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Immediate Effects of Ankle Binder on Hip and Knee Range of Motion in Swing Phase in Sagittal Plane of Acute Stroke Patients: An Experimental Study

Manav Rajpurohit[1], Sonal Patole[2]

[1]Resident, Department of Neurophysiotherapy, P.E.S's Modern College of Physiotherapy, Shivaji Nagar, Pune, Maharashtra, India,
[2]Associate Professor, P.E.S's Modern College of Physiotherapy, Shivaji Nagar, Pune, Maharashtra, India,

Corresponding Author:
Manav Rajpurohit
manavstan99@gmail.com

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Abstract

Background: Stroke is a neurological dysfunction related acute focused injury of the central nervous system by a vascular source, leading to over 50% of them having long-term disabilities and need aid with carrying out daily duties. Hemiplegic gait is mostly caused by foot drop brought on by stiff plantar flexors, weak dorsiflexors, and increased spasticity. When a patient is unable to dorsiflex their ankle joint during the swing phase, it is commonly referred to as foot drop. Ankle binder which is often used to stabilize the ankle in chronic ankle instabilities and sprains will provide stability as well as functional mobility without endangering neuromuscular deconditioning. The ankle binder has a reduced surface area in contact with the skin compared to standard AFOs, making it more effective in delivering input to the proprioceptive senses which might also improve gait in hemiplegic patients by affecting hip and knee range of motion. Therefore, the objective of the study is to compare the immediate effects of ankle binder on hip and knee range of motion in swing phase in sagittal plane of acute stroke patients using the Kinovea Motion Analysis Software
Methodology: The present study type is Pre-Post Experimental study. A total of 67 patients having unilateral stroke were selected using purposive sampling. Pre intervention gait was recorded, post intervention was carried out by strapping ankle binder to the foot in dorsiflexion with eversion position and gait was recorded with smartphone. Frames/Sections were taken in Early swing phase (for Hip Extension), Midswing phase (for Hip and Knee Flexion) and Late swing phase (for Knee Extension) for range of motion analysis. The pre-post measurement data was analyzed with the help of Kinovea Motion Analysis Software and statistical analysis was done
Results: The present study showed a significant improvement in the hip flexion, knee flexion and knee extension range of motion with a p value < 0.0001. While no significant improvement in hip extension range of motion with p = 0.116 in swing phase in sagittal plane of acute stroke patients.
Conclusion: The present study concludes that there was significant improvement in hip flexion, knee flexion and knee extension range of motion but no significant improvement in hip extension range of motion in swing phase when seeing the immediate effects of ankle binder on hip and knee range of motion in swing phase in sagittal plane of acute stroke patients.

Keywords: *Acute stroke, Stroke rehabilitation, Ankle binder, Foot drop, Gait rehabilitation, Physiotherapy*

1. Introduction

A stroke is characterized as a neurological dysfunction resulting from an acute, localized injury to the central nervous system (CNS) due to a vascular event. More than one-third of stroke survivors require ongoing care, and approximately half experience long-term disabilities that necessitate assistance with daily activities. In a recent systematic review, it has been reported that the annual incidence of stroke in India ranges from 105 to 152 per 100,000 individuals. with many of the studies being cross-sectional (1)

Over 80% of stroke patients have motor deficits in their contralateral limbs in acute phase and 40% of patients are in the chronic phase. Inability to move after a stroke can cause hardships for stroke victims and their families [2]

Hemiplegic gait is mostly caused by foot drop brought on by stiff plantar flexors, weak dorsiflexors, and increased spasticity. When a patient is unable to dorsiflex their ankle joint during the swing phase, it is commonly referred to as foot drop [3]

Patients with foot drop flex their knees more than usual to keep their toes from dragging, which increases joint loading and may lead to osteoarthritis over time. Foot drop during the swing phase of walking causes the patient to flex the hip joint more than usual to avoid falling. However, during the initial contact phase, the toes are the first to touch the ground. Patients with foot drop have trouble walking because of their irregular gait pattern, which is known as steppage. This leads to increased energy consumption when walking, slower walking speeds and distances, and a longer time in the double support phase to maintain balance and avoid falls.

Patients with foot drop compensate by tilting the trunk and anterior pelvis in the direction of movement. This pelvic posture might cause excessive strain in the two ischiocrural joint muscles. When this group is recruited at the same time as the gastrocnemius muscle, the hip joint may experience limited flexion during loading in the standing phase. [3]

Also, the placement of the equinus foot is frequently linked to future knee hyperextension while in stance, it is unclear if there is a causal link between the positioning of the equinus foot and abnormal knee extension. Movement may also be hampered by plantar flexor and/or quadriceps spasticity, which is characterized by early or prolonged activation of these muscles [4]

Therefore, it is generally agreed that enhancing gait speed and pattern by ongoing foot drop therapy is the most crucial objective in stroke rehabilitation [5]

Ankle-foot orthoses (AFOs) are commonly used to correct foot drop gaits in those with neurological problems. AFOs can improve gait quality and balance for persons with limited ankle dorsiflexion, as well as medial and lateral stability. [6]

Several research imply that AFO use results in aberrant muscle activation, causing soreness and weariness in the lower limbs [7].

AFOs also restrict ankle joint movement, which reduces muscular utilization. As a result, they do not contribute to muscular activity restoration. [8][9][10]

Furthermore, patients complain about discomfort while walking due to the different sensations caused by wearing plastic AFOs, but AFOs may also impair the action of the plantar flexor since they come into touch with most of the lower leg, preventing ankle dorsiflexion.

The changed kinematics and clonus caused by the usage of AFOs made several medical professionals believe that they do not aid patients in learning how to walk again [11]

Having said that, all hemiplegic patients cannot afford this exoskeleton as it is expensive. So, there is a need to find out feasible alternatives which would help in achieving hip and knee range of motion and make the mobility factor easier for such patients

Ankle Binder or Ankle Elastic Strap is often used in ankle sprains and post-arthroscopic Anterior Talofibular Ligament, Chronic Ankle Instabilities because it provides stability as well as functional mobility without endangering neuromuscular deconditioning and chronic regional pain syndrome [12]

The device is lightweight, portable, low-resistance, and adjustable to meet different needs. The ankle elastic strap or ankle binder demonstrates greater efficiency in delivering input to proprioceptive senses due to its reduced skin contact area compared to alternative methods like traditional AFOs, reducing patients' sense of unfamiliarity and allowing them to feel their feet touch the ground.

Assumptions that using the Air-Stirrup would improve proprioception in both anesthetic and non-anesthetic conditions. These theories were predicated on the presumption that proprioceptive deficits are likely to occur due to diminished afferent feedback originating from anesthetized ligaments., and that proprioceptive facilitations would result from increased afferent feedback from cutaneous receptors during AirStirrup application [13]

The calculation of the kinematical and spatiotemporal properties of human movement is managed by the software Kinovea® [14][15]

Using this program, a researcher examined the ankle, knee, and hip joint angles in older persons at various stages of the gait cycle. As a limitation on hip extension, the authors present kinematic asymmetries in the individuals' gait pattern. (16)

2. Methodology

After getting approval from the institutional ethical committee of PES modern college of physiotherapy the study will be conducted in OPD of modern college of physiotherapy, the samples were screened based on inclusion and exclusion criteria and then were recruited in the study. The target population for the experimental study was individuals with unilateral stroke between age group 18 to 60 living in and around pune. The duration of the study was 18 months. Sample Size: 67 [Sample size calculated from the reference article: Khan F et.al. Prediction of Factors Affecting Mobility in Patients with Stroke and Finding the Mediation Effect of Balance on Mobility: A Cross-Sectional Study(2)]. By G Power 3.1.9.7 with alpha = 0.05, Power = 0.95 and Effect size= 0.4. The inclusion criteria for the study was as follows: Individuals with age between Age 18 to 60, both males and females, individuals diagnosed with acute stroke < 12 weeks involving Middle cerebral artery, clinical diagnosis of unilateral stroke (16), able to walk 5 mts without aids (16), range of motion on passive ankle dorsiflexion ≥0° with full knee extension (16), active range of motion for hip flexion ≥10° & hip extension ≥ 15°; knee flexion ≥20° & knee extension ≥0°, Modified Rankin Score (mRS) of ≤ 3 (Indicating- The patient has moderate disability; requiring some external help but able to walk without the assistance of another individual), scored greater than 24 on Mini-Mental State Examination (MMSE) (17). The exclusion criteria was as follows: Stroke with more than one focal lesion involving hemisphere, Transient Ischaemic Attack, Subarachnoid hemorrhage or cerebellar or brainstem stroke (16), a history of recent injuries of lower limb that would interfere with performing a gait analysis, medical comorbidities that might significantly interfere with gait (including a previous stroke with persisting gait deficits) (16), medical conditions that might lead to inability to comply with the study protocol (16), cognitive impairments. Having said that, we did set withdrawal criteria as: Subject's participation in this project is completely voluntary, The subject may withdraw from the project at any moment for any reason or without reason without incurring any penalties or forfeiting any benefits to which he/she would otherwise be entitled, also, while getting consent, subjects were made aware of and explained their right to "Withdrawal of Participation." The study database contains the participant's data up until the time of withdrawal.

3. Outcome Measures

1. Range of Motion – Kinovea Motion Analysis Software (reliability= 1, validity= 1):

Kinovea is a free 2D motion analysis program that measures kinematic characteristics. This inexpensive technology has been applied in the clinical and research domains as well as sports sciences. The ability to measure an object (or person) passing in front of the camera while taking into account the perspective between the camera and the recorded object is one intriguing feature. It makes it possible to analyze coordinates, angles, distances, and spatial-temporal data from a video recording frame by frame. Since the software performs calibrations in non-perpendicular planes to the camera-object line under analysis, these measurements can be taken from various angles. (18)

4. Operational Definitions:

1. Ankle binder- Ankle Binder is an effective device to support, compress and partially immobilize the ankle.
2. Heel Strike- It refers to the instant the foot of the leading extremity strikes the ground. (19)
3. Early Swing Phase – It is the phase where toe leaves the ground and continues until midswing, or the point at which the swinging extremity is directly under the body. (19)

4. Midswing Phase- The phase that occurs approximately when the extremity passes directly beneath the body, or from the end of acceleration to the beginning of deceleration. [19]
5. Late Swing Phase- The phase that occurs after midswing when the limb is decelerating in preparation for heel strike. [19]

5. Procedure

- A 9-meter pathway was measured and marked. The first and last 2 meters were not counted as patient was in acceleration and deceleration phase, respectively. Therefore, the actual significant walkway became of 5 meters where a cone was placed at the Beginning (Point A) i.e at 2 m and Ending (Point B) that was at 7 m of the 9m pathway.
- An additional cone was placed at the mid-point of the 5m actual pathway (Point C) i.e at 4.5 m of the 9 m pathway.
- The significance of the cone at mid-point was to start analyzing the gait video in Kinovea only after the patient crossed the Point C to reach Point B from where the Early swing phase for hip extension (Figure 1), Mid swing phase for Hip and Knee flexion (Figure 2) and Late Swing phase for Knee extension (Figure 3) was captured in frames/sections of the video as an image.
- A tripod with Phone was placed at 3 meters perpendicular to the pathway. Participants were asked to wear shorts and t-shirts
- Non-reflective surface stickers were placed at Greater Trochanter and Lateral Condyle of Femur, Lateral Malleoli of Affected Lower Extremity
- The patient was seated in a manner so as the camera can record the entire 9m pathway with the cones placed at 2m,4.5m and 7m.
- The patient was instructed to walk in a straight line adjacent to the cones to not interfere with the video being recorded and not to accidentally perform obstacle walking.
- Participants were video-graphed on the same lines as mentioned above and different frames/sections were obtained for pre-intervention data and analyzed with the help of Kinovea Motion Analysis Software for Pre Intervention Range of Motion
- Participants were later strapped with ankle binder to the foot in dorsiflexion with eversion position and were again video graphed in the similar manner for post intervention data of hip flexion and extension, knee flexion and extension and analyzed using Kinovea Motion Analysis Software for Post Intervention Range of Motion
- The protocol for pre gait analysis and post gait analysis has been issued intellectual property rights with the Copyright Office, Government of India Certificate No. LD-20250172677

6. Results and Statistical Analysis

- Statistical analysis was performed using Instat Application (.exe) software.
- Descriptive statistics was used to find the mean and standard deviation for outcome variables.
- Shapiro-wilk test was applied to check the normality of the data. Significance level was < 0.05 and a non-directional (two-tailed) analysis was applied.

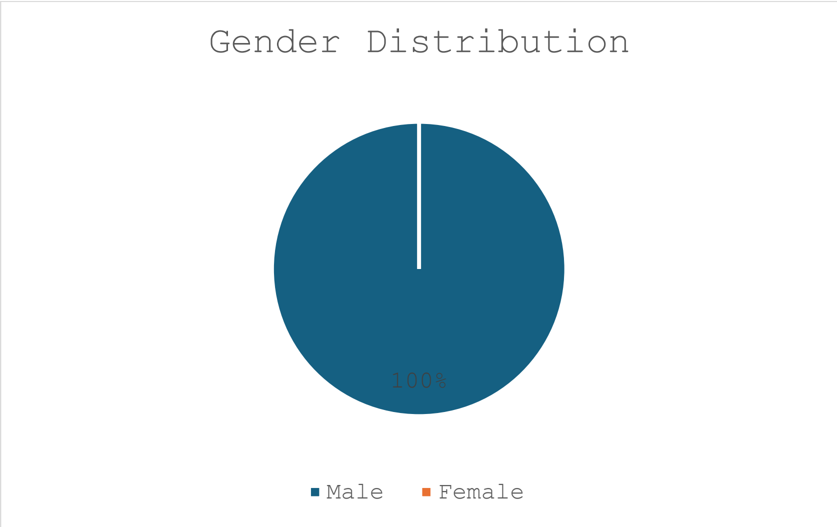
As the data was not normally distributed Wilcoxon matched-pairs signed-ranks test was applied for statistical comparison of pre and post intervention data for hip flexion, hip extension, knee flexion and knee extension range of motion.

7. Discussion:

Tables and graphs: Statistical analysis of descriptive data of study population

Table 1: Demographic Data

Demographic Data		
Age Mean ± SD	47.70 ± 10.045	
Gender	M	67
	F	0

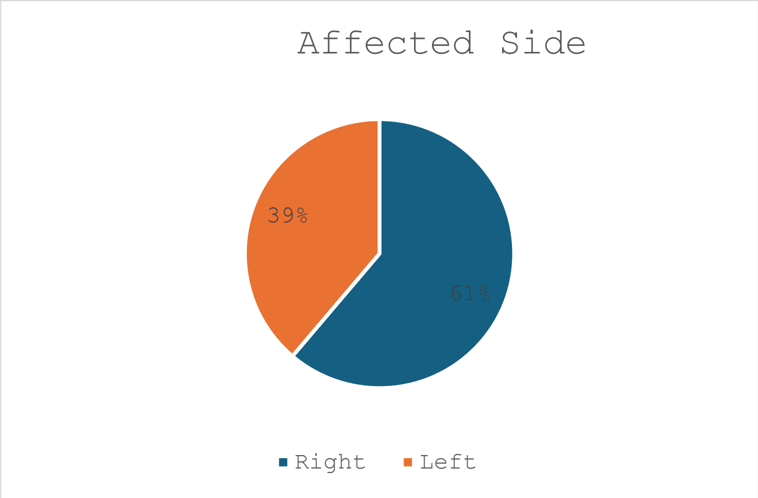


Graph 1: Gender wise distribution

Interpretation: The above table and graph represent gender wise distribution of 67 subjects with mean age of 47.70 ± 10.045 which includes all male subject.

Table 2: Representation of Affected Side

Side of affection	No. of subjects
Right	41
Left	26



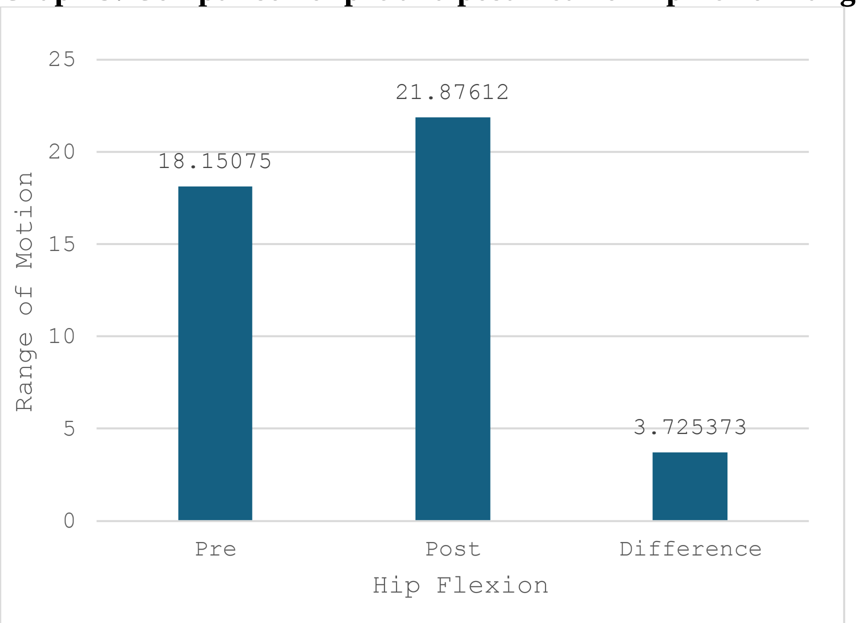
Graph 2 : Distribution of Affected Side

Interpretation: The above table and graph represent the affected side of the subjects. 41 subjects had right side affection and 26 subjects had left side affection

Table 3: Data of hip flexion range of motion (pre and post intervention)

Hip Flexion Range of Motion	Pre Intervention	Post Intervention	Difference
Mean	18.150	21.876	3.725
SD	7.604	6.194	
R	0.828		
P value	<0.0001		

Graph 3: Comparison of pre and post mean of hip flexion range of motion

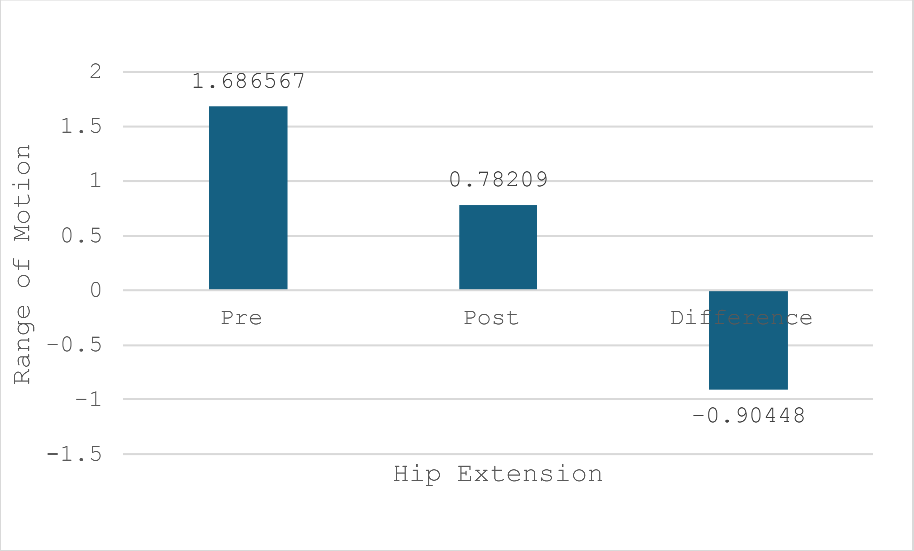


Interpretation: The above table and graph represent comparison of pre and post values of hip flexion range of motion. There were extremely significant changes in hip flexion ranges with a pre mean of 18.150 and post mean of 21.876 after using ankle binder with the positive difference of 3.725 with p value <0.0001.

Table 4: Data of hip extension range of motion (pre and post intervention)

Hip Extension Range of Motion	Pre Intervention	Post Intervention	Difference
Mean	1.687	0.782	-0.904
SD	8.980	6.839	
R	0.826		
P value	0.1160		

Graph 4: Comparison of pre and post mean of hip extension range of motion

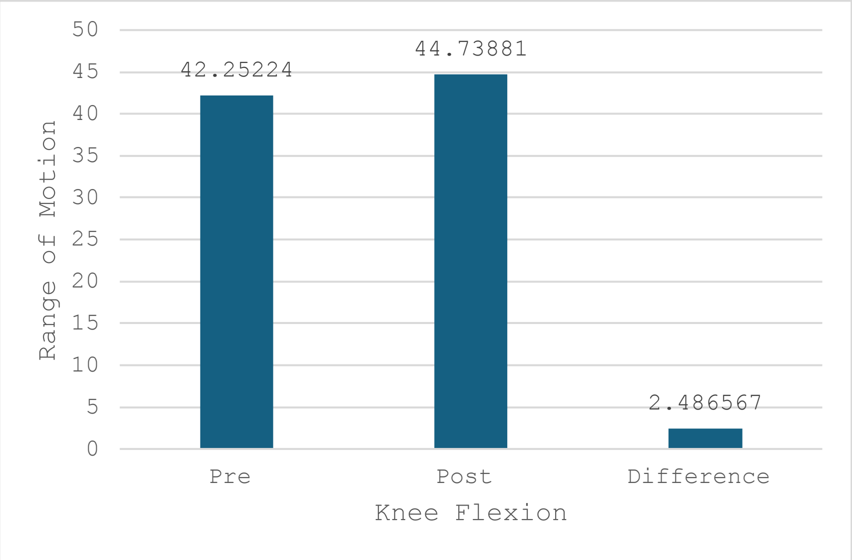


Interpretation: The above table and graph represent comparison of pre and post values of hip extension range of motion. There were no significant changes in hip extension ranges with a pre mean of 1.687 and post mean of 0.782 after using ankle binder. Additionally, there was a hip extensor lag with a mean difference of 0.904 with p value of 0.1160

Table 5: Data of knee flexion range of motion (pre and post intervention)

Knee Flexion Range of motion	Pre Inter-vention	Post Inter-vention	Differ-ence
Mean	42.252	44.738	2.48
SD	13.036	16.195	
R	0.9725		
P value	<0.0001		

Graph 5: Comparison of pre and post mean of knee flexion range of motion

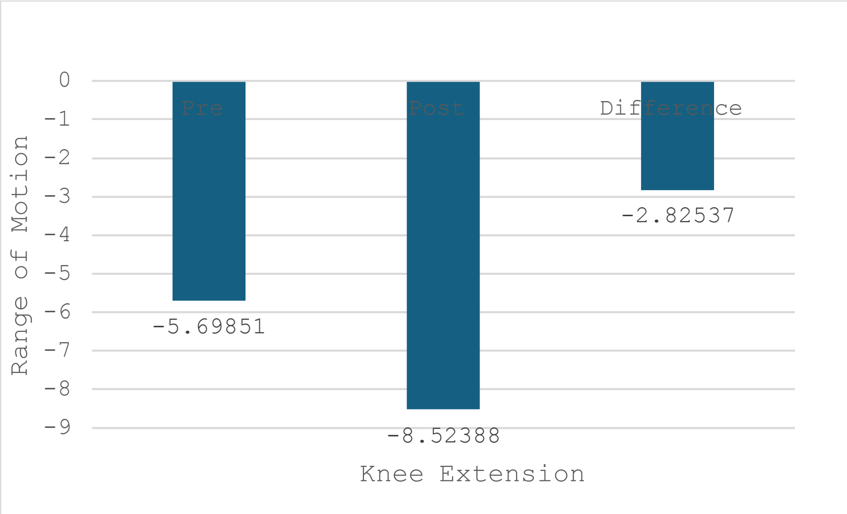


Interpretation: The above table and graph represent comparison of pre and post values of knee flexion range of motion. There were statistically significant changes in knee flexion ranges with a pre mean of 42.25 and post mean of 44.73 after using ankle binder with the positive difference of 2.48 with p value of <0.0001.

Table 6: Data of knee extension range of motion (pre and post intervention)

Knee Extension Range of Motion	Pre In-terven-tion	Post Interven-tion	Difference
Mean	-5.698	-8.523	-2.825
SD	8.631	5.342	
R	0.744		
P value	0.0009		

Graph 6: Comparison of pre and post mean of knee extension range of motion



Interpretation: The above table and graph represent comparison of pre and post values of knee extension range of motion. There was statistically significant difference between knee extension ranges with a pre mean of -5.698 and post mean of -8.523 after using ankle binder. Additionally, there was a knee extensor lag with a negative mean difference of 2.825 with a p value of 0.0009

8. Discussion:

In the present study, we aimed to study the immediate effect of ankle binder on hip and knee range of motion in swing phase in sagittal plane of acute stroke patients using the Kinovea Motion Analysis Software. A total of 67 subjects with foot drop participated in this study to see the immediate effects of ankle binder on hip and knee range of motion in swing phase in sagittal plane; swing phase viz. Early swing, Mid swing and Late swing for hip extension, hip and knee flexion, knee extension respectively. The pre and post intervention hip and knee range of motion were compared using the Kinovea Motion Analysis Software.

In the above study, Table 1 and Graph 1 suggests that out of 67 subjects having foot drop all of them were males. The mean age of the participants was 47.70 ± 10.04.

In a study of older adults in India, 1.71% reported having a stroke (95% CI: interval: 1.61-1.80). Individuals with diabetes and high cholesterol are 1.5 times more probable to experience a stroke than those without either condition. Age (AOR=1.57 for 55-69 years and AOR 2.05 for ≥70 years), male gender (AOR=1.75; 95% CI 1.36-2.26), and economic status (AOR=1.58; 95% CI: 1.21-2.06) were all associated with a higher risk of stroke, which was in cohesion with our study. [20]

In Table 2 and Graph 2 it is observed that 67 participants were enrolled, 41 had a stroke affecting the right side and 26 were impacted with the left side.

In this study, it is seen that there was a significant improvement in the hip flexion range of motion between the pre and the post intervention data with a mean difference of 3.725 as shown in Table 3. The improved hip flexion range of motion could be due to the ankle binder supporting the ankle in dorsiflexion, as opposed to static AFO that inhibits dorsiflexion. In the swing phase, healthy individuals shorten the distance from their hip joint to their toe (leg shortening) by coordinating knee flexion and ankle dorsi flexion. [21]

However, hemiparesis impairs leg shortening, forcing patients to use compensatory movements to obtain foot clearance. Because the forefoot is not supported in an ankle binder, there is still a chance that the forefoot will touch the ground, and when it does, the patient must exert extra effort in flexing the hip for toe clearance.

If dorsiflexion is adequate for toe clearance, a lower level of peak hip flexion is required; conversely, if dorsiflexion is insufficient, hip flexion is raised to lessen the danger of falling.

In cohesion with the current results a study on the relationship between hip flexion and ankle dorsiflexion during the swing phase found that the biomechanical behavior in chronic stroke patients, the hip and ankle joints are linked during the swing phase of the gait cycle.

They also imply that two techniques exist: if sufficient ankle dorsiflexion is available, less hip flexion is required (distal-strategy), and if dorsiflexion is reduced, it can be made up for by a gain in peak hip flexion (proximal-strategy). (22)

Table 4 depicts that there was no significant change in hip extension range of motion and continued as a hip extensor lag of 0.9 after using ankle binder.

Table 5 depicts that there was a statistically significant difference in knee flexion range of motion post ankle binder with a mean difference of 2.48. It is possible that these biarticular muscles (gastrocnemius and rectus femoris) play a role in the biomechanical relationship between the knee and ankle.

A study done on post- stroke elderly patients in gait with use of elastic band variety of AFO suggested that as ankle dorsiflexion rose, plantar flexion decreased. This demonstrates that the negative association persisted, even though the range of angular shifts remained relatively constant. Similarly, as flexion rose, the knee joint's extension decreased. This shows a negative association between opposing movements. In other words, when ankle dorsiflexion and knee flexion (positive phenomena) increase, ankle plantar flexion (drop-foot) and knee extension (back knee) (negative phenomena) decrease. (23)

Marcelo's research, which reported that an adequate use of the AFO leads to increase in knee flexion. Furthermore, the results of their experiment help us understand why wearing hard plastic-type AFO had such minimal impacts. The hard plastic-type AFO produced smaller angular differences at the ankles (range: dorsiflexion-plantar flexion) than wearing nothing. This outcome is related to the extreme restriction caused by the plastic material on the ankles, which limits dorsiflexion, which has a favorable effect. Furthermore, significant angular constraint on the ankles is regarded the source of the hard plastic-type AFO's ineffectiveness during knee flexion extension. (24)

In a study done in 2021, it was discovered that the resistance to plantar flexion exerted by the ankle strap may further increase the knee flexion angle during landing. (25)

Table 6 describes, that there was statistically significant improvement in the knee extension range of motion with a mean difference of 2.82, rather there was decrease in knee extension angle, i.e. knee extensor lag was seen. A similar study on the lower extremities using the elastic strap attaching technique revealed increased flexion of the knee angles during the stance stage of stroke patients' gait phases, pointing to the usefulness of wearing a binding strap to decrease knee hyperextension as well the stiff motion pattern happening at the knee joint resulting from muscle rigidity when walking. (26)

Effective ankle binder strapping at the ankle joint can cause plastic alterations in cortical electrical activity in the area that controls dorsiflexor function. As a result, it can speed up the motor recovery process in stroke patients with foot drop. Neuroscience studies reveal that the functional consequence of neuroplasticity is task-driven and depends on the type of the training. (24)

The strap binding technique boosts sensorimotor activity in stroke patients, allowing them to adjust to the coupling of walking while focusing on typical walking goals. It improves gait for stroke patients and provides proprioceptive feedback to regulate motor cortex excitability. (27)

Highly repeated and salient sensory feedback, such as proprioceptive stimulation from supported ankle dorsiflexion motions and pressure sensation from mechanoreceptors under foot soles, may serve as stimulants that reinforce induced plastic alterations in gait patterns. Neuroscience research indicates that motor training with deliberate motivation and appropriate afferent feedback can alter motor cortex excitability. (27)

Rehabilitation of people with stroke may be directly related to brain remodeling, which involves strengthening preexisting synaptic conduction and establishing new connections. (28)

9. Conclusion

The present study concludes that there was significant improvement in hip flexion, knee flexion and knee extension range of motion but no significant improvement in hip extension range of motion in swing phase when seeing the immediate effects of ankle binder on hip and knee range of motion in swing phase in sagittal plane of acute stroke patients.

10. What is already known on the topic

Ankle-foot orthoses (AFOs) are commonly used to correct foot drop gaits in those with neurological problems. AFOs can improve gait quality and balance for persons with limited ankle dorsiflexion, as well as medial and lateral stability. (6)

Ankle Binder or Ankle Elastic Strap is often used in ankle sprains and post-arthroscopic Anterior Talo-Fibular Ligament, Chronic Ankle Instabilities because it provides stability as well as functional mobility without endangering neuromuscular deconditioning and chronic regional pain syndrome. (12)

11. What this study adds

The device is lightweight, portable, low-resistance, and adjustable to meet different needs. The ankle elastic strap or ankle binder demonstrates greater efficiency in delivering input to proprioceptive senses due to its reduced skin contact area compared to alternative methods like traditional AFOs, reducing patients sense of unfamiliarity and allowing them to feel their feet touch the ground.
Effective ankle binder strapping at the ankle joint can cause plastic alterations in cortical electrical activity in the area that controls dorsiflexor function. As a result, it has the ability to speed up the motor recovery process in stroke patients with foot drop. Neuroscience studies reveal that the functional consequence of neuroplasticity is task-driven and depends on the type of the training. (24)

12. Competing Interests

None

13. Author’s Contribution:

All authors contribute equally in conceptualizing the topic, MR collected, documented and analyzed the data, MR drafted the final manuscript, MR and SP approved the final draft.

14. Acknowledgement

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15. Figures

Figure 1: Showing pre and post comparison of the hip extension range of motion

Figure 2 : Showing pre and post comparison of the hip flexion range of motion

Figure 3 : Showing pre and post comparison of the knee flexion range of motion

Figure 4 : Showing pre and post comparison of the knee extension range of motion

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