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Original research article

Gait Kinematics in Spastic Hemiplegic Patients - A Descriptive Study

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Abstract

Background: Stroke-related gait disability has a substantial influence on stroke survivors' quality of life. Instrumental gait analysis aids in the identification of gait abnormalities, the development of appropriate treatment methods, and the monitoring of therapeutic intervention effectiveness. The objective of the study is to determine the gait kinematics in spastic hemiplegic patients using the Instrumental Gait Analysis (IGA) system.

Methods: The present descriptive study was done in the Department of Orthopedics, Prathima Institute of Medical Sciences, Karimnagar. A sample size of 100 subjects was obtained fulfilling the inclusion criteria. Gait analysis was carried out in the gait laboratory using the iSen3.08 system and STT-IWS sensors and kinematic data collected. Descriptive statistical analysis was performed to find out the mean and standard deviation for the quantitative data and qualitative data was expressed as frequency and percentage.

Results: Peak hip extension was reduced in the late stance phase, while peak hip flexion was reduced in the swing phase. During the loading response phase, knee flexion was reduced, and knee hyperextension was observed at mid-stance. During the late stance and swing phases, knee flexion was reduced. The majority of respondents' ankles stayed in plantar flexion at first contact, and their ankle plantar flexion was reduced during terminal stance and their ankle dorsiflexion was reduced during the swing phase.

Conclusion: Hemiplegic gait analysis aids in the development of effective treatment strategies and the provision of appropriate therapies. Gait study reveals the necessity for a variety of interventional treatments such as rehabilitative exercises, medicinal management, neurolysis, orthotic aids, and surgical interventions. This improves ambulation ability and overall quality of life.

Keywords: Stroke, Hemiplegia, Gait, Kinematics, Spastic Paralysis.

Introduction

Stroke, often known as a Cerebrovascular accident, is a global health issue that is the third greatest cause of disability. [1] The stroke survivor demonstrates different grades of spasticity, muscle weakness, and gait impairment which significantly alters functional independence and reduces the quality of life. [2-4] Hemiplegic patients regain walking ability in 52 to 85 percent of cases; however, their gait differs from that of healthy people. The degree and depth of participation, responsiveness to treatment, suitable rehabilitation therapies, co-morbidities, and psychosocial factors all influence the gait pattern of such a person. Hemiplegic gait is characterized by reduced stride length, gait velocity, cadence, and increased energy consumption when compared to normal subjects. [5] Abnormal patterns in spastic hemiplegia include reduced hip flexion, reduced knee flexion, knee hyperextension during stance, and excessive ankle plantar flexion (equinus) during both the swing and stance phase of the gait. [6] Dynamic knee recurvatum is predisposed by ankle equinus. Compensatory maneuvers such as hip circumduction, hip hiking, and contralateral vaulting may be used as a result. [7-8] Gait analysis is used to identify gait problems in hemiplegic patients. In clinical practice, observational gait analysis is the most prevalent method for evaluating gait disorders. It is low-cost, but the results are qualitative and depend on the observer. Instrumental gait analysis (IGA) provides three-dimensional information of human walking and is the gold standard for gait evaluation in patients with gait abnormalities. Modern gait analysis systems also quantify Spatio-temporal, kinetic, kinematic, and electromyographic (EMG) parameters of gait. [9] Following hemiplegia, rehabilitation methods allow individuals to restore their motor capabilities and become functionally independent. Interventions to enhance gait are an important part of stroke recovery. This includes efforts to increase propulsion, prevent or decrease contractures, reduce spasticity, improve power, coordination, and balance, and prevent or minimize contractures. Conventional physiotherapy measures, robotic management, interventions using botulinum toxins or phenol, orthotic management, and surgical measures constitute the various modalities employed for the rehabilitation of a stroke patient. Gait analysis aids physicians in identifying gait impairments and compensatory methods used by hemiplegic patients, which, when paired with a neurologic evaluation, aids in identifying the reasons for deviations and assisting them in designing the optimal gait training program for their patients. This also opens several therapeutic options for improving gait characteristics. A laboratory gait assessment can objectively measure a patient's response to a particular intervention. Even though gait analysis is an important rehabilitation component and research is undertaken, kinematics and kinetics literature are scarce in our state. The present study attempts to provide an early understanding of the angular excursions of the hip, knee, and ankle in post hemiplegic gait which enables in designing rehabilitation interventions.

Material and Methods

This was a descriptive study carried out Department of Orthopedics, Prathima Institute of Medical Sciences, Karimnagar from March 2019 to March 2020. Institutional Ethical approval was obtained for the study. 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 patients who reported to the outpatient clinic were recruited for the study as per the inclusion criteria.

Inclusion criteria

1. Patients with a 'first stroke' with unilateral hemiplegia
2. unilateral hemispheric lesions confirmed by computed tomography (CT) or magnetic resonance imaging (MRI)
3. Aged 45-65 years
4. Male and Females
5. hemiplegia lasting 1-12 months
6. ability to walk at least 10 meters without assistance or assistive devices
7. ability to understand verbal commands and cooperate with the experimental procedures
8. No other diagnosed diseases known to affect walking performance were included

Exclusion criteria

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

The sample size of 100 was obtained based on the observations of Bourdarham et al., [21] in the kinematic parameters of gait in hemiplegic patients. 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

$SD=0.20$

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

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

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

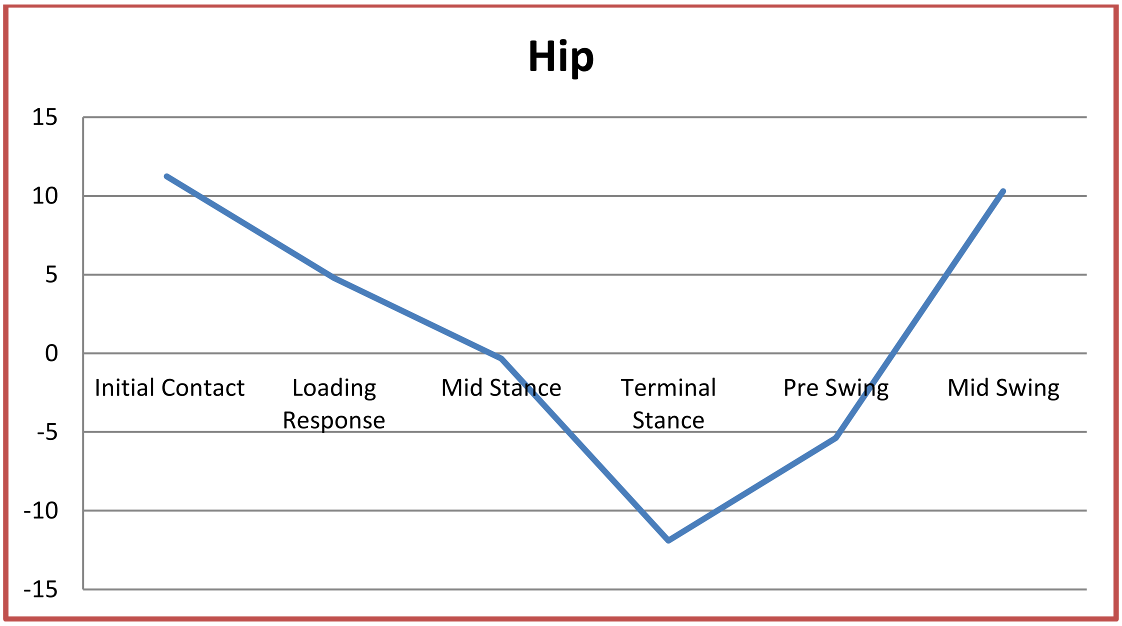
$d^2= 0.0016$

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

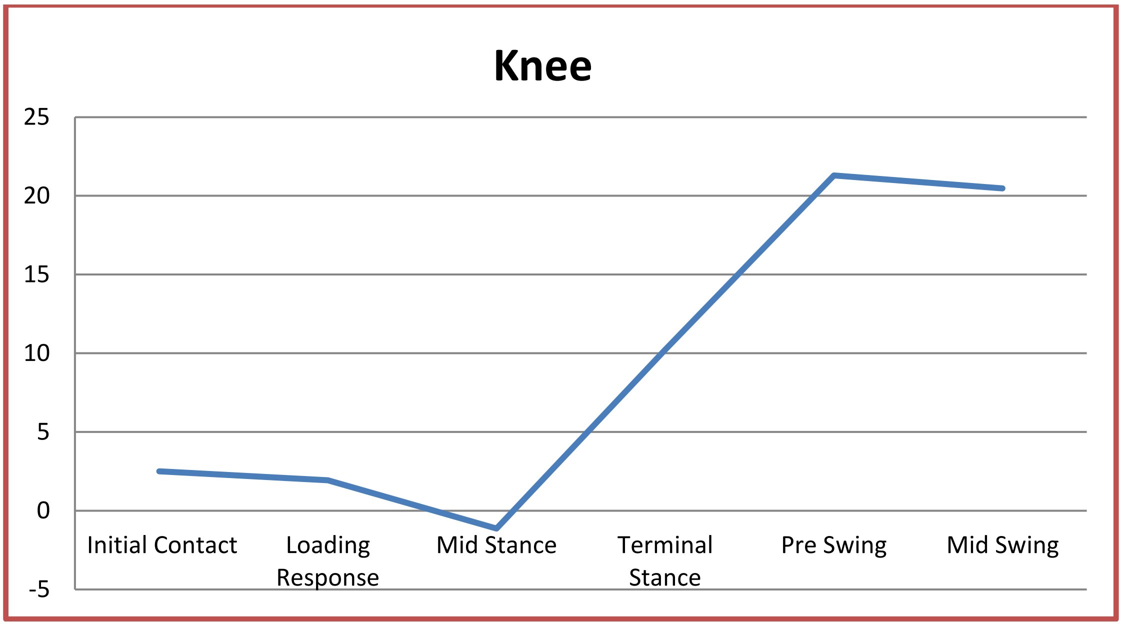
Patients with a 'first stroke' with unilateral hemiplegia, unilateral hemispheric lesions confirmed by computed tomography (CT) or magnetic resonance imaging (MRI), aged 45-65 years, hemiplegia lasting 1-12 months, ability to walk at least 10 meters without assistance or assistive devices, ability to understand verbal commands and cooperate with the experimental procedures, and no other diagnosed diseases known to affect walking performance were included. We excluded subjects with a previous history of severe diseases of heart, lung, liver, kidney, etc., patients with concomitant neurological diseases, stroke due to traumatic brain injury and tumor, patients with impaired comprehension, aphasia, and cognitive disorders, and non-cooperative patient/ caregiver. Data was collected from each patient and recorded in a pre-prepared proforma. The kinematic data of hemiplegic patients were recorded by a motion capture system and multiple sensors. STT-IWS inertial sensors were used in an iSen system to track the movement of individual body segments and to transfer real-time data to the software. The sensors were placed on thighs, legs, and feet and one at the mid pelvis. The subjects were required to walk barefoot at their natural velocity. The distance covered in one direction is 5 meters. The joint movements were captured by the sensors and the virtual image of joint motion was recorded in the computer using the iSen 3.08 application. For the evaluation, one gait cycle was used. That is, from the sick limb's first contact to the next limb's first contact. During each step of the gait cycle, the sagittal plane joint excursions (hip flexion and extension, knee flexion and extension, and ankle dorsiflexion and plantarflexion) were examined. *Statistical Analysis:* Data was summarized in an excel sheet. Descriptive statistics were performed to find out the mean and standard deviation for demographic and outcome variables. Quantitative data are expressed in mean and standard deviation and qualitative data in frequency and percentage.

Results

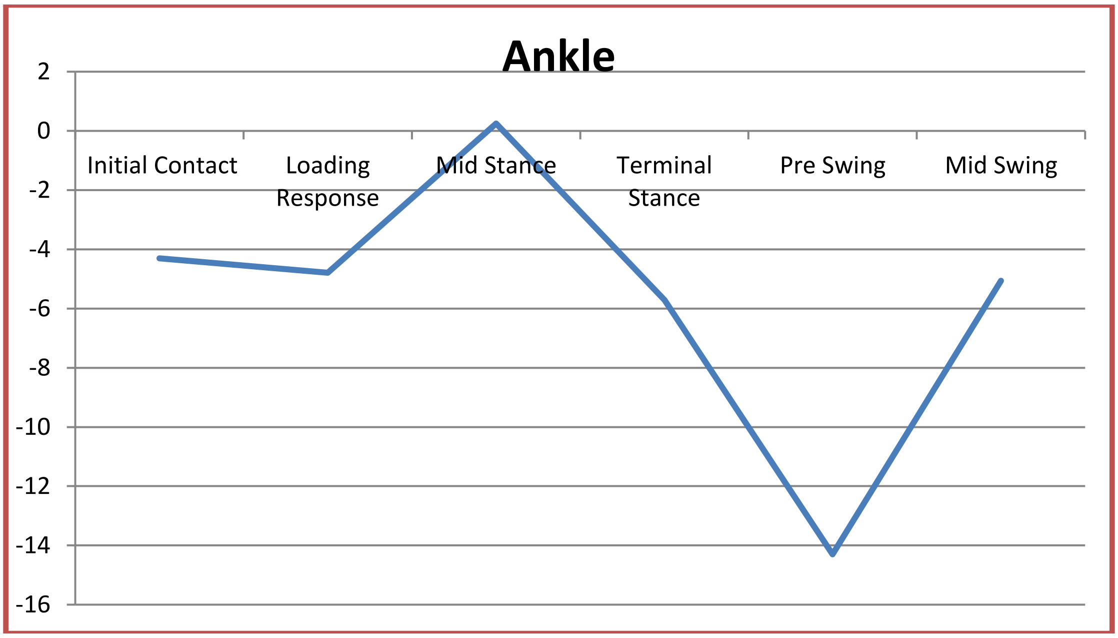
At initial contact, the mean hip angle is +11.24° with a standard deviation (SD) of 7.11 and the mean knee angle is +2.5° with a standard deviation of 4.53 and the mean ROM at the ankle is -4.30° with a standard deviation of 5.44. During the Loading Response phase, the mean hip angle is +4.78° (SD=5.35), the mean knee angle is +1.93° (SD= 6.31), and the mean angle at the ankle is -4.79° (SD= 4.28). At the midstance phase, the mean hip ROM is -0.34° (SD= 4.63), the mean knee angle is -1.13° (SD= 4.53), and the mean ankle is +0.25° (SD= 3.51). At the terminal stance, the mean hip angle is -11.90° (SD= 6.62). The mean knee angle is +10.23° (SD= 6.99) and the mean angle at the ankle joint is -5.71° (SD= 4.24). At the pre-swing phase, the mean hip angle is -5.37° (SD= 7.99), the mean angle at the knee joint is +21.30° (SD= 7.43), and the mean angle at the ankle is -14.30° (SD= 7.56). At the mid-swing phase, the mean angle at the hip joint is +10.30° (SD= 8.66), the mean angle at the knee joint is +20.47° (SD= 13.85) and the mean angle at the ankle joint is -5.06° (SD= 6.60).



Graph 1: Sagittal Plane Kinematics of Hip



Graph 2: Sagittal Plane Kinematics of Knee



Graph 3: Sagittal Plane Kinematics of Ankle

Table 1: showing gait deviation frequency

Phases	*Location*	*Deviation*		*Frequency*
Initial contact	Ankle	Toe contact	Abnormal	74
		Heel contact	Normal	26
Mid stance	Knee	Hyperextension	Abnormal	60
		Flexion	Normal	40
Mid swing	Ankle	Plantar flexion	Abnormal	73
		Dorsiflexion	Normal	27

74% of the subjects have ankle plantarflexion at initial contact. In 60% of the subjects, there is knee hyperextension at mid-stance and in 73% of the subject's ankle is plantarflexed at mid-swing.

Discussion

In the present study, the mean hip angle of the affected side at initial contact was +11.24°. The maximum hip flexion at initial contact was +32.05°. In 68% of the subjects, the hip flexion at initial contact was <15°. In 6% of the subjects, the hip remained in extension at initial contact. The mean hip extension at terminal stance was -11.90° and at mid-swing, the mean hip ROM was 10.30°. Kramers et al., [6] in their study reported reduced hip extension in the stance phase and delay in the initiation of hip flexion during the pre-swing phase. The hip joint ROM in the affected side showed a significant reduction in the sagittal plane when compared to the unaffected side. A decreased hip extension has been a commonly reported kinematic deviation following hemiplegic stroke. This may be due to reduced power of the hip extensor muscles, hip flexor contracture, or spasticity of the hip flexors. Ankle plantar flexor spasticity in the stance phase also contributes to a reduced hip extension during the late stance phase. [6] The reduced hip flexion during mid-swing may be attributed to the reduced power of the rectus femoris and iliopsoas muscle which tends to accelerate the limb in the swing phase. [10] In hemiplegic patients, the sagittal plane hip ROM showed a higher diversity of abnormal joint movements during the stance phase. At first touch, hip flexion was reported to be reduced or increased. In comparison to normal subjects, the amount of peak hip extension during the stance phase is reduced, notably at late stance and push-off, and the hip may be flexed during toe-off. [11] The findings of our investigation are consistent with these findings. Straudi S et al., [12] in their low functioning walking cluster group found that hip motion reflected a slight flexion reduction in the stance (20.5°) and a lack of extension in the late stance phase (-2.4°). In the present study mean hip extension at the terminal stance phase was -11.90°. The difference may be due to the larger sample size in the present study. Our study did not stratify subjects as low, medium, and high functioning walking groups.

In the present study, the mean knee ROM at initial contact was found to be 2.51°. One-fourth of the subjects had knee hyperextension at the initial contact. The mean knee ROM at loading response was 1.93°. There was a reduced flexion during the loading response phase and in 42% of the subjects, there was knee hyperextension. At mid-stance, the mean knee ROM was -1.13° and 60% of the patient's knee goes into hyperextension. At the late stance, the knee goes into flexion, but the mean ROM is reduced (10.23° and 21.30° at the terminal stance and pre-swing respectively). The mean knee flexion at the swing phase was 20.47°. The hyperextension of the knee in the early part of the stance phase is due to the weakness of the quadriceps or spasticity of ankle plantar flexors. The reduced knee flexion during the swing phase may be attributed to the reduced power of the hamstrings, spasticity of the quadriceps, and reduced hip flexion and ankle dorsiflexion due to which the patient may adopt some compensatory strategies like circumduction, hip hiking, or contralateral vaulting. [13] Jiang X et al., [14] in their quantitative analysis of knee abnormalities in hemiplegic subjects observed that the ROM at initial contact on the affected side was 4.49° and maximum extension in stance phase on the affected side was -0.89°. These results are comparable with the present study. Straudi S et al., [12] in the low functioning walking group identified a stiff-knee pattern with reduced flexion both in early stance (1.0°) and swing phases (13.7°). In the intermediate-functioning walkers, the knee joint had a normal flexion during loading response (10.4°) with a slight hyperextension in the stance phase (-5.2°) and in the swing phase, the knee flexion was reduced (24.5°). In the high-functioning walkers, the knee flexion during loading response was normal (11.2°) and hyperextension in midstance (-11.0°). Knee flexion during the swing phase was also reduced (39.0°). Our study also demonstrates hyperextension in the stance phase and reduction in the knee flexion during the swing phase. In the present study, the mean ankle ROM at initial contact was -4.30°, at loading response -4.79°, mid-stance +0.25°, terminal stance -5.71°, pre-swing -14.30° and at mid-swing -5.06°. In 76% of the subjects, the ankle remained in plantar flexion at initial contact. A plantarflexed ankle will result in a forefoot contact or toe strike instead of a heel strike. This may be due to weakness of the tibialis anterior and other dorsiflexors or due to gastrosoleus spasticity or tendoachilles contracture. The relative ankle dorsiflexion at midstance is reduced because of the reduced knee flexion at loading response (1.93°) which rotates the tibia forward over the fixed foot. At pre-swing, the ankle ROM was -14.30°, negative indicating plantarflexion, which is found to be slightly reduced. This may be due to the inability to produce sufficient active tension with the ankle plantar flexor muscles in a late stance. [13] At mid-swing also the mean ankle ROM was -5.06°. This could be due to ankle dorsiflexor weakness or severe ankle plantar flexor spasticity. A plantarflexed ankle will make it difficult to clear the toes, forcing the patient to use compensatory techniques. In a study conducted by Kesikburun S et al., [15] in hemiplegic patients the mean ankle ROM at initial contact was -6.80° and at mid-swing was -5.69°, comparable with our study. Kramer in his study also observed reduced ankle dorsiflexion during the swing phase. Straudi S et al., [12] in their study reported reduced dorsiflexion (5.0°) in the mid-stance phase. In the study by Pongpipatpaiboon K et al., [16] in hemiplegic patients the mean ankle ROM from mid-stance to mid-swing was -10.4°. These findings are consistent with our observations. Pongpipatpaiboon K et al., [16] found that wearing an AFO reduced mean ankle ROM to -6.1°, which was statistically significant, and improved toe clearance and reduced compensatory movements during the swing phase of gait.

Limitations

Because this was a descriptive study, there was no control group. The hemiplegic side was not compared to the unaffected side. There was no consideration of kinetic analysis or spatiotemporal characteristics. There were no follow-up studies conducted.

Conclusion

During the various phases of walking, it was discovered that the hip moved in a small range. Knee flexion was reduced throughout the loading response phase, while knee hyperextension was observed during mid-stance. Knee flexion was shown to be reduced throughout the late stance and swing phases. At first contact, the ankle remained in plantar flexion, resulting in a forefoot strike in most cases. During terminal stance, ankle plantar flexion is minimized. During the swing phase, ankle dorsiflexion was observed to be reduced. As a result, it can be inferred that in hemiplegic patients, the mean range of motion of the hip, knee, and ankle in the sagittal plane was reduced in both the stance and swing phases of gait. Various rehabilitation interventions are undertaken based on the clinical and functional status of the patient as evidenced by gait analysis. This signifies the role of instrumental gait analysis in planning and monitoring treatment strategies in post-stroke hemiplegic patients.

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