.03)	**S**
Lt hip	A	12.15(6.39)	0.0002	13.54(9.22)	<0.0001	14.82(9.62)	0.0003
	B	-0.08(8.88)	**E.S**	0.81(5.32)	**E.S**	1.03(8.21)	**E. S**
Rt knee	A	12.57(8.50)	0.0006	10.99(9.71)	0.0014	9.83(9.30)	0.0078
	B	2.22(5.75)	**E.S**	0.41(5.96)	**V.S**	1.52(6.04)	**V.S**
Lt knee	A	11.04(6.62)	0.0005	12.40(9.30)	0.0004	13.53(10.42)	0.0005
	B	2.41(5.14)	**E.S**	1.34(4.67)	**E.S**	0.44(7.06)	**E. S**
Rt ankle	A	2.95(2.57)	0.0443	3.89(2.73)	0.0171	4.76(3.59)	0.0320
	B	0.57(3.40)	**S**	0.39(4.42)	**S**	0.69(5.76)	**S**
Lt ankle	A	5.79(4.89)	0.0177	6.66(5.67)	0.0014	6.65(4.71)	0.0002
	B	1.28(4.72)	**S**	0.52(3.38)	**V.S**	0.60(2.40)	**E. S**

E.S= Extremely Significant, S= Significant, V.S= Very significant, SD= Standard Deviation, Rt= Right, Lt= Left.

Table 4. Comparison of mean flexion angles of bilateral Hip-Knee-Ankle at Initial Contact, Mid Stance, Terminal Stance between post intervention & follow up in Group A.

Group B		Initial contact		Mid stance		Terminal stance	
		Mean(SD)	P value & Significance	Mean(SD)	P value & Significance	Mean(SD)	P value & Significance
Rt hip	Post	35.33(13.53)	0.8520	19.95(12.34)	0.9643	6.03(9.58)	0.8261
	FU	37.29(13.10)	**N.S**	21.08(13.33)	**N.S**	5.87(11.46)	**N.S**
Lt hip	Post	36.50(10.64)	0.7883	19.95(12.08)	0.7080	6.58(11.26)	0.5450
	FU	37.98(10.09)	**N.S**	19.84(13.01)	**N.S**	5.23(12.65)	**N.S**
Rt knee	Post	26.98(15.66)	0.9040	21.62(16.42)	0.8156	21.04(17.04)	0.8306
	FU	26.69(17.12)	**N.S**	21.30(16.08)	**N.S**	20.97(16.05)	**N.S**
Lt knee	Post	25.64(15.82)	0.9869	19.39(18.52)	0.7206	16.65(19.21)	0.7291
	FU	26.05(19.01)	**N.S**	18.70(19.60)	**N.S**	16.00(20.58)	**N.S**
Rt ankle	Post	8.45(5.90)	0.7558	11.80(5.16)	0.4778	13.72(5.97)	0.6382
	FU	9.68(8.62)	**N.S**	12.80(4.76)	**N.S**	14.47(6.04)	**N.S**
Lt ankle	Post	7.05(6.29)	0.9532	9.62(5.30)	0.5978	12.39(6.89)	0.2882
	FU	8.04(6.19)	**N.S**	10.74(4.71)	**N.S**	10.83(5.48)	**N.S**

N.S= Not Significant, SD= Standard Deviation, Rt= Right, Lt= Left.

Conclusion

Isokinetic (closed kinetic chain) strength training along with conventional therapy is effective in reducing crouch gait in children with spastic diplegia (age group 6 to 14 years).
And it is seen to retain the improvements in gait even after stopping isokinetic strengthening intervention.

Clinical implication: Strength training of lower limbs using isokinetic exercises (closed chain mode) can be made a part of regular physiotherapy program in children with spastic diplegia having crouch gait.

Limitation:

- The study has small sample size.
- The follow up assessment was not done in control group.

Suggestions:

1. This study can be done with larger sample size.
2. The assessment at follow up can be done in both control and experimental group rather than just in experimental group.
3. Future studies are needed to consider the effect of isokinetic strengthening (closed chain mode) on Spasticity, balance and voluntary motor control in the same population.
4. Future studies can be done considering eight to ten weeks duration for strength training & can see the long term effects of isokinetic strengthening for children with spastic diplegia.

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Refrences:

1. Watt J, Sims D, Harckham F, et al. A PROSPECTIVE STUDY OF INHIBITIVE CASTING AS AN ADJUNCT TO PHYSIOTHERAPY FOR CEREBRAL PALSIED CHILDREN.
2. Perry J, Antonelli DA, Ford W. Analysis of knee-joint forces during flexed-knee stance. The Journal of Bone & Joint Surgery. 1975 Oct 1;57(7):961-7.
3. Stout J, Koop S. Energy expenditure in cerebral palsy. CLINICS IN DEVELOPMENTAL MEDICINE. 2004:146-64.
4. Graham HK, Selber P. Musculoskeletal aspects of cerebral palsy. JOURNAL OF BONE AND JOINT SURGERY-BRITISH VOLUME-. 2003 Mar 1;85(2):157-66.
5. Sutherland DH, Cooper L. The pathomechanics of progressive crouch gait in spastic diplegia. The Orthopedic Clinics of North America. 1978 Jan;9(1):143-54.
6. Opheim A, Jahnsen R, Olsson E, et al. Walking function, pain, and fatigue in adults with cerebral palsy: a 7 year follow up study. Developmental Medicine & Child Neurology. 2009 May 1;51(5):381-8.
7. Arnold AS, Anderson FC, Pandy MG, et al. Muscular contributions to hip and knee extension during the single limb stance phase of normal gait: a framework for investigating the causes of crouch gait. J Biomech 2005;38:2181–2189
8. Steele KM, Damiano DL, Eek MN, et al. Characteristics associated with improved knee extension after strength training for individuals with cerebral palsy and crouch gait. Journal of pediatric rehabilitation medicine. 2012;5(2):99-106.
9. Bernhardt DT, Gomez J, Johnson MD, et al. Strength training by children and adolescents. Pediatrics. 2001 Jun;107(6):1470-2.
10. McCubbin JA, Shasby GB. Effects of isokinetic exercise on adolescents with cerebral palsy. Adapted Physical Activity Quarterly. 1985 Jan 1;2(1):56-64.
11. Da Silva EM, Brentano MA, Cadore EL, et al. Analysis of muscle activation during different leg press exercises at submaximum effort levels. The Journal of Strength & Conditioning Research. 2008 Jul 1;22(4):1059-65.
12. Ergović V. Models and methods for locomotion analysis of lower limbs.
13. Moreau NG, Holthaus K, Marlow N. Differential adaptations of muscle architecture to high-velocity versus traditional strength training in cerebral palsy. Neurorehabilitation and neural repair. 2013 May 1;27(4):325-34.
14. Durstine, J.L., Painter, P. and Franklin, B.A.: Physical activity for the chronically ill and disabled. Sports Med. 2000,30: 207-219.
15. Sherman, P. and Norton, F.: Issues in measuring change in motor function in children with cerebral palsy: A special communication. Phys. Ther. 1990, 70: 125-131.
16. El Dien MS. Effect of Limb Strengthening on Gait Parameters in Spastic Diplegic Cerebral Palsied Children. Bulletin of Faculty of Physical Therapy. 2008;13(1).
17. Arnold AS, Anderson FC, Pandy MG, et al. Muscular contributions to hip and knee extension during the single limb stance phase of normal gait: a framework for investigating the causes of crouch gait. Journal of biomechanics. 2005 Nov 30;38(11):2181-9.
18. Damiano DL, Kelly LE, Vaughn CL. Effects of quadriceps femoris muscle strengthening on crouch gait in children with spastic diplegia. Physical therapy. 1995 Aug 1;75(8):658-67.
19. Unger M, Faure M, Frieg A. Strength training in adolescent learners with cerebral palsy: a randomized controlled trial. Clinical Rehabilitation. 2006 Jun 1;20(6):469-77.
20. Mockford M, Caulton JM. Systematic review of progressive strength training in children and adolescents with cerebral palsy who are ambulatory. Pediatric Physical Therapy. 2008 Jan 1;20(4):318-33.

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