Current Physiotherapy Evidences for Various Gait Training interventions for Knee Hyperextension among Post Stroke Survivors - A Systematic Review

Dr. Tanishqa Coutinho [1], Dr. Suraj B Kanase [2]*, Dr. G.Varadharajulu [3]

[1,2,3] Department of Neuro Physiotherapy, Krishna Vishwa Vidyapeeth (Affiliated to Deemed to be University) Karad, Maharashtra. India
**Corresponding Author: Dr. Suraj B Kanase. Email: drsurajkanase7@gmail.com*

KEYWORDS
Stroke, Knee hyperextension, Gait training, Physiotherapy intervention

ABSTRACT
Stroke patients often exhibit dissimilarities in their gait patterns. One of the dissimilarities is the hyperextension of the knee. Knee hyperextension is common deviation seen among 48-68% of ambulating hemiparetic patients. Genu recurvatum, commonly referred to as "knee hyperextension," occurs when the ground reaction force passes anterior to the knee joint, causing full knee extension (0°) or even greater. Several potential aetiologies contribute to knee hyperextension, including diminished activation of the knee extensors, inadequate eccentric control of these muscles, quadriceps and plantar flexor spasticity, hamstring weakness, and proprioceptive deficits. Over time, this condition may compromise walking speed, reduce gait efficiency, increase energy expenditure, and may be associated with knee pain. Although various Neurophysiological rehabilitation strategies exist to correct hemiparetic gait, they generally address gait abnormalities without specifically targeting knee hyperextension. Therefore, the aim of this review is to identify gait rehabilitation approaches that focus on reducing knee hyperextension in post-stroke patients. The study reviewed evidence that targeted gait interventions that effectively prevent and reduce knee hyperextension in individuals recovering from stroke.

1. Introduction and Background

Stroke is a significant global health issue and one of the major causes of disability and mortality worldwide [1]. In India, the incidence of stroke varies between 105 and 152 cases per 100,000 individuals annually [2]. Furthermore, the prevalence of stroke is influenced by age, with higher rates observed in younger females and increased occurrences in older males.

A stroke is defined as an acute/chronic neurological event resulting from a disruption in cerebral blood flow due to vascular compromise. The brain's blood supply is primarily regulated by two internal carotid arteries anteriorly and two vertebral arteries posteriorly, which together form the circle of Willis[3]. There are two principal classifications of stroke: ischemic and hemorrhagic. Ischemic strokes constitute approximately 80% of cases and are the most prevalent type[4]. In contrast, hemorrhagic strokes account for roughly 10–15% of all strokes and are associated with a significantly elevated mortality rate [5].

Ischemic stroke arises from insufficient blood and oxygen delivery to the brain, while hemorrhagic stroke is characterized by the rupture of blood vessels, leading to bleeding within or surrounding the cerebral tissue.It also results in sudden loss of conscious and neurological function. To be classified as stroke, neurological defects must persist for at least 24 hours[4]. Atherosclerosis in the aortic arch is a significant risk factor for ischemic stroke. It involves the accumulation and calcification of atheromatous plaques on the arterial intima, leading to endothelial irregularities. This promotes arterial stenosis or thrombus formation. Atherosclerosis changes within the cerebrovascular system can precipitate ischemic events, increasing the chance of ischemic stroke [6].

In hemorrhagic stroke, a ruptured cerebral vessel leads to increased intracranial pressure and restricts blood flow within the brain. Intracerebral hemorrhage occurs when a cerebral vessel ruptures, causing bleeding directly into brain tissue. In contrast, subarachnoid hemorrhage results from bleeding in the subarachnoid space, primarily involving the brain's larger blood vessels [4].

Stroke survivors worldwide require some assistance or are either fully dependent on their caregivers for their activities of their daily living after stroke[7]. The activities in the daily living with the greatest independency is walking and also a skill lost by 80% of stroke survivors. Thus, Rehabilitation is one of an important aspect of recovery for anyone who suffers a stroke. And among all the rehabilitation goal being able to walk again is one of a highest expected goal among the stroke survivors[8].

Approximately 48% to 68% of individuals who have survived a stroke exhibit hyperextension of the affected limb during the stance phase of their gait cycle. Knee hyperextension, also known as genu recurvatum, occurs when the force vector shifts in front of the knee, leading to complete knee extension (0°) or beyond[9]. This condition can negatively impact walking speed and gait, increase energy expenditure during walking, and may be linked to knee pain. Additionally, knee hyperextension can diminish gait symmetry, affecting the overall appearance during walking and can also be associated with knee pain [10].

Knee hyperextension can arise from a single factor or a combination of factors, including weakness, spasticity, or retraction of the muscles in the affected limb, restricted ankle mobility, proprioceptive deficits, and reduced velocity characteristics of the distal limb muscles [11].This hyperextension complicates the necessary knee flexion during the swing phase for ground clearance, leading to a circumductory gait and increased energy expenditure while walking [12].Prolonged knee hyperextension results in an abnormal weight-bearing response at the knee joint. Walking with such hyperextension often leads to knee pain and joint lesions, contributing to cumulative degenerative changes and damage. A significant kinematic alteration associated with hyperextension is an increased peak extensor torque, likely due to quadriceps weakness. This elevated torque is concerning, as the increased extensor moment at the knee poses a risk of damaging the posterior aspect of the menisci. The menisci are vital for increasing the contact area between the femur and tibia, enhancing the knee's ability to withstand loads that can be five to ten times greater than the body weight. Furthermore, proprioceptive impairments are observed in approximately 50% of stroke survivors, which can lead to inhibitory interactions that destabilize the knee joint and hinder effective motor control. This issue is closely linked to damage to the nerve fibers innervating the peripheral regions of the menisci, including the anterior and posterior horns [13].

Thus, a considerable variation in the gait is often exhibited by stroke survivors depending upon the severity of sensorimotor impairment and residual function. A gait is defined as a coordinated movement of the body as a whole.In one gait cycle, each leg goes through two main phases: the stance phase and the swing phase. A stance phase is observed when some part of the foot is in contact with the floor, which makes up about 60% of the gait cycle, and a swing phase is observed when the foot is not in contact with the floor, which makes up to remaining 40% of the gait cycle. A stance phase is subdivided into two tasks first weight acceptance, subdivided into initial contact (IC) and loading response (LR) and second single limb support consisting of three phases mid stance, terminal stance, and pre-swing[14].

Previous literature describes various interventions for treating knee hyperextension, including functional electrical stimulation (FES), electro-goniometric feedback, proprioceptive training, prowling techniques, and orthotic interventions. Functional electrical stimulation has shown to increases peak ankle dorsiflexion during swing phase and knee flexion during the loading phase of gait cycle. Also, proprioceptive training improves knee hyperextension by mechanoreceptors being stimulated resulting in better joint sense knee control in terminal range. While prowling improves the quadricep muscle strength and provides advantage to the muscle by changing movement arm However, yet the health care professionals have not made a clear preferences of various gait training interventions for knee hyperextension among post stroke survivors. Therefore, the aim of the current study was to systematically review the scientific literature in order to provide more clarity on the preferred gait training methods to address knee hyperextension in post-stroke survivors.

2. Review

Methods:

We performed a systemic review for the various physiotherapy interventions on gait training for knee hyperextension among post stroke patients. For the purpose of this review, an electronic search for relevant articles was conducted using CINHAL, PUBMED, MEDLINE, Pedro and various research database from year 2014 to 2024 was done. The search terms such as stroke or cerebrovascular accident, knee hyperextension, genu recurvatum, gait training free words were used.The articles were chosen based on their relevance to capability, self-awareness, and philosophical practice. Additionally, relevant books were also reviewed. The search was limited only to RCTs involving individuals with knee hyperextension post stroke. We excluded observational study, case reports, systemic review, meta-analysis and also studies where full text was not available.

Search Strategy:

The articles were retrieved from databases including Cochrane, PubMed, Medline, Embase, the Physiotherapy Evidence Database (PEDro), and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) between June 9 2023 to December 3 2024. A reference list of eligible studies was compiled, and the authors were contacted to obtain additional data, unpublished studies, and full-text articles.

Inclusion Criteria:

All relevant articles that were published from 2014 to 2024. The articles selected were those that included various gait training approaches as their intervention among post stroke patients with knee hyperextension. Only RCTs that identified various gait training interventions that proved to be effective for reducing knee hyperextension in post stroke patients were included

Exclusion Criteria:

All the studies that were duplicate and did not include gait training for post stroke patients with knee hyperextension were excluded. Also, those articles that did not include full text were excluded. The figure 1 provides a detailed overview of the inclusion and exclusion criteria, along with the search strategy used for selecting the articles.

Previousstudies

Identification of new studies via databases and registers

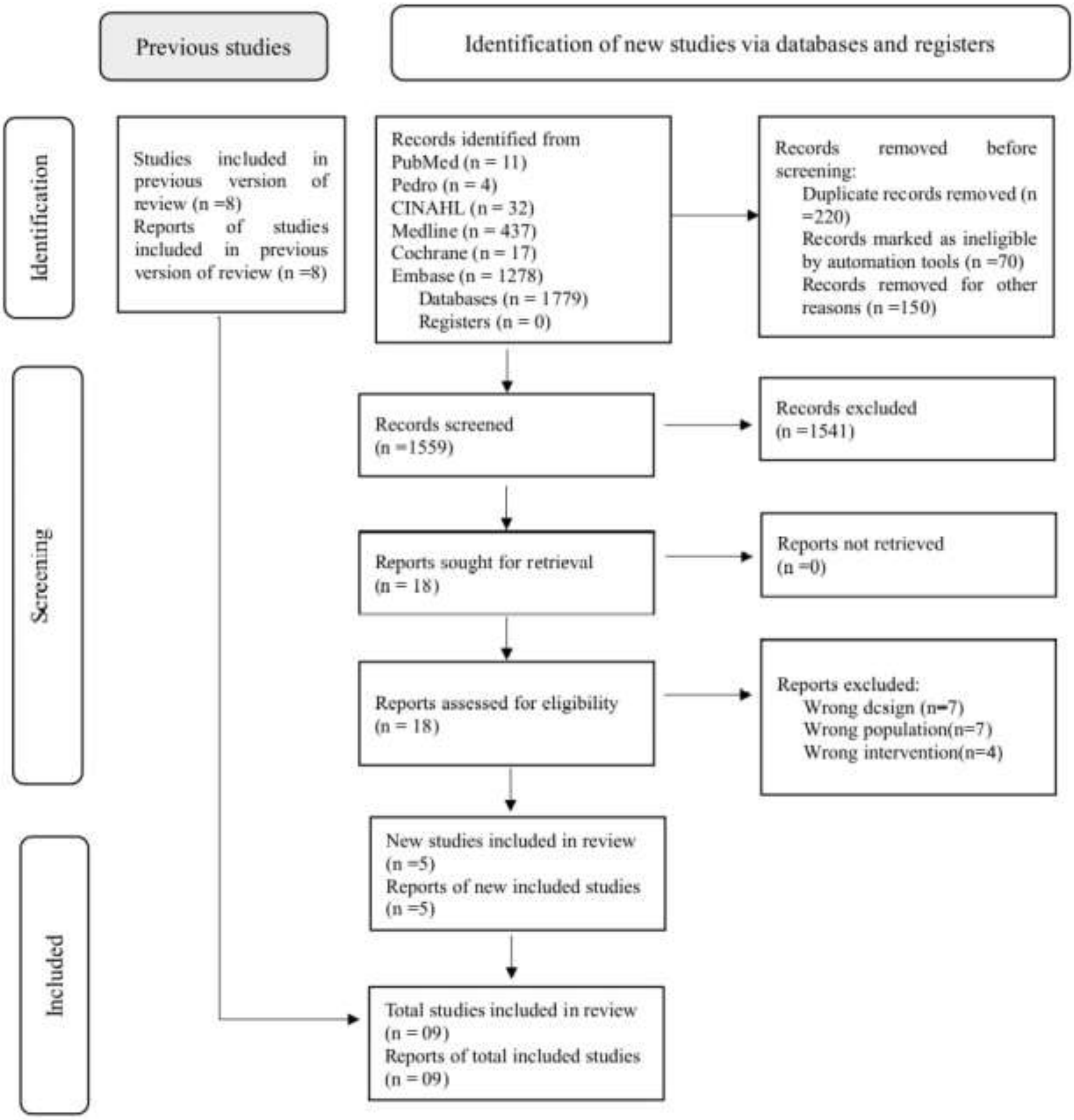

Figure 1: PRISMA flow diagram for updated systematic review which included searches of database and registers only.

3. Data Collection and Analysis

Data Extraction:

A single investigator selected studies based on the inclusion criteria. The reviewer assessed the titles and abstracts of all studies, and the full texts of relevant articles were reviewed and selected if they met the inclusion criteria. The extracted data included study design, study population, physiotherapy intervention, physical effects, chosen outcomes, and key findings.

Assessment of Study's Risk of Bias:

Two investigators independently reviewed the methodological quality of the selected studies and analysed the studieson basis of risk of bias domainsand adding their summary in Table1.

Results:

A search across multiple databases resulted in the extraction of 1779 abstracts. Out of these, nine studies that met the established inclusion criteria and were considered sufficiently significant were selected for further analysis.

Demographics:

The studies included were of the same study design i.e. randomized controlled trail. These studies demonstrated positive effects of physiotherapy interventions in patients recovering from a stroke. Studies revealed that various gait training interventions fixed knee hyperextension by increasing quadricep strength and improving proprioception.

Table No 1. Summary of Review of Literature

Title	Aim of the Study	Study Design	Sample Size	Study Duration	Outcome Measure	Result
Khushboo K. Dala et.al. 2018[12].	The aim of this study was to evaluate the effectiveness of prowling combined with proprioceptive training in reducing knee hyperextension	Randomized Controlled Trail	32 samples	6 sessions	Wilconsin gait scale, Gait analyser to analysis knee and ankle range.	Prowling along with proprioceptive training is effective in reducing knee hyperextension, increasing dorsiflexion range and improving spatio -temporal gait parameters.
Suleyman Korkusuz et.al 2024[15].	To investigate the impact of adding non-immersive virtual reality game-based training to conventional	Randomized Controlled Trail	25 samples	6 weeks	Functional reach test, Timed up and go test, Barthel index and computerized gait analysis.	Non-immersive virtual reality game-based training along with conventional rehabilitation led to improvement in balance and knee hyperextension among the patients.
Ling-Fung Yeung et.al.	We assessed effect of	Randomized	19 sample	3 months	Fugul-Meyer scale,	Robot assisted gait training

Title	Aim of the Study	Study Design	Sample Size	Study Duration	Outcome Measure	Result
2018 [16].	robot assisted gait training with assistance to ankle dorsiflexion.	Controlled Trai	s		Modified Ashworth scale, Berg balance scale, 10m walk test, 6m walk test.	with ankle dorsiflexion assistance improved gait independency and weight bearing.
Ahmad Rifai Sarraj et.al.2019[17].	This study aimed to assess the effect of combining motor imagery (MI) with action observation (AO) on reducing genu recurvatum in post-stroke patients.	Randomized Controlled Trail	20 samples	2 weeks	Motor assessment scale, Electro goniometer to measure ROM.	Motor imagery combined with action observation was effective in reducing genu recurvatum
Yong -Jun Cha et.al. 2018 [18].	The purpose of this study was to determine which type of gait training most effectively enhances walking and balance skills in adult patients with chronic hemiplegic stroke.	Randomized Controlled Trail	31 samples	6 weeks	A 10 -m walking test, functional gait assessment and timed 'up and go	Auditory feedback with active weight bearing on effected extremity is more effective than general gait training in improve the walking and balancing abilities in hemiplegic stroke patients
Jeong lee et.al.2017 [19].	To compare the immediate effect of conventional treadmill gait and guidance tubing gait (GTG) on	Randomized Controlled Trail	33 samples	1 day	Mini-Mental scale, Modified Ashworth scale, Berg balance scale, MMT, ROM of knee, EMG	Guidance tubing gait training was superior over conventional treadmill gait training in improving the knee joint kinematics

Title	Aim of the Study	Study Design	Sample Size	Study Duration	Outcome Measure	Result
	electromyographic neuromuscular imbalance and knee joint kinematics in hemiparetic gait					
ChuanGuo et.al.2015[20].	To investigate the effect of whole-body vibration training on gait performance and lower extremity function in stroke patients with knee hyperextension	Randomized Controlled trail	30 samples	8 weeks	Fugal Meyer Scale, 10m walk test, subjective observation of knee	8 weeks of whole-body vibration training decreases knee hyperextension and enhances walking speed in stroke patients.
Sigal Portnoy et.al.2015 [21].	To evaluate the effect of hinged soft knee orthosis on the gait pattern and symmetry of post stroke patients with chronic symptoms and knee hyperextension	Randomized Controlled Trail	31 samples	8 weeks	Berg balance scale, 6min walk test, 10 min walk test, timed up and go test	Hinged soft knee orthosis can be used to prevent genu recurvatum and restore balance, confidence and improve foot clearance.
Young-hyeon Bae et.al.2014 [22].	To investigate the effect of Gait Training Combined with Functional Electrical	Randomized Controlled Trail	20 samples	5 weeks	Modified Motor Assessment Scale (MMAS), Timed Up-and-Go Test, Berg Balance	Robot-assisted gait training combined with functional electrical stimulation enhances locomotor

Title	Aim of the Study	Study Design	Sample Size	Study Duration	Outcome Measure	Result
	Stimulation on Locomotor recovery in patients with chronic stroke				Scale, gait analyser	abilities and improves knee flexion.

Table 2. Risk of bias domains

Study	D1	D2	D3	D4	D5	Overall
Khushboo K. Dala et.al. 2018	Low	Low	Low	Low	Low	Low
Suleyman Korkusuz et.al 2024	Some concern	Low	Low	Low	Low	Some Concern
Ling-Fung Yeung et.al. 2018	Some Concern	Low	Low	Low	Low	Some Concern
Ahmad Rifai Sarraj et.al.2019	High	Low	Some concern	Low	Low	High
Yong -Jun Cha et.al. 2018	Some concern	Low	Low	Low	Low	Some concern
Jeong lee et.al.2017	Some concern	Low	Low	Low	Low	Some concern
Chuan Guo et.al.2015	Low	Low	Low	Low	Low	Low
Sigal Portnoy et.al.2015	High	Some concern	Some concern	Low	Low	High
Young-hyeon Bae et.al.2014	Low	Low	Some concern	Some concern	Low	Some concern

D1- Bias due to randomization

D2- Bias due to deviation from intended intervention

D3- Bias due to missing data

D4- Bias due to outcome measurement

D5- Bias due to selection of reported result

Clinical Characteristics and Management Strategies:

In a study report conducted by Khushboo K. Dala et.al [12]examined the efficacy of proprioceptive training along with prowling in reducing knee hyperextension. 32 participants selected were divided into two groups with one receiving conventional neurological rehabilitation while, other receiving additional proprioceptive training. Using a Wilcoxon gait scale and gait analyser to interpret the result the study found that participants receiving proprioceptive training showed improvements in ankle dorsiflexion and spatiotemporal gait parameters. Thus, thisresult mimicthe studies, where specific therapeutic interventions targeting the knee and ankle joint resulted in better gait control and reduced hyperextension. Similarly, another report by Suleyman Korkusuz et.al [15] arandomized controlled trial involving 25 subjects, focused on the impact of adding non- immersive virtual reality game-based training to conventional rehabilitation. This study utilized a gait analyser along with other measures to assess the gait pre and post the intervention. The end result showed that there was a positive impact on balance and knee hyperextension among patients who underwent conventional rehabilitation with addition of non- immersive virtual reality game-based training. This research complements a unique finding to achieve reduction in knee hyperextension and gain good dynamic balance among stroke patients. In anotherreport by Ling-Fung Yeung et.al [16]in their randomized controlled trial on 19participants evaluated the impact of a novel robot assisted ankle-foot orthosis (AFO) gait training. This report displayed that using the robot assisted orthosis causedassistance during c gait training causes significant improvements in ankle dorsiflexion during the swing phase and knee flexion during the loading response. Thus, report emphasized the benefits of using orthotic devices to enhance gait mechanics in stroke patients. Extending the focus on improvinggait, by means of a physical intervention another study report was conducted by Ahmad Rifai Sarraj et.al [17] that explored the impact of cognitive interventions on gait rehabilitation. The electro goniometer and motor assessment scale were used as the outcome measure. Theyconducted a comparative study in which a total of 22 subjects were selected and allotted into 2 groups. The end result of the comparative study demonstrated that participants receiving motor imagery combined with action observation exhibited significantly greater improvements compared to those receiving conventional neurological rehabilitation. This emphasizesthe potential of integrating cognitive therapies as a unique physical intervention for effective gait rehabilitation strategies. Further emphasizing on another unique practice to reduce knee hyperextension was to make use of an external auditory feedback. This report was conducted by Yong-Jun Cha et.al [18]a single blinded randomized controlled comparative study on 31 participants who were assembled into 3 groups. At the end of the study report their results indicated that active weight-bearing on the paretic limb with auditory cues was particularly effective in enhancing both walking and balance. This feedback-based approach complements findings from studies utilizing orthoses, suggesting that sensory feedback mechanisms canalso play a crucial role in improving motor control and gait during rehabilitation. Also, Jeong J. Leeet.al [19]in a randomized controlled trial on 33 subjectsinvestigated a novel form of assisted gait training using guidance tubing to stabilize the knee during midstance and increase knee flexion during mid-swing. The subjects were arbitrary divided into two groups. The control group received conventional treadmill gait training while the experimental group received guidance tubing gait training. Ashworth scale, sensory test, manual muscle testing knee joint range of motion and Korean mini mental scale were used as the outcome measures. The result of the trail demonstrated superior improvements in knee joint range of motion and strength in the experimental group. This mechanical assistance method, much like orthoses and feedback mechanisms, proved effective in optimizing knee function and overall gait performance. However, another unique thought by Chuan Guo et.al [20]addeda different dimension to gait rehabilitation by introducing whole-body vibration training. In this randomized controlled trail, 30 participants were divided into 2 groups. The control group was given placebo while the experimental group underwent 8 weeks of whole-body vibration training which included squats, single leg stance along with vibration training. Outcome measures were assessed pre and post the test. The end result concluded that participants who underwent 8 weeks of vibration training showed significant reductions in knee hyperextension and improvements in walking speed. This innovative approach broadens the repertoire of interventions available for enhancing gait mechanics and emphasizing the versatility of modern rehabilitation techniques. In the similar vein Sigal Portnoy et.al [21] also conducted a study investigating the effects of another external hinged knee orthosis on gait parameters. In this randomized controlled trail 31 participants who met the inclusion criteria were selected. Berg balance scale, 6-minute walk and 10-meterwalk test along with time up and go test were the outcome measures used to assess. The end result of this report also suggested that orthosis can significantly reduce knee hyperextension and improved knee flexion during the swing phase, ultimately increasing foot clearance. This finding supports the widespread conclusion that orthotic devices along with gait rehabilitation are effective in improving gait dynamics, particularly by mitigating hyperextension of knee. Finally, Young-Hyeon Bae et.al [22]explored a unique approach of robotic assistance with electrical stimulation. 20 participants were included and divided into two groups. The control group underwent robot assisted gait training while the experimental group underwent robot assisted gait training along with functional electrical stimulation for ankle dorsiflexors of affected limb. The result observed on basis of pre and post outcome revealed that combined robot assisted gait training with functional electrical stimulation showed better improvement in locomotor recovery along with significant improvement in knee flexion with underscoring the benefits of integrating robotic technology with electrical stimulation in enhancing gait.

4. Discussion

The present study reviewed significant research from the past 10 years on various gait training interventions for managing knee hyperextension in post-stroke patients. A total of 11 relevant studies were identified, most of which were based on randomized controlled trials, offering strong evidence for treatment approaches along with the use of an external orthosis. Khushboo K. Dala et.al [12] concludedin theirstudy that walking with bilateral knee flexion (Prowling) increased quadricep strength and improved motor control of the knee joint, resulting in reduced knee hyperextension. Additionally, proprioceptive training enhanced muscle strength and neuromuscular control, allowing for better joint position sense and improved control of terminal knee extension during walking. Similarly, Suleyman Korkusuz et.al [15]alsoemphasized that knee hyperextension along with dynamic balance can be improved with addition of non-immersive virtual reality game-based training to conventional rehabilitation. Their findings indicated that combined training led to improved specific muscle activation and control along with screen-based task caused patients to stabilize their body and maintain balance along with relying on their knee for support thus causing compressive forces on knee joint thereby improving proprioception and joint sense. Thus, this led to a unique pathway of effectively managing knee hyperextension among the post stroke patients. In another study report by, Ling-Fung Yeung et.al [16]found that a robot assisted ankle-foot orthosis used during gaittraining led to correctingknee hyperextension (genu recurvatum) during the stance phase. The result stated that using the robot assisted ankle-foot orthosis led to passive assistance during walking. It reduced knee hyperextension by providing controlled support and assistance to ankle during the gait cycle thus enhancing stable functional gait mechanics. While, Ahmad Rifai et.al [17]demonstrated a unique approach to reduce hyperextension of the knee througha combined technique of motor imagery and action observation. The end result of the report stated that motor imageryand action observation (MI+AO) combined proved to be more effective than conventional rehabilitation in reducing knee hyperextension among stroke patients. Cognitive training through motor imagery and action observation led to a unique observation with significant reduction in knee hyperextension after the intervention. Another, report suggested by Yong-Jun Cha et.al [18] uncovered the impact of auditory feedback in improving gait and balance. The auditory feedback facilitated appropriate weight shifts, improving weight support on the paretic limb during the stance phase, which resulted in better balance and walking ability. Thus, formulating it to be superior over general gait training in improving walking and balance ability. Similarly. Jeong lee et.al [19] report stated similar results to that of previous report that showed proprioception to have positive impact on hyperextended knee among stroke patients. Thus, current report stated that guidance tubing gait training was effective in restoring knee joint imbalance in stroke patients with knee hyperextension gait. The improvement in proprioception and joint sense led to corrected kinematic knee joint movement patterns during dynamic locomotion in post stroke individuals. Later in similar manner, Chuan Guo et.al [20]conducted ainterventionthat varied from the rest showing the positive impact of an 8-week whole-body vibration training in significantly reducingknee hyperextension and thus improving walking speed in stroke patients.The training improved proprioceptive input, enhancing muscle activation and knee control, which led to reduced knee hyperextension among the post stroke patients. Additionally, Sigal Portnoy et.al

[21]made use of an external hinged knee orthosis that could effectively prevent hyperextension of the paretic limb, thus increasing the knee flexion range during the swing phase. This device not only prevented the paretic knee from going into hyperextension but also facilitated better knee flexion. Finally, Young-Hyeon Bae et.al [22] madeanother unique approach in reducing knee hyperextension among stroke patients by using robotic assistance with electrical stimulation. The end result showed significant improvement in knee flexion and changes in stride length thus, ultimately leading to reduction in knee hyperextension.

5. Summary

A total of 09 articles were included in this study. The reviewed articles had consistent study design i.e. randomized controlled trial. one articles that were included in the study had a study duration for one day the rest remaining studies had a minimum duration of 1 week and maximum of 8 weeks. All the studies had worked in improving and preventing knee hyperextension among stroke patients.

6. Conclusion

A total of 09 articles were included in this study, all of which adhered to a consistent study design—specifically, randomized controlled trials—offering strong evidence for the findings. Of these studies, one had a duration of just one day, while the remaining studies spanned between one week and eight weeks. Each study focused on exploring various interventions aimed at improving and preventing knee hyperextension in stroke patients. The diverse durations of these studies provided valuable insights into the short-term and long-term effects of the interventions. Several techniques, such as prowling (bilateral knee flexion walking), proprioceptive training, whole-body vibration therapy, functional electrical stimulation, and the use of various orthotic devices combined with robot assisted gait traininglike ankle-foot orthoses were shown to be potentially effective in managing and reducing knee hyperextension. These methods collectively highlight the importance of targeted interventions in addressing gait abnormalities in post-stroke rehabilitation, offering a broader understanding of how to effectively manage knee hyperextension through both conventional and advanced therapeutic approaches.

Conflict of Interest: None.

Acknowledgement: The authors mentioned above would sincerely like to extend gratitude towards our colleagues from the department of neurosciences of Krishna College of Physiotherapy.

References:

[1] HassanIM, Elkeblawy MA, Elerian AE, Shehata HS, Elsherif AA, Elkeblawy MM:Electromotive drug administration of magnesium sulphate on spastic gastrocnemius muscle ofstrokepatients. J Pharm Negat Results.2022,13:1443-1451.**10. 47750/pnr.2022.S3.S06.192**

[2] Kamalakannan S, Gudlavalleti ASV, Gudlavalleti VSM, Goenka S, Kuper H: Incidence and prevalence of stroke in India. A systematic review. Indian J Med Res. 2017, 146:175-185.https://pubmed.ncbi.nlm.nih.gov/29265018

[3] Kuriakose D, Xiao Z: Pathophysiology and treatment of stroke. Present status and Future Perspectives. Int J Mol Sci.2020, 21:7609.**10.3390/ijms21207609**

[4] O'Sullivan SB, Schmitz TJ, Fulk G: Physical rehabilitation.O'Sullivan SB, Schmitz TJ, Fulk G (ed 6th): F.A. Davis USA; 2014.

[5] Rymer MM: Hemorrhagic stroke.Intracerebral hemorrahage. Mo Med. 2011, 108:50-54.https://pubmed.ncbi.nlm.nih.gov/21462612

[6] Liu J, Zhu Y, Wu Y, Liu Y, Teng Z, Hao Y: Association of carotid atherosclerosis and recurrent cerebral infraction in the Chinese population: A meta-analysis. Neuropsychiatr Dis Treat. 2017, 13: 527-

533.10.2147/NDT.S124386

[7] Kamalakannan.SK, Venkata MG, Prost. A, et.al:Rehabilitationneeds of stroke survivorsafter discharge fromhospital in India. ArchPhys Med Rehabil. 2016, 97:1526-1532.10.1016/j.apmr.2016.02.008

[8] Li S, Francisco EG, Zhou P: Post -stroke hemiplegic gait. New perspective and insights.Front Physiol. 2018, 9: 1021.10. 3389/fphys.2018.01021

[9] Bleyenheuft C, Bleyenheuft Y, Hanson P, Deltombe T: Treatment of genu recurvatum in hemiparetic adult patients. A systematic literature review. AnnPhysRehabil. Med. 2010, 53:189–199.**10.1016/j.rehab.2010.01.001**

[10] Geerars M, Van der feenNM, Huisstede B: Treatment of knee hyperextension in post- stroke gait. A systematic review.Gait and Posture. 2022, 91:137-148. 10.1016/j.gaitpost.2021.08.016

[11] HigginsonJS, Zajac FE, Neptune RR, Kautz SA, BurgarCG, Delp SL: Effect of equinus foot placement and intrinsic muscle response on knee extension during stance. Gait and Posture. 2006, 23:32–36**.10.1016/j.gaitpost.2004.11.011**

[12] Dalala KK, Joshuaa AM, NayakaA, MithrA P, Misri P,Unnikrishnan B: Effectiveness of prowling with proprioceptive training on knee hyperextension among stroke subjects using videographic observation. A randomised controlled trial. Gait & Posture. 2018,61:232–237.**10.1016/j.gaitpost.2018.01.018**

[13] Li W, Li T, Xi X,Zhang R et.al: Does higher knee hyperextension in patients with hemiplegia affect lateral and medial meniscus volume in the paretic leg. A cross-sectional study.SportsSci Med Rehabil.2023, 15:4.**10.116/s13102-022-006111**

[14] Levangie PK, Norkin CC: Joint structure and function. A comprehensive analysis. Levangie PK, Norkin CC (ed 5th): F.A. Davis, USA; 2011.

[15] Korkusuz S, Taskin G, Korkusuz BS, Ozen MS, Yuruk ZO: Examining the effects of non-immersive virtual reality game-based training on knee hyperextension control and balance in chronic stroke patients. A single blinded randomized controlled study. Neurol Sci. 2024. 10.1007/s10072-024-07830-z

[16] Yeung LF, Ockenfeld C, Pang MK, Wai HW, Soo OY, Li SW, Tong KY: Randomized controlled trail of robot assisted gait training with dorsiflexion assistance on chronic stroke patients wearing ankle-foot orthosis. J Neuroeng Rehabil. 2018, 15: 51. 10.1186/s12984-018-0394-7

[17] Sarraj AR, Jammoul N, Zeid PA, Khatib A: Effectiveness of motor imagery combined to action observation in controlling stroke-related genu recurvatum: A randomized controlled trail. Fifth international conference on Advances in Biomedical Engineering (ICABME). 2019. **10.1109/ICABME47164.2019.8940192**

[18] ChaYJ, KimJD, Choi YR, Kim NH, Son SM: Effects of gait training with auditory feedback on walking and balancing ability in adults after hemiplegic stroke: a preliminary,randomized controlled study. IntJ Rehabil Res. 2018, 41:239- 243.10.1097/MRR.0000000000000295

[19] Lee. JJ,YouJH: Effects of novel guidance tubing gait on electromyographic neuromuscular imbalance andjoint angular kinematics during locomotion in hemiparetic stroke patients.Arch Phys Med Rehabil. 2017, 98:2526-2532.**10.1016/ j.apmr.2017.04.018**

[20] Guo C, MiX, Liu S, et.al. Whole body vibration training improves walking performance of stroke patients with knee hyperextension: A randomized controlled pilot study. CNS NeurolDisdord Drug Targets. 2015,14:1110-1115.10.2174/ 1871527315666151111124937

[21] Portnoy S, FrechtelA, RavehE, Schwartz I: Prevention of genu recurvatum in poststroke patients using a hinged soft knee orthosis. PM&R. 2015, 7:1042-1051.**10.1016/j.pmrj.2015.04.007**

[22] Bae YH, Ko YJ, Chang WH, et.al: Effects of robot-assisted gait training combined with functional electrical stimulation on recovery of locomotor mobility in chronic stroke patients: A randomizedcontrolled trail. J Phys Ther Sci. 2014, 26:1949-1953.**10.1589/jpts.26.1949**