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ANGULAR KINEMATICS OF HEMIPLEGIC GAIT-A COMPARISON BASED ON LATERALIZATION

Dr. Vipin Kumar K	Physiatrist.
Dr Sreejith K	Professor, Physical Medicine and Rehabilitation, Government Medical College, Kottayam
Dr Muralidharan PC*	Associate Professor, Physical Medicine and Rehabilitation, Government Medical College Kozhikode *Corresponding Author

ABSTRACT

Background: A major chunk of stroke survivors show abnormal gait patterns. Independence in mobility is a key factor influencing rehabilitation and quality of life. Gait deviations associated with stroke are due to residual weakness and differential tone of muscles affecting various phases of gait. Spatiotemporal and Kinematic parameters of hemiplegic gait have been widely analyzed in various settings. However such studies are scarce in Kerala. Majority of existing studies focused on temporal parameters. Our aim was to carry out a comparative analysis of angular kinematics of affected hip, knee and ankle in stroke survivors during gait cycle based on side of involvement, using Instrumental Gait Analysis (IGA) system. **Methods:** The present observational study was conducted in the Gait Laboratory of Department of Physical Medicine and rehabilitation, Medical College Kottayam. 100 subjects were selected as per the inclusion criteria. Gait analysis was carried out using iSen3.08 system and STT-IWS sensors and kinematic data was collected. Descriptive statistical analysis was performed to find out the mean and standard deviation for the quantitative data. Qualitative data was expressed as frequency and percentage. **Results:** In our study, out of 100 subjects, 58 had right hemiplegia while 42 had left hemiplegia. The mean age was not statistically significant between the groups. Stroke survivors showed variations in the gait pattern with involvement of hip, knee and ankle kinematics. In the comparison of gait analysis parameters, the ankle in the preswing phase showed -11.86 on the left side and -16.09 on the right. In the mid swing phase of gait the values were -3.18 and-6.42 respectively. These values were statistically significant. None of the other variables in our study were found statistically significant. **Conclusion:** Right hemiplegics showed more severe involvement with statistically significant involvement of the ankle joint in the pre swing and mid swing phases of the gait when compared to left hemiplegics.

KEYWORDS : Stroke, angular kinematics, lateralization

INTRODUCTION

Stroke, a leading cause of disability[1], constitutes a global health issue with increasing incidence in the low and middle income countries including India[2,3]. Though the Western countries report a decrease in the incidence of stroke, the incidence is high in India[4]. India reports an incidence of 135-145 strokes per one lakh each year with 500000 people living with stroke related disability[3]. Of this 10-15% are young stroke and this proportion is found to be 9.5% in Kerala[5]. Stroke has a significant impact on the lives of the survivors affecting their physical, mental, social and vocational domains[6,7]. It leaves behind residual effects in many survivors who suffer some form of long term disability and report a decline in their quality of life[8]. Of the stroke survivors, 55-70% becomes fully independent in one year while about 7-15% remains completely dependent[9].

Mobility and gait influence the functional outcome and quality of life. 80% of stroke survivors show some form of gait impairment and walking dysfunction[10]. Though walking ability returns in about 52 to 85% of hemiplegic patients, their gait pattern shows significant deviation from normal healthy subjects.[11] The gait pattern in such subjects show variations in the spatio temporal and kinematic characteristics[12]. Abnormalities in gait can lead to increased risk of fall[13], dependence and reduced quality of life[14]. Goal of gait rehabilitation is restoration of the ability to walk[15].

The excursions of the hip, knee and ankle show variations depending on the physical and kinetic factors. Post stroke hemiplegic patients show significant changes in the kinematic variables[11]. In the hip there may be alterations in the flexion – extension angles, characterized by a reduced hip flexion at heel strike and decreased hip extension at toe off. This has an impact on the initiation of gait. There is increased knee flexion at initial contact and reduced knee flexion at toe off and during swing. In some patients, there may be reduced flexion in the early stance, followed by knee hyperextension in late stance and delayed movement into flexion before swing. The ankle remains in plantar flexion leading to initial contact being foot flat or foot slap instead of heel strike and also in swing. Decreased plantar flexion is noted at toe off. Further, the ankle exhibits irregular dorsiflexion in mid stance and push off.

One of the most common goals of stroke rehabilitation is the regaining independent walking ability with about 85% of stroke survivors achieving the goal[16]. Rehabilitation in stroke is achieved through meaningful, task specific trainings of sufficient intensity and repetitions in an enriched environment facilitating neuroplasticity which in turn compensates for the functional loss. Maladaptive plasticity associated with compensatory mechanisms should also be reckoned while devising rehabilitation strategies[17].

Task specific gait training, robotics, FES, virtual reality, mental practice and motor imagery, neurolysis, botulinum toxins, brain computer interface training, assistive devices and locomotor aids form the components of rehabilitation strategies, besides conventional physiotherapy[18]. The kinematic and spatio temporal analysis throw light on the individual treatment requirements. The application of Artificial Intelligence and Expert systems[19] provide advanced evaluation techniques which could help to identify these variations early. Because of the wide variations in temporal and kinematic parameters, a single or common reeducation program is rendered unsuitable for all stroke survivors. This inadequacy of a single reeducation plan for all patients necessitates the identification of unique deficiencies and development of personalized treatment strategies for each patient[20,21]. Subtle changes can also be identified which help to monitor the timing of treatment as well as evaluation of its efficacy.

Lateralization influences gait in stroke survivors[22]. Gait dysfunction and recovery differ with respect to the hemisphere involved[23]. Inter lateral asymmetry between the two hemispheres may be responsible for the differences observed. There is left hemisphere dominance for motor functions and right for spatial orientation. Therefore left sided lesions (right hemiplegics) predominantly cause motor and voluntary dysfunctions. Right-handedness add on to the functional compromise in right hemiplegics. Right hemispherical lesions cause predominant loss of spatial attributes and postural functions. It causes alterations in vertical orientation of the body, stance control, sway and shifting of body weight between the limbs. Lesions of the left hemisphere reduce the dynamic capacity of walking while right hemispheric lesions affect the segmentary motor control [24]. Left sided lesions are reported to have greater impact on the quality of movement. Functional ambulatory potential is higher for left hemiplegics[24]. The pattern of recovery of gait may also differ depending on the paralytic and unaffected sides The recovery of gait is reportedly faster in left hemiplegics since it develops a compensatory and protective strategy shifting the centre of gravity to right limb[21].

The various gait deviations are reflected in the spatiotemporal and kinematic parameters studied through gait analysis. The temporal factors associated with hemiplegic gait are widely evaluated[20] .There is paucity of studies using kinematic variables, especially among Kerala population. Our study was to perform a comparative analysis of the effect of lateralization in brain on the angular kinematics of the hip, knee and ankle in hemiplegic gait. The evaluation of angular kinematics may help in the early identification of the deviations involving the individual joints and help to design the best personalized rehabilitative program and interventional techniques suitable for individual patients.

MATERIAL AND METHODS

This was a descriptive observational study conducted in the gait laboratory, Department of Physical Medicine and Rehabilitation, Government Medical College, Kottayam from March 2019 to March 2020 among the stroke patients attending the out patient clinic. Based on a previous study (Boudarham J) [11] on the kinematic parameters of gait in hemiplegic patients, a sample size of 100 was calculated. The standard deviation of stride length was taken from the study for sample size calculation.

$$n = \frac{4 \times SD^2}{d^2}$$

n= sample size, SD= standard deviation, d= precision = 20% x SD

$SD=0.20$

$SD^2= 0.20\times0.20=0.04$

$4SD^2=4 \times0.04= 0.16$

$d= 20\%\times SD= 20\%\times 0.2= 0.04$

$d^2= 0.0016$

$n=4SD^2/d^2= 0.16\div0.0016 = 100$

The inclusion criteria were (1) persons with a 'first stroke' with unilateral hemiplegia, unilateral hemispheric lesions confirmed by computed tomography (CT) or magnetic resonance imaging (MRI), (2) age between 45-65 years, (3) hemiplegia of 1-12 months duration, (4) ability to walk at least 10 meters without any help or assistive devices, (5) understanding verbal commands and cooperative patients and (6) no other diagnosed diseases known to affect walking performances.

Subjects with (1) previous history of severe diseases of heart, lung, liver, kidney etc and concomitant neurological diseases, (2) stroke due to traumatic brain injury and tumor, (3) impaired comprehension, aphasia and cognitive disorders and (4) non-cooperative patient/ caregiver were excluded.

Ethical clearance from Institutional Review Board was obtained. Informed consent was obtained in the prescribed format from patients. Confidentiality and anonymity of the patients' information were maintained during and after the study. The data collected from each patient were recorded in pre prepared proforma. Gait analysis was done during one gait cycle using sensors laced on thighs, legs, feet and mid pelvis .The movements of the joints were captured by the sensors and the virtual image recorded in the computer. The joint excursions in the sagital plane were analyzed during the different phases of gait cycle.

Data analysis was performed by SPSS (version 17) for windows. Alpha value was set as 0.05. Descriptive statistics was performed to find out mean, standard deviation for the demographic variable and outcome variables. Unpaired t test was used to find out difference in scores between groups for gender wise comparison, Unpaired t test was used to compare the age difference between above mentioned groups. Microsoft excel, word was used to generate graph and tables.

RESULTS

Our study included an analysis of excursions of hip, knee and ankle during the stance and swing phases of the gait of hemiplegic patients and comparison based on the side of involvement.

58% of the subjects in the study group had right hemiplegia while 42% had left sided involvement. Their age varied between 46 years and 65 years in both groups. The mean age group in the left hemiplegia was 57 years while that of right was 58 years. Of these, 26 males had left hemiplegia and 16 females had left hemiplegia.

Table I: Kinematic variables based on the side of hemiplegia

Sl.No	Variable		Left	Right	P-value
1	Number		42	58	
2	Age		56.45±6.13	57.02±5.92	>0.644
3	Initial Contact	Hip	11.01±7.03	11.41±7.22	>0.781
		Knee	2.56±4.51	2.48±4.59	>0.926
		Ankle	-3.89±5.91	-4.60±5.10	>0.524
4	Loading Response	Hip	5.72±4.83	4.09±5.64	>0.133
		Knee	1.65±6.74	2.13±6.03	>0.706
		Ankle	-4.10±4.22	-5.28±4.28	>0.174
5	Mid Stance	Hip	-0.78±4.30	-0.02±4.86	>0.420
		Knee	-1.91±4.67	-0.56±4.38	>0.144
		Ankle	0.34±3.02	0.19±3.86	>0.828
6	Terminal Stance	Hip	-11.61±7.80	-12.12±5.68	>0.706
		Knee	10.50±7.38	10.03±6.75	>0.743
		Ankle	-5.53±4.82	-5.84±3.81	>0.723
7	Pre Swing	Hip	-4.92±5.56	-5.70±9.41	>0.635
		Knee	20.64±7.83	21.77±7.16	>0.452
		Ankle	-11.83±9.18	-16.09±5.54	<0.005
8	Mid Swing	Hip	9.85±8.36	10.63±8.93	>0.658
		Knee	18.69±12.59	21.75±14.67	>0.278
		Ankle	-3.18±5.19	-6.42±7.20	<0.014

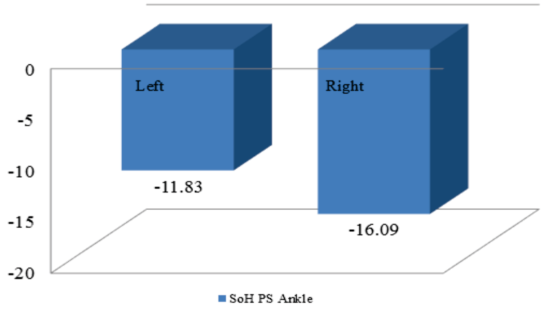
The hip oscillated in a narrow range in the entire gait cycle, with the maximum hip flexion being +32 degrees. In our study, there was reduction in the hip flexion at initial contact and reduced extension in the swing. Knee flexion was reduced in early stance and swing phases. The ankle plantar flexion was reduced in the terminal stance and the ankle remained in plantar flexion in the entire swing phase. The hip moved into flexion of 11.01 (SD 7.03) in left hemiplegics while it moved through 11.41(SD 7.22) in right hemiplegics. In the rest of the stance phase, the hip moved into extension till it reached -11.61 (SD 7.80 in left hemiplegics and -12.12 (SD 5.68) in right hemiplegics.

Knee in stance phase moved from2.56 (SD4.51) in left hemiplegics and 2.48(SD4.59) in right hemiplegics to 10.5 (SD

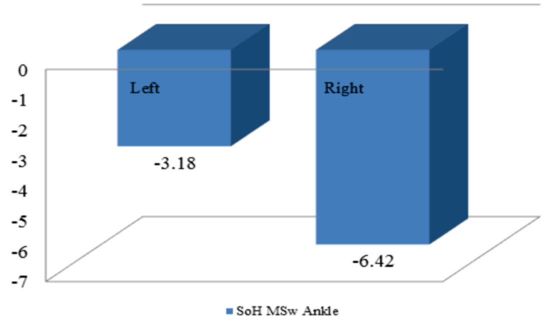
7.38) and 10.03 (SD6.75) . Knee went into extension -1.95 (SD 4.67) in left hemiplegics and -0.56 (SD 4.38) in the right. There was more limitation of movement in the hip and knee in left hemiplegics though none of these values were statistically significant.

The ankle was in plantar flexion – 3.89 (SD 5.98) in left hemiplegics and -4.62 (SD4.10) in right during initial contact. It reached a dorsiflexion of 0.34 (SD 3.02) and 0.19 (SD 3.86) in mid stance. In the terminal stance, the ankle went into plantar flexion again. The variations observed in the stance phase were not statistically significant.

In the gait analysis comparison, only Pre swing Ankle and Mid swing ankle were statistically significant. Pre swing ankle was - 11.86 in left hemiplegics whereas it was -16.09 in the right hemiplegics. The midswing ankle values were -3.18 in left hemiplegics and -6.42 for right hemiplegics. These indicated that ankle showed reduced dorsiflexion and increased plantarflexion with more involvement in right hemiplegics.



Graph I:



Graph II:

DISCUSSION

In our study, hemiplegic patients showed multiple variations in the pattern of their gait. There was reduced hip extension in stance, reduced hip flexion in mid swing, reduced flexion of hip and knee and reduced dorsiflexion of the ankle in the swing phase. Our observations were in line with the studies reported in literature[25, 26, 27]. Motor weakness and spasticity are the major determinants of gait impairment in post stroke patients[28]. The variations in gait pattern could be due to weakness of the hip extensors, hip flexor tightness, hip flexor spasticity contributing to reduced extension while in stance and reduced power of rectus femoris and iliopsoas contributing to reduced hip flexion in swing phase. Knee showed reduced flexion during loading response and in some subjects, went into hyperextension. Late stance had reduced knee flexion which was attributed to spasticity in quadriceps, weak hamstrings, reduction in hip flexion and ankle dorsiflexion.

Compartmentalized differences in function and gait pattern have been reported between the two hemispheres[22]. In our study some of the variables showed differences based on the side of lesion. Analysis of gait among our subjects showed statistically significant variation in the involvement of the ankle joint in the pre swing and mid swing phases of the gait, with right hemiplegics more affected than the left hemiplegics. There was no statistically significant variation in the kinematics of hip and knee between the two groups.

The ankle joint in right hemiplegics remained in greater plantar flexion and showed reduced dorsi flexion in the pre swing and mid swing phases. During initial contact, the ankle went into plantar flexion, more on the right side and this is likely to produce more toe or fore foot strike or lateral foot contact. The foot position in swing is a result of coordinated activity of muscles of lower limbs directly and trunk and upper limbs indirectly. The increased weakness of tibialis anterior and other dorsi flexors and spasticity or contracture of gastro soleus can account for the increased plantar flexion. There is reduction in knee flexion in pre swing which effectively reduces the dorsiflexion of the ankle at mid stance as in literature[26]. The reduction in knee flexion could be due to spasticity in rectus femoris. The right hemiplegics have more motor defects. They have more weakness and those activities which require planning and coordination are more affected. This could be due to more severe involvement of left hemisphere in controlling the movement dynamics and motor control, as reported in literature[23,24.] The residual muscle weakness, spasticity, synergistic patterns, cognitive functions and their interactive coupling account for the high prevalence of these gait deviations[29].

Priscila Garcia Lopes et al[30], in their study reported no significant differences in performance of gait and balance between the two sides involved but their focus was more on posture. In the studies by Ween et al[31] and Ekusheva et al [32], the left hemiplegics showed more significant involvement.

In contrast, Hedna et al[33] found that right hemiplegics with left hemispheric ischemic stroke to be more severe and with worse outcome than their counterparts. Shabbir M et al[24] and Voos MC[34] et al also reported more significant involvement in the right hemiplegics. Our study was found to be in agreement with these studies. These observations could be due to greater contribution of left hemisphere to motor control. More compromise may be noted in right dominant persons. The left hemiplegics have more deficits in attention and contra lateral perception. Processing of sensorimotor information and maintenance of postural stability are affected in them. Therefore it affects the quality of ambulation[24]. There may be greater contribution of right hemisphere to spatial orientation and posture and spatial attention may be more compromised. These patients may have better segmentary control. Vismara et al[24], in their studies reported right hemiplegics to have worse spatiotemporal parameters, but better kinematic parameters Our study did not elucidate the temporal parameters, but focused on the angular kinematics of the lower limb.

Knee hyperextension is a common deviation in stroke .This occurs because of the inability to activate the knee extensors or due to ineffective hip and ankle mechanisms. However, in our study no significant differences in knee extension were noted. Since knee extensor strength is reported to be responsible for stability of gait and forms a key factor in rehabilitation process[35], any subtle variations can also be considered relevant in rehabilitation. More dissimilarity was observed in right hemiplegics in the first month and the asymmetry reduces with chronicity[36]. Our subjects ranged from 1-12 months and this could also influence the gait pattern.

Gait is often considered as a factor of high quality as far as independence in activities of daily living (ADL) is concerned and hence given a high priority in rehabilitation[23]. The kinematic variations observed in the respective joints suggest that the right hemiplegics have more involvement as regards the motor power, spasticity and joint position in space.

Interventions like conventional physiotherapy, oral medications to improve spasticity and use of appropriate orthotic devices instituted early can minimize the impairments and improve function. Further application of newer gadgets like robot assisted training, virtual reality, botulinum toxins neurolytic agents and biofeedback technique evaluation instituted at appropriate time help in reduction of asymmetry in gait and improve walking ability. The evaluation of the kinematic variables, along with temporal variables provide an insight into the authenticity and efficiency of the individualized and specific treatment strategies designed to improve the gait pattern in stroke survivors.

CONCLUSION

This study confirms that the gait pattern in right hemiplegics are more significantly affected when compared with left hemiplegics. The main differences are observed in the preswing and mid swing phases of gait cycle in the ankle joint.

Limitations

There was no control group in our study and it was only a descriptive one. The temporo spatial and kinetic analysis were not carried out. The study was a limited one, confined to a particular point of time. The sample was randomly selected and the implications of age and gender were not considered.

Future scope: The analysis of kinematic variables in gait rehabilitation can help in initiating an individualized energy effective gait training programme and also in monitoring the efficacy of various programmes. With the advent of newer technologies in gait analysis and smart approaches to rehabilitation, even the subtle changes can be made use of in designing rehabilitation strategies.

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