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Effect of Four Weeks Level Ground Side Walking Training on Gluteus Medius Muscle Activation and Gait Parameters in Subjects with Post Stroke Chronic Hemiparesis

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ABSTRACT

The Chronic Stroke is the period of recovery that takes place at least six months after the initial stroke event. Regaining the ability to walk is a major goal in stroke rehabilitation. Muscle weakness has been implicated as a factor underlying deficits in gait performance in subjects with stroke. The functions of the Gluteus Medius (Gmed) include initiation of hip abduction and lateral pelvic tilting. Individuals with hip abductor weakness leads to compensatory motion of the lower back, hip, and knee. So aim of the study was to activate gluteus medius muscle by level ground side walking. Subjects with 40-65 years of age both male and female with Post stroke duration more than 6 months and able to walk 10 meter with or without aid or orthosis were included. Subjects with severe spasticity, fixed contractures of adductor group of muscles & Traumatic orthopaedic Disorder of Lower Extremity were excluded. Subjects in this study participated in intervention group 30 minutes of conventional therapy with 30 minutes of level ground side walking training and in control group along with conventional treatment 30 minutes of forward walking training were given. Gluteus medius muscle activation and strength using surface Emg and hand held dynamometer, gait speed using 10MWT and spatiotemporal gait parameters using instrumented shoes along with Foot prints were taken prior and 4 weeks post intervention. On analysis, there was significant improvement in gluteus medius muscle strength and activation, there was significant difference in gait speed and spatiotemporal gait parameters. Based on the results of present study, it can be concluded that level ground side walking is effective in improving strength of hip abductors, spatiotemporal gait parameters and walking speed in post stroke chronic hemiparesis.

Keywords: Gluteus medius muscle, side walking, Stroke

INTRODUCTION

Stroke (cerebrovascular accident [CVA]) is the sudden loss of neurological function caused by an interruption of the blood flow to the brain. Two types of brain stroke are haemorrhagic and ischemic. Hemorrhagic stroke, which is due to blood vessel rupture, accounts for 20% of CVAs. Ischemic stroke due to brain vessels occlusion and blockage includes 80%.[2] Stroke is a significant global health problem and a major cause of mortality and morbidity in developed countries and increasingly in low-middle income countries (LMICs).[3] In a recent systematic review, consisting mainly of cross-sectional studies, the incidence of stroke in India was estimated to be between 105 and 152/100,000 people per year.[4] People living with stroke present several sensorimotor deficits such as contralateral and ipsilateral muscular weakness, spasticity, lack of coordination, impaired sensitivity, and impaired balance.[5] Most patients with hemiplegic stroke display increasing recovery of their independent walking ability.[6] Regaining the ability to walk is a major goal in stroke rehabilitation.[7] Of those patients who survive the acute phase, about 20% to 30% are unable to walk, whereas many others have moderate to severe walking disability with reduced walking speeds months after stroke.[8]Early intensive rehabilitation in which motor control of the gait cycle is relearned is an important aspect of effective treatment regimes. It is especially in the first weeks after the stroke that the acquisition of motor control of the paretic lower limb goes through synergy dependent stages.[9] The appearance of gross extensor and flexor limb synergies may evolve into adaptive motor coordination to accomplish the motor task.[10] This adaptive strategy results in fewer degrees of freedom to be controlled and a preferred proximal motor control by fixation of the pelvis and lumbar spine.[11] However, little is known about the way muscle coordination of the lower limb evolves when gait is regained after stroke. Persons with lower extremity weakness following stroke often demonstrate difficulty with weight transfer and paretic lower extremity loading. These deficits in turn, can lead to problems with lateral stability, or the ability to control movement of the center of mass in the frontal plane.[12] Furthermore, the gait patterns of such patients have been described as slow and asymmetric. An extremely debilitating gait can lead to loss of independence. The decreased velocity of hemiplegic gait in comparison to normal gait has also been repeatedly reported, along with associated limitations in cadence, stride length, and gait cycle.[13] Stroke survivors usually have decreased stance phase and prolonged swing phase of the paretic side. Further, the walking speed is decreased and the stride length is shorter. These gait abnormalities along with muscle weakness place stroke survivors at a high risk of falls.[14] Muscle coordination is likely to change through, changes in muscle strength and the timing of muscle activation.[15] Muscle strength after stroke can change through changes in the mass of the muscle, changes in muscle fiber type (as a result of immobilization in the early stages post stroke), or aerobic capacity. The literature shows that muscle force can be influenced after stroke.[16] **Muscle weakness** has been implicated as a factor underlying deficits in gait performance in subjects with stroke.[17] The **Gluteus medius muscle (Gmed)** is a hip stabilizer, stabilizing the femoral head in the acetabulum during different hip rotations. The functions of the Gmed include initiation of hip abduction and lateral pelvic tilting. The magnitude of force required by the hip abductors to stabilize the pelvis is approximately 2.5 times the individual’s body weight.[18] Thus, the strength of the abductor muscles together must be higher than the individual’s body weight. When there is enough strength to support the individual’s body weight, his or her gait pattern is normal, and the joints work properly. If weight overload or muscle weakness occurs, an adaptation of the upper body will be triggered in an attempt to bring the center of gravity closer to the center of hip rotation.[19] In other words, individuals with hip abductor weakness leads to compensatory motion of the lower back, hip, and knee.[20] In Post stroke most common pattern of walking impairment is hemi paretic gait, which is characterized by asymmetry associated with an extensor synergy pattern of hip extension and adduction, knee extension, and ankle plantar flexion and inversion. There are characteristic changes in the spatiotemporal, kinematic and kinetic parameters, and dynamic electromyography patterns in hemiparesis, which may be assessed most accurately in a motion studies laboratory.[21] Much is uncertain about the timing and spatiotemporal recruitment of the paretic muscles of the lower limb evolves as gait improves in hemiplegic patients.[22]In stroke rehabilitation, the current trends emphasize the movement or gait patterns of stroke patients exposed to a variety of experimental environments, which may be essential to increase activity levels and social participation, through which the quality of life can be enhanced.[23] Being able to walk sideways steadily also facilitates people's participation in the community. Individuals with stroke have impaired performance in walking and daily activities[24], As the metabolic cost of walking sideways is 3 times greater than that of walking forwards.[25] after stroke individuals use more energy in postural control and walking than healthy persons performing the same task.[26] In clinical settings, **Side Walking Training (SWT)** is currently being used by some therapists; however, there are no published data documenting the effectiveness of SWT in patients with hemiplegic stroke. Side walking training is used by orthopedic surgeons and sports therapists for many purposes[27], including use as a strengthening exercise for the side of the hip and knee muscles, especially the adductors and abductors.[28] Thus, their sideways walking ability may serve as an indicator of their general functional capability in walking sideways and their participation in daily activities at home and in the community. Side walking training would be effective in increasing the walking function of post stroke patients.[29] **Surface electromyography (sEMG)** study has addressed changes in muscle activity during recovery in patients with stroke. These studies explore one or more relating to "body function" like muscle activation, gait parameters and walking speed. One's muscle activation pattern can be quantified by analyzing the relevant electromyogram signals. This is because the EMG signals can be easily accessed non-invasively using portal device in term of surface electromyography and interpreted by technology assisted platform.[30] Using **FSRs (Force Sensitive Resistors)** fitted below one's feet and detect one's gait related events such as heel strike, toe off, etc. that in turn can be used to measure spatiotemporal gait parameters.[31]

MATERIALS & METHODS

After taking Ethical approval from institutional review board (IRB) 1 year of Experimental study (Pre-Post Two group study design.) with convenient sampling was done in Subjects diagnosed with chronic hemiparesis and who had complaints of gait disorder, coming to neurological OPD of S.B.B College of physiotherapy from various OPDs of VS general hospital, S.V.P Hospital campus Ahmedabad, as well as other clinics and hospitals. Keeping the power of the study 80% & level of significance 5% the estimated sample size was found to be n=20. Duration of intervention was 1 hour/day, five times a week for four weeks. (20 sessions) Subjects following age of 40 – 65 years, Post stroke duration > 6 months, Able to walk 10 meter with or without aid or orthosis, Functional ambulatory category (FAC) score >=3, MMSE > 24, Both males and females, Both ischemic and hemorrhagic stroke, Berg balance scale (BBS): Low Fall Risk, Able to understand Borg scale of fatigue were included. Subjects with severe spasticity MAS (3, 4), fixed contractures of adductor group of muscles, Unstable medical condition such as severe uncontrolled Hypertension, Angina pectoris, Auditory or Visual perceptual deficits, Traumatic orthopaedic Disorder of Lower Extremity were excluded.

PROCEDURE

Purpose and procedure of the study were explained to subjects. An informed consent in vernacular language was taken. Study was conducted in two groups. GROUP A **CONTROL GROUP** 30 minute conventional therapy and 30 min forward walking (1hour/day) for 5 times a week for 4 weeks (20 Session) were given. GROUP B **INTERVENTIONAL GROUP** 30min conventional therapy with additional 30 minute level ground side walking training (1hour/day) for 5 times a week for 4 weeks (20 Session) were given. Participants were equally divided into two groups by coin method. Conventional Therapy were given by therapist which include Slow relaxed passive Stretching and of biceps, long finger flexors, hamstring and calf, strengthening of involved upper extremities and lower extremity, Hand muscles gripping exercise.

FOR LEVEL GROUND SIDE WALKING TRAINING:

10 meter plane obstacle free pathway in well-lit space was selected. Subjects were instructed to wear their usual footwear or orthosis during the training session**.** Instruct the subject to initially stand with their lateral border of unaffected foot touching the starting point. Then step by step side walk with unaffected extremity first at self-paced speed. After reaching the end point, the subject would side walk back to the starting point with affected extremity first. During this procedure therapist's position was behind the patient and placing her hand over the gluteus medius muscle for familiarization and to move the leg in correct position (manual contact, stabilization) When the subject start mastering the movement in correct pattern, the amount of assistance was gradually reduced. All subjects were allowed to continue their normal daily activities.

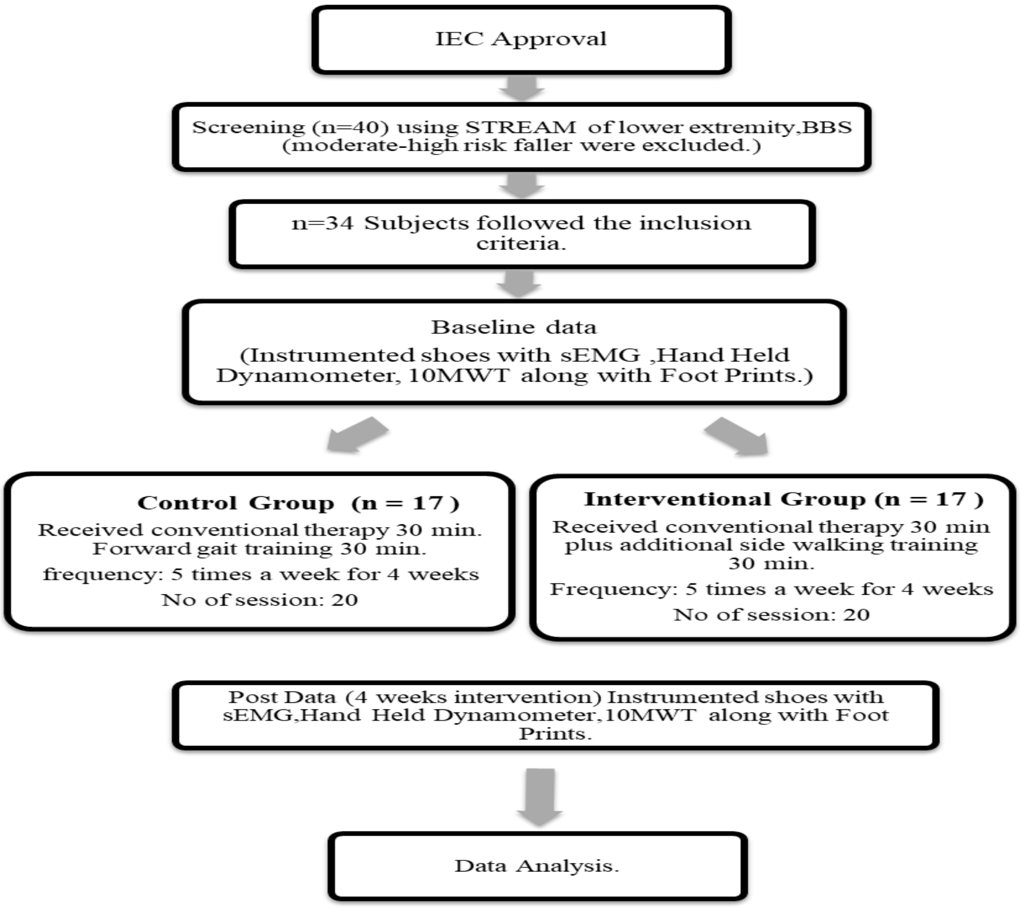
Fig 1: Hand Placement to re-educate Gluteus Medius Muscle

Fig 2: Side Walking With Un-Affected Side

Fig 3: Side Walking With Affected Side

Fig 4: Side Walk with unaffected with marking **Fig 5: Side Walk with affected Side side with marking**

STUDY FLOW CHART



STATISTICAL ANALYSIS

The present study was conducted to determine the effect of level ground side walking training on gluteus medius muscles activation and gait parameters in subjects with post stroke chronic hemiparesis. Data of the present study was analyzed using the SPSS version 16 and Microsoft Excel. Prior

to the statistical tests, a preliminary analysis of the data was performed to check for normal distribution. As the sample size was less than 30 per group normality was checked using the Shapiro Wilk test. Within group, analysis was done by comparing the pre and post data for all the outcome measures. Between groups analysis was done using the mean difference of the two groups. For the data which was not normally distributed, Wilcoxon rank sum test was used for within group analysis and Mann-Whitney U test was used for between group analyses. The level of significance was kept at 5% with a confidence interval of 95%.
The effect size was calculated to determine the clinical significance of the given intervention, which implies to the magnitude of the treatment effect. It was done using Cohen's d for all the outcome measures.[32] Cohen classified effect sizes as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$).[33]

RESULT

n=34 Subjects with post stroke Chronic hemiparesis were included in the study and were randomized into Group A being control group with conventional treatment and forward walking and Group B being interventional group with conventional treatment and level ground sideward walking. Each group consisted of 17 subjects.

Table 1 Demographic data within group:

VARIABLES	GROUP A: CONTROL GROUP	GROUP B: INTERVENTION GROUP
AGE (YEARS) (MEAN±SD)	52.52±9.40	52.88±8.15
GENDER(MALE/FEMALE)	13/4	13/4
DOMAIN (RIGHT/LEFT)	15/2	16/1
SIDE OF STROKE (RIGHT/LEFT)	4/13	9/8
POST STROKE DURATION (MONTHS) MEAN±SD	20.76±8.20	24.41±15.09
TYPE OF STROKE (ISCHEMIC/HEMORRHAGIC)	7/10	12/5

Table 2 Baseline comparison of demographic data (Mann-Whitney U test)

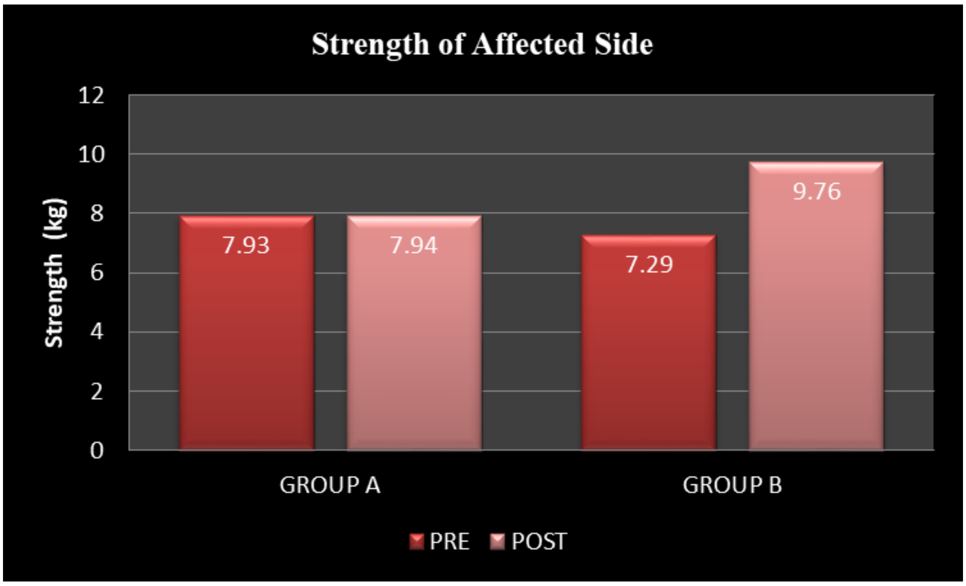
Variable	Group A Mean±SD	Group B Mean±SD	U value	p value	Significance
Age (Years)	52.52±8.40	52.88±8.15	127	0.325	**NOT SIGNIFICANT**
Post Stroke Duration	20.76±8.20	24.41±15.09	125	0.703	**NOT SIGNIFICANT**

Table 3 Baseline Comparison for Pre Intervention Outcome Measures:

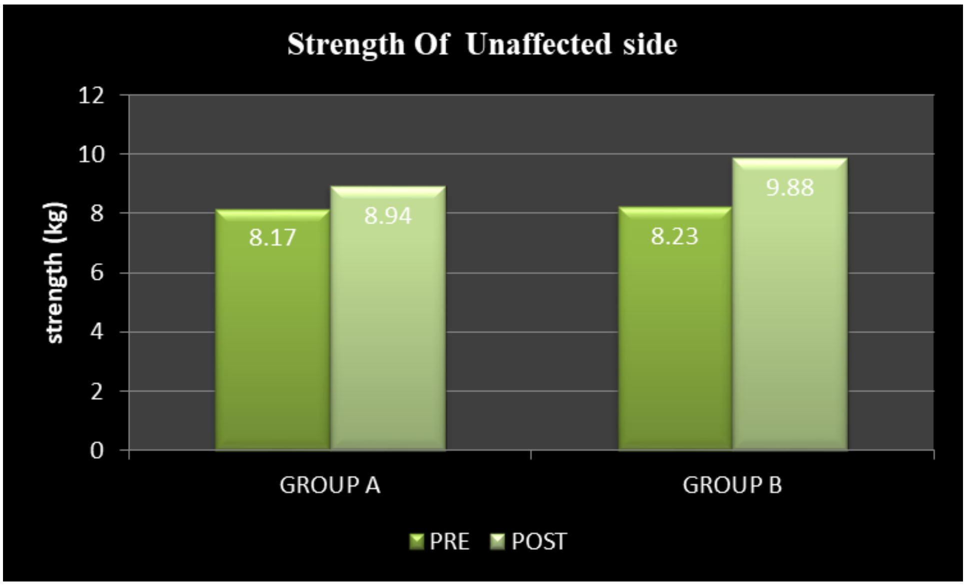
Variables		Group A Control Group Mean±SD	Group B Intervention Group Mean±SD	U value	P value	SIGNIFICANCE
MAV of gluteus medius muscle	Affected	16.6± 2.26	17.86± 2.36	113	0.278	**NOT SIGNIFICANT**
	Unaffected	18.88± 2.46	20.47± 3.35	106	0.190	
Strength of hip abductor	Affected	7.93±1.11	7.29±1.21	99	0.425	**NOT SIGNIFICANT**
	Unaffected	8.17±1.28	8.23± 0.90	97	0.375	
10MWT (self-selected walking speed)		0.69±0.13	0.72±0.13	9.76	0.345	**NOT SIGNIFICANT**
10MWT (fast selected walking speed)		0.75± 0.14	0.75±0.13	12.6	0.327	**NOT SIGNIFICANT**
Step width		11.35±1.96	11.09±1.08	125	0.496	**NOT SIGNIFICANT**
Cadence		79.58±6.08	80.41±0.93	131	0.640	**NOT SIGNIFICANT**

(MAV – Mean Absolute Value)

Comparison of Hip Abductor Muscle Strength using Hand Held Dynamometer (HHD)



Graph 1 within group comparison of affected side strength of Hip Abductor



Graph 2 within group comparison of unaffected side strength of Hip Abductor

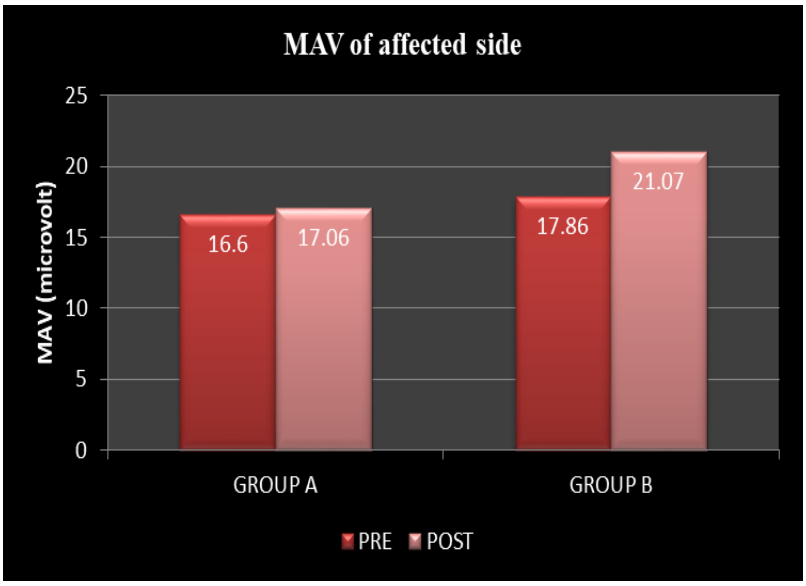
Table 4 Between group comparison for the mean difference of Affected side hip abductor muscles strength using HHD (Mann-Whitney U –test)

Outcome	Group A Mean±SD	Group B Mean±SD	U Value	p value Interpretation	Cohen's d Interpretation
Strength of hip abductor muscle	0.94±0.55	2.47±0.87	23	0.001 **SIGNIFICANT**	2.12 **Large Effect size**

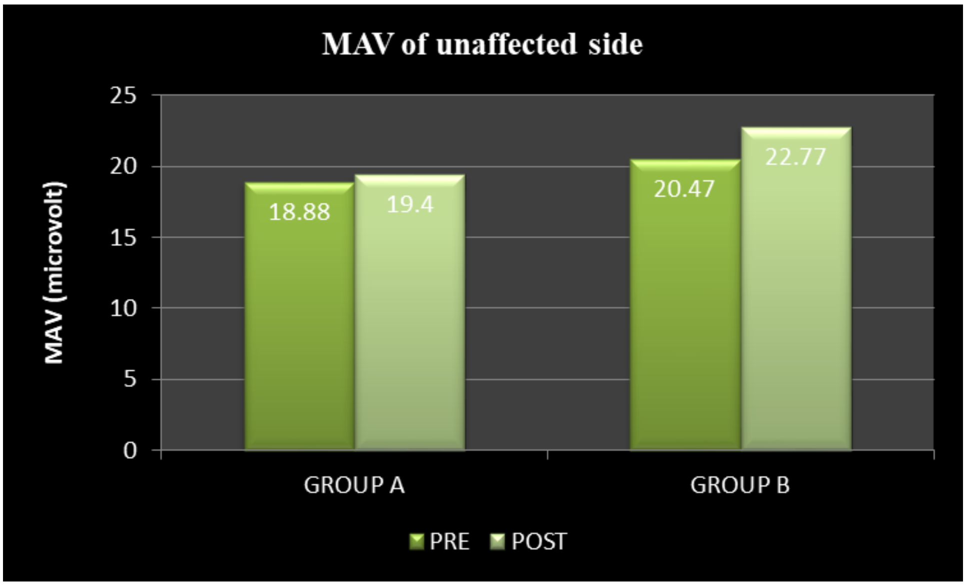
Table 5 between group comparisons for the mean difference of unaffected side hip abductor muscles strength using HHD (Mann-Whitney U –test)

Outcome	Group A Mean±SD	Group B Mean±SD	U value	p value Interpretation	Cohen's d Interpretation
Strength of hip abductor muscle	0.76±0.56	1.64±0.70	52	0.001 **SIGNIFICANT**	1.39 **Large effect size**

COMPARISION FOR MAV OF GLUTEUS MEDIUS MUSCLES



Graph 3 within group comparison of affected side MAV of Gluteus medius muscle



Graph 4 within group comparison of unaffected side MAV of Gluteus medius muscle

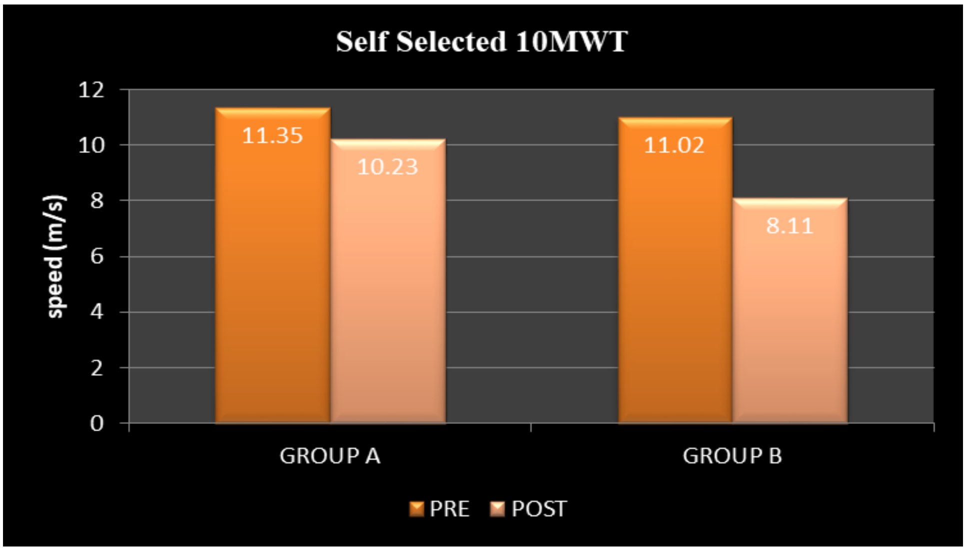
Table 6 between group comparisons for the mean difference of Affected side MAV of Gluteus Medius muscles (Mann-Whitney U –test)

Outcome	Group A Mean±SD	Group B Mean±SD	U Value	P value Interpretation	Cohen's d Interpretation
MAV of gluteus medius muscle	0.56±0.36	3.21±0.88	4.97	0.001 **SIGNIFICANT**	2.21 **Large effect size**

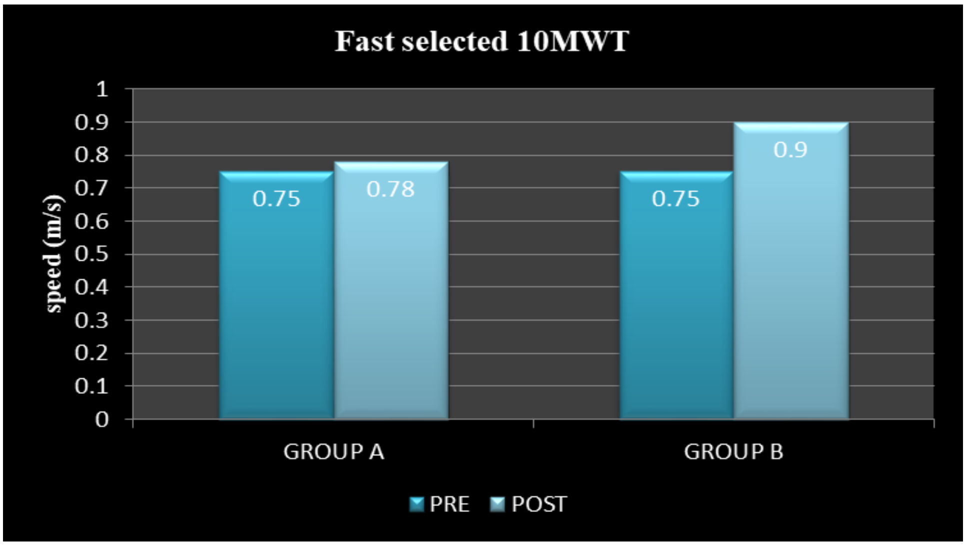
Table 7 Between group comparison for the mean difference of unaffected side MAV of Gluteus medius muscles (Mann-Whitney U –test)

Outcome	Group A Mean±SD	Group B Mean±SD	U value	P value Interpretation	Cohen's d Interpretation
MAV of gluteus medius muscle	0.51±0.44	2.29±0.85	6.50	0.001 **SIGNIFICANT**	2.65 **Large effect size**

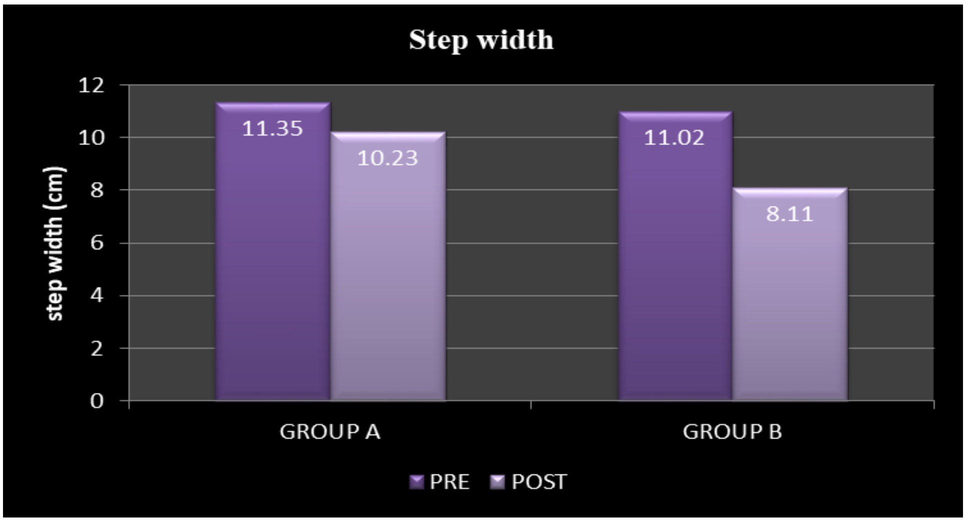
COMPARISON FOR 10MWT, STEP WIDTH AND CADENCE



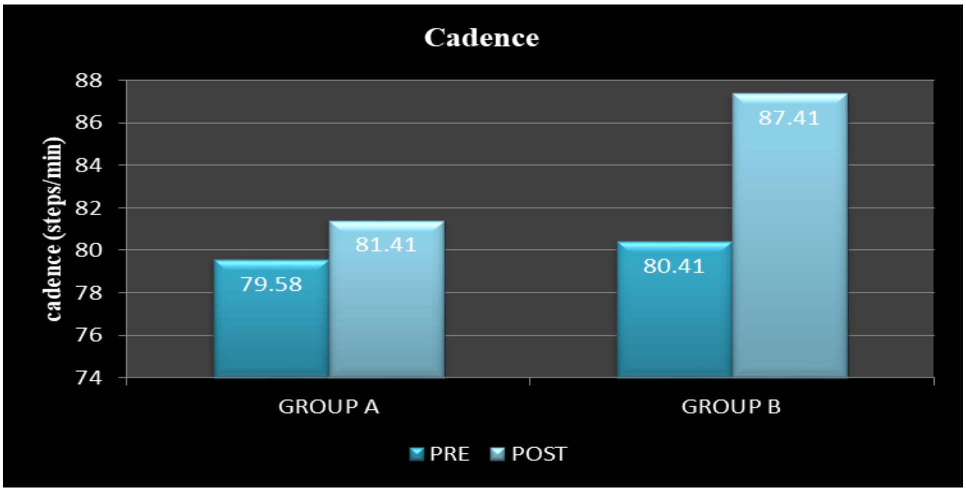
Graph 5 within group comparison of Self Selected 10MWT



Graph 6 within group comparison of Fast Selected 10MWT



Graph 7 within group comparison of Step Width

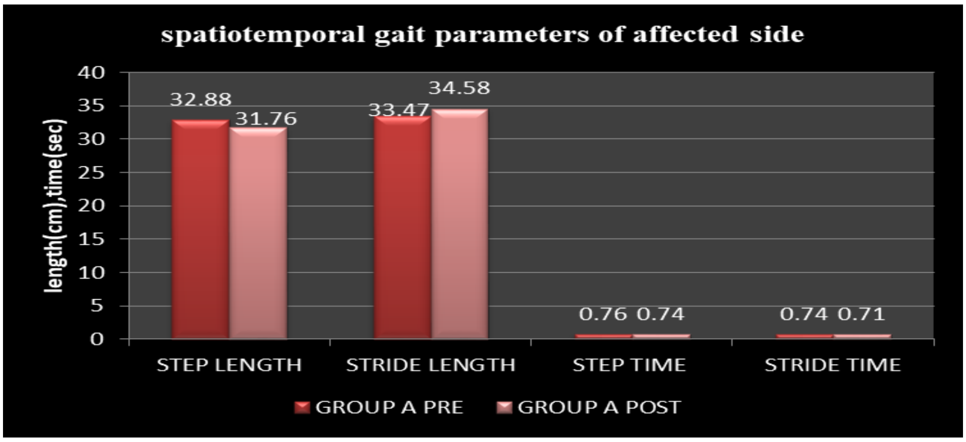


Graph 8 within group comparison of Cadence

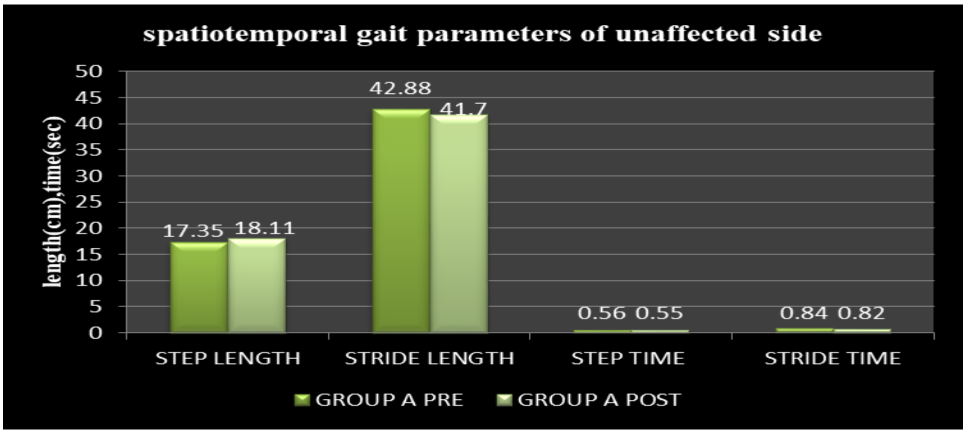
Table 8 between group comparison of 10MWT, Step width and Cadence:

Outcome	Group A	Group B	U value	p value Interpretation	Cohen's d Interpretation
10MWT (self-selected velocity	0.031±0.026	0.14±0.06	8.50	0.001 **SIGNIFICANT**	2.72 **Large Effect size**
10MWT(fast selected velocity)	0.028±0.013	0.15±0.08	11.02	0.001 **SIGNIFICANT**	2.44 **Large Effect size**
Step width	1.11±0.78	2.88±0.78	18.50	0.001 **SIGNIFICANT**	2.45 **Large Effect**

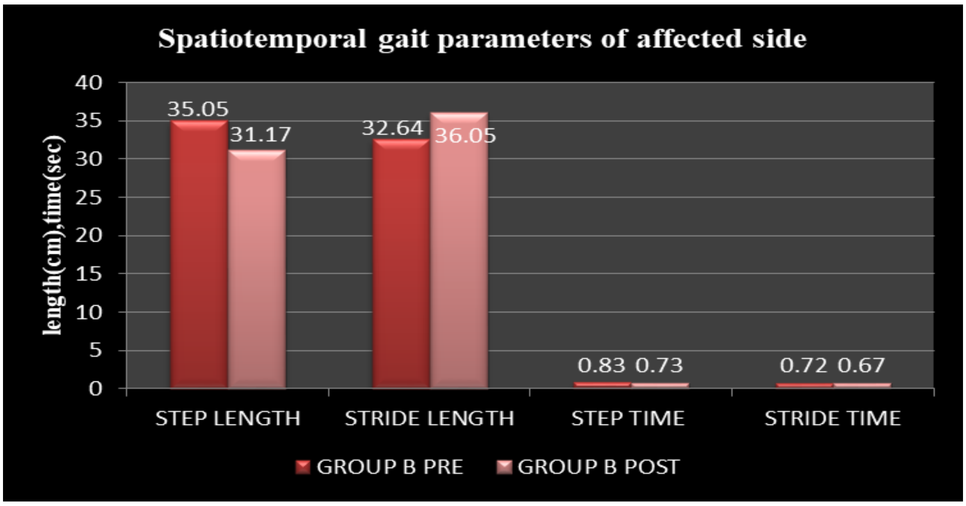
COMPARISON FOR SPATIOTEMPORAL GAIT PARAMETERS:



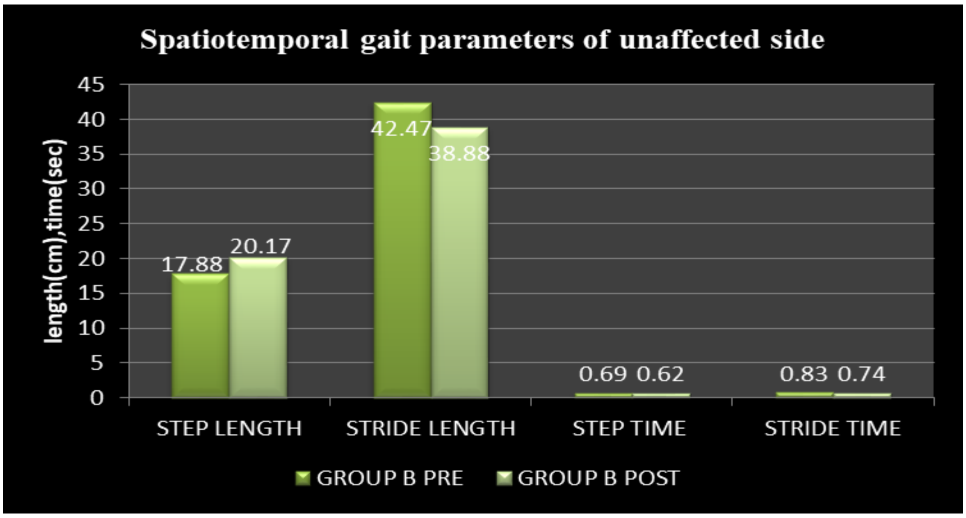
Graph 9 within group comparison for Group A affected Side spatiotemporal gait parameters



Graph 10 within the group comparison for Group A unaffected Side spatiotemporal gait parameters



Graph 11 within the group comparison for Group B affected Side spatiotemporal gait parameters



Graph 12 within the group comparison for Group B unaffected Side spatiotemporal gait parameters

Table 9 between group comparisons of mean difference of affected side spatiotemporal gait parameters (Mann-whitney U test)

Outcomes	Group A Mean± SD	Group B Mean± SD	U value	p value Interpretation	Cohen's d Interpretation
Step length	1.11±1.26	3.88± 1.11	15.50	0.001 **SIGNIFICANT**	2.34 **Large Effect size**
Stride length	1.11± 0.85	3.41± 1.32	22.50	0.001 **SIGNIFICANT**	1.86 **Large effect size**
Step time	0.011± 0.06	0.10± 0.07	68.04	0.001 **SIGNIFICANT**	1.39 **Large effect size**
Stride time	0.03 ±0.02	0.61± 0.11	56.87	0.001 **SIGNIFICANT**	1.91 **Large Effect size**

Table 10 between group comparisons of Mean difference of unaffected side spatiotemporal gait parameters (mann-whitney U test)

Outcomes	Group A Mean±SD	Group B Mean±SD	U value	p value Interpretation	Cohen's d Interpretation
Step length	0.76±0.83	2.29±0.77	24	0.001 **SIGNIFICANT**	1.91 **Large effect size**
Stride length	1.17±0.88	1.84±1.00	13	0.001 **SIGNIFICANT**	0.71 **Large effect size**
Step time	0.01±0.02	0.06±0.04	25.50	0.001 **SIGNIFICANT**	1.78 **Large effect size**
Stride time	0.01±0.007	0.09±0.05	3.50	0.001 **SIGNIFICANT**	1.81 **Large effect size**

DISCUSSION

Subjects were evaluated for their lower extremity function in term of strength of hip abductor muscle using hand held dynamometer (HHD) and surface electromyography (sEMG). Gait speed and spatiotemporal gait parameters using 10MWT and sensor shoes along with foot prints, All the outcome measures were taken before and at the end of 20 sessions of intervention. The groups were found to be similar in all aspects which suggest that the difference in the outcome measures in both groups was solely due to the intervention given to the particular group. The results of the present study showed that there is a statistically significant improvement in strength of gluteus medius muscle, spatiotemporal gait parameters and walking speed in subjects with post stroke hemiparesis for both the groups ($p<0.05$) as compared to the baseline. Level ground side walking training with conventional therapy in interventional group was superior in terms of improving strength, gait and speed. Effect size for between the group analysis was large suggestive of level ground side walking to be clinically more significant for gluteus medius muscle activation. The present study showed there was statistically significant improvement seen in gluteus medius muscle activation in form of strength in interventional group possible reason for that the hip abductor muscles play an important biomechanical role in humans and are an essential pivotal point in the mobilization of body weight[34].Sidewalk training might have improved the strength of gluteus medius (hip abductors). These muscles are the primary hip stabilizers and the improved strength might have contributed for improved stability at the hip. Side walking exercise effectively improves walking abilities and reduces asymmetrical weight bearing on the lower limbs, because it emphasizes side stability more and encourages more dynamic weight shifts to the affected side in the coronal plane[35].The primary finding of this study revealed significantly greater gluteus medius muscle activation in the level ground side walking training. Present results are supported by Neumann et al with regard to frontal plane stability of the pelvis during walking. With respect to the gluteus medius muscle, results from the present study and those from previous investigators also reported side walking exercises produced levels of gluteus medius muscle activation that exceeded 50% then forward walking[36].In present study there was statistically improvement in spatiotemporal gait parameters and walking speed in side walking training of between and within group ($p<0.05$) This can be possibly because of gluteus medius muscle activation during side walking[37]. A greater number of subjects receiving lateral walking training had enhanced walking ability, with an increased stride length, decreased step length on affected side. These results suggest that the use of Lateral Walking Training could produce more positive effects than Forward Walking Training on the improvement of gait performance in individuals with hemiplegic stroke[38].The gait velocity increment has important functional implications. Fast walking velocity has traditionally been attributed to increased joint movement amplitudes and step lengths, as well as to the ability to produce selective movement in the joints. Previous studies regarding hemiplegic gait identified characteristic improved walking velocity, reduced swing phase, and increased stride length[39].The results of cadence in the study done by Falconer JA et al indicate no significant differences in Lateral Walking Training Group. This may be due to the fact that cadence is often regarded as a compensatory mechanism for reduced stride length[40].Possible reason for increase cadence in present study is improved muscles strength helps to improve walking speed and reduce gait asymmetry after intervention. Results of the present study shows that within and between group analysis of control group suggests a statistically significant improvement in strength of hip abductor muscles ($p<0.05$)

walking speed ($p<0.05$), spatiotemporal gait parameters ($p<0.05$). In present study statistically significant improvement was seen in hip abductors ($p<0.005$) for affected as well as non affected lower limb in between and within group of conventional with forward walking training. Possible reason for that side lying abduction was consistent with strengthen gluteus medius as its anatomical role as a primary hip abductor[41].The possible cause for increase in muscle strength was improvement in motor unit recruitment, motor learning and cortical reorganization. The improvement in motor learning occurs through development of neuromotor pattern coordination between agonist and antagonist muscles through practice of a skill[42] and that of cortical reorganization occur through repetitive practice of meaningful task with verbal cuing. Nelles G et al[43] in one of his study on stroke subjects found evidence of cortical reorganization in bilateral motor system and Jang S et al[44] has also witnessed an increase in primary motor cortex activities by resistance training. The evidence of cortical reorganization and neuroplasticity can be seen in different cortical regions post stroke. In the present study there was statistically significant improvement seen in walking speed and spatiotemporal gait parameters in control group which is supported by Janaine C et al (2013) they found 0.14 m/s faster walking and 40 m greater distance in their conventional with forward walking group than no intervention/non-walking intervention immediately after intervention and these benefits were maintained beyond the intervention period. The probable reason for the same could be facilitated practice of more normal walking pattern using mechanical assistance which would be forcing appropriate timing between lower limbs and promotes hip extension during the stance phase of walking and discourages common compensatory behaviors such as circumduction[45].It also thought that walking speed has increased, because the patients muscle activities were increased by the movements of their affected side lower extremity, and their mental states or self confidence in walking improved as a repeated walking training in stable walking environment[46].The outcomes of the strength, gait velocity, stride length, step length, step width and cadence were found to be more favorable in the lateral walking training group than in the other group. These gait outcome variables are critical factors that influence a patient’s chances of returning to premorbid environments.[47] The typical hemiplegic gait is characterized by asymmetry of timing in the single-limb support phase of the affected and unaffected legs. In the lateral walking training group significant pre-test to post-test differences were also found in form of reduce circumduction, whereas the other groups showed no significant differences.[48] It can be interpreted that lateral walking training appears to create greater muscle activity in proportion to effort, demanding better functional gait performance than forward walking training. Improvements in strength provide an important clinical factor for recovery. It is also thought that this may be explained by active participation of the hip adductors and abductors during side walking training, which is particularly useful for patients who have hemiplegia with synergy influence in the lower extremities.

CONCLUSION

Based on the results of present study, it can be concluded that level ground side walking is effective in improving strength of hip abductors, spatiotemporal gait parameters and walking speed in post stroke chronic hemiparesis. Level ground side walking training can be an adjunct to conventional exercise program. Limitation of this study is long term post intervention effects were not evaluated.

Declaration by Authors

Ethical Approval: Approved

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Conflict of Interest: The authors declare no conflict of interest.

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