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Effect of Rigid Ankle Foot Orthosis on Postural Control and Functional mobility in Chronic Ambulatory Stroke Patients

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Abstract

Stroke is the leading cause of long-term disability in adults. Damage to the motor cortex or corticospinal tract often results in contralateral hemiplegia with significant persistent distal weakness. Gait impairments are common in stroke patients and are mainly attributed to motor control deficits. Majority of the stroke patients exhibit a spastic equinus foot. This is usually related to spasticity of triceps surae or contracture of this muscle or tendon, resulting in reduced active ankle dorsiflexion both during stance and swing phases, which is referred to as drop foot. Another common finding in the gait of stroke patients is varus deformity of the foot, which is frequently caused by spasticity of the posterior tibial muscle.

Keywords: Stroke; Ankle foot orthosis; Equinovarus foot shift; Spasticity

Introduction

Equinovarus foot shifts the weight support of the heel to the lateral plantar surface of the foot, and may cause a loss of balance and a reduction in stride security. Insufficient dorsiflexion during the swing phase, ankle instability, and poor lift during the last phase of walking all disturb the normal walking pattern [1,2]. Patients are unable to successfully transfer weight in the frontal plane during the transition to single-limb stance [3]. This gait impairment can result in compensatory movement patterns, slowed gait velocity, limited functional mobility, and increased risk of falls [4]. Postural control is also affected and causes problems with static and dynamic balance, thus increasing the risk of falls and secondary injuries [5].

An ankle-foot orthosis (AFO) is typically used as an adjunct to physical therapy to compensate for the effects of impairments on walking, in particular in cases of equinus and/or varus foot for inadequate dorsiflexion in swing and mediolateral subtalar instability during stance [6,7,8]. It is presumed that bracing with the AFO compensates for the weakness of muscles around the affected foot and improve peripheral stability preventing foot drop during swing phase ensuring toe clearance and proper contact with the heel. Such approach is found to be effective for improvement in gait parameters such as velocity, cadence, and step length. Few studies have also reported a positive effect on the patient's self-confidence during functional activities [9,10].

Evidence regarding biomechanical effects of AFOs on balance post stroke is inconclusive and less strong than for the effects of AFOs on gait [11,12]. Currently available clinical evidence consists of just a few articles with small sample sizes and poor methodological quality [9, 13-16]. There is a lack of insight into the influence of orthoses on the underlying impairments and there are no evidence based guidelines for AFO prescription. AFOs are routinely prescribed to stroke patients in the acute stage which the patient continues to use even in the chronic stage which can lead to certain negative effects on postural control. The "traditional" ankle-foot orthoses are rigid and designed to immobilize the ankle joint at a right angle or in one or more planes. Given that balance may be compromised when joint range of motion is restricted, an understanding of the relative effects of AFOs on balance performance is clinically relevant. Previous literature is controversial and the value of orthoses used in stroke patients is still a matter of debate. Few studies indicate that the use of such an orthosis may force adaptive behavior on the individual by interfering with the ankle plantarflexion that occurs at the balance activity. Some researchers hold the view that an AFO can prolong dependence on a mechanical device, leading to an increase in muscle disuse, especially the dorsiflexors of the ankle, with a consequent delay in functional recovery [4]. Methodological limitations exist as most studies are based on evaluation in acute phase and very few studies have addressed the effects of an AFO on the balance activities of chronic hemiplegic patients. Moreover, we could not find any published information on the effects of AFOs on balance performance of stroke survivors using quantitative balance measures.

Thus, this study aimed to determine the effect of rigid AFO on postural control and functional mobility of chronic ambulatory stroke patients. Results of this study will enhance our understanding of the effects of AFO on postural control and provide better basis for prescription of AFOs in ambulatory patients with stroke.

Materials and Methods

This was a crossover, quasi-experimental study with within-subject, repeated measures design and randomization for interventions. It was conducted on a convenience sample of stroke patients receiving outpatient rehabilitation in a tertiary care centre. Individuals i) between the age group 18-65 years, ii) having unilateral hemiplegic involvement due to stroke, iii) duration of stroke > 6 months, iv) spasticity <3 on modified Ashworth scale, v) passive dorsiflexion of ≥ 90º with the knee extended, vi) using rigid AFO for last ≥ 2-3 weeks, viii) able to stand up from a chair independently, ix) ability to remain standing unaided for 20 to 90 seconds with and without AFO, x) ambulatory xi) sufficient cognitive ability to understand the task (MMSE score ≥ 24) were recruited. Individuals were excluded from participation if they had i) complete sensory loss in lower extremity, ii) perceptual deficits, iii) uncorrected visual impairment, iv) vestibular impairment, v) neurological conditions apart from stroke, vi) symptomatic musculoskeletal conditions which affect balance and mobility, vii) unstable medical conditions, viii) skin or other lesions contraindicating AFO. Institutional review board approved design and conduct of the study. The procedures followed protocol and accord with the ethical standards of the institutional review board. All the participants were volunteers and informed written and verbal consent was obtained from them before participation in the study. For every participant demographic data, duration of stroke, duration of rigid AFOs use, MMSE score, ankle range of motion by goniometry, ankle voluntary control, ankle muscle spasticity using the modified Ashworth scale was recorded. 57 individuals were screened and 42 patients met the study criteria.

The AFO prescription was made by a neurophysiotherapist after thorough evaluation. Majority of the patients had spastic equinovarus foot with dynamic deformity requiring an AFO. The AFO provided was rigid polypropylene and custom-moulded (by an orthotist). Patients received gait and other functional mobility training while wearing the AFO and were encouraged to use it throughout the day especially while walking. As per requirement of the study, patients were enrolled if they had been using the AFO for previous ≥ 2-3 weeks to be considered as habitual users. Only those individuals who showed good compliance and adherence to the AFO use (usage for more than 80% during ambulatory activities) were included in the study. Out of 42 patients enrolled after initial screening, 30 patients met this criterion and hence were considered for further assessment.

All the subjects were assessed under two test conditions viz. ‘with AFO’ and ‘without AFO’ (barefoot) and the order of testing were randomized to eliminate practice effect. The ‘without AFO’ condition served as a control condition. Adequate rest period was given between the tests. Use of assistive devices was prohibited during the tests.

Postural control was assessed from Center of Pressure (COP) based measures obtained using Basic balance manager system (Neurocom International, version 8.6) [17]. Functional mobility was assessed using Timed Up and Go Test [18].

Postural control on balance manager system

The Balance Master equipment consists of a fixed force plate (approximately 18” × 60”) that rests on force transducers mounted along the front-to-back center line of the plate and are connected to a personal computer with its monitor positioned at eye level. This force plate detects the vertical forces exerted through the patient's feet to measure center of gravity position and postural control. These technologies have been found to possess good to excellent reliability for static and dynamic balance assessment in stroke [19].

Static postural control was assessed with mCTSIB test and dynamic postural control was assessed using Limits of Stability; Sit to Stand; and Walk Across test. The footprints were marked to ensure constant foot position and base of support during subsequent assessments in both the conditions.

mCTSIB=modified Clinical Test of Sensory Interaction on Balance: mCTSIB is a modification of the original CTSIB [20] or “Foam and Dome,” in which balance control is assessed under altered visual and/or surface conditions. The mCTSIB eliminates the “dome” and adds objective analysis of a patient’s functional balance control to quantify postural sway velocity during four sensory conditions: 1. Eyes open firm surface 2. Eyes closed firm surface 3. Eyes open unstable surface (foam) 4. Eyes closed unstable surface (foam) [17].

For this test, the subject was instructed to stand on the force platform with hands relaxed by the side, lateral malleolus perpendicular to the horizontal line marked on the force plate. Majority of the patients were unable to stand on foam surface, thus, the subject was assessed on firm surface only, under two conditions viz. firm surface-eyes open and eyes closed conditions. Each condition involved three trials of 10 seconds each. The parameter recorded was COP sway velocity (degrees/second). 3 readings were taken and average value was noted for each condition.

Limits of Stability (LOS): The LOS protocol quantifies impairments in ability to intentionally displace the center of gravity (COG) to the patient’s stability limits without losing balance. The patient performs the task while viewing a real-time display of their COG position in relation to targets placed at the center of the base of support and at the stability limits.

The LOS quantifies the maximum distance the patient can intentionally displace their COG in the four cardinal directions and the four diagonal directions, and maintain stability at those positions. These eight directions involve- Forward, Right Forward, Right, Right Backward, Backward, Left Backward, Left, and Left Forward. Patient is instructed to hold the cursor in a centrally positioned target box representing the patient's COG. For each of eight trials, the patient, on command, moves the COG cursor as quickly and accurately as possible towards a second target located on the LOS perimeter, set at 100% of the theoretical limits of stability, and then holds a position as close to the target as possible. The patient is allowed up to 8 seconds to complete each trial. Subjects are instructed not to move their feet and are asked to stand with their arms at their sides throughout the testing procedure.

For each of eight directions, the test measures movement reaction time, movement velocity, movement distance, and movement directional control. Maximum excursion is the maximum distance achieved during the trial (expressed as % of the theoretical limit of stability) and was considered for analysis in this study.

Sit to Stand (STS): The STS quantifies the patient's ability to rise from a seated to a standing position. Key components of this task include shifting the body COG forward from an initial position over the seat to a location centered over the base of support, followed by extension of the body to an erect stand while maintaining the centered COG position. The measured parameters were weight transfer time, rising index (force exerted to rise), sway velocity after rising phase, and left/right symmetry of the rising force.

- Weight Transfer is the time in seconds required to voluntarily shift COG forward beginning in the seated position and ending with full weight bearing on the feet.
- Rising Index is the amount of force exerted by the legs during the rising phase. The force is expressed as a percentage of the patient's body weight.
- COP Sway Velocity documents control of the COG over the base of support during the rising phase and for 5 seconds thereafter. Sway is expressed in degrees per second.
- Left/Right Weight Symmetry documents differences in the percentage of body weight borne by each leg during the active rising phase.

Walk across Test (WA): The WA quantifies characteristics of gait as the patient walks across the length of the force plate (approximately 18" × 60"). The test characterizes steady state gait by having the patient begin well behind and continuing beyond the force plate. Patient is instructed to walk at his/her usual speed and with as natural pattern as possible. Measured parameters are average step width, average step length, speed and step length symmetry.

TUG test

The timed up and go (TUG) test developed by Podsiadlo and Richardson [18] is a simple method used to evaluate functional mobility. This test measures, in seconds, the time taken by an individual to stand up from a standard arm chair (approximate seat height of 46 cm, arm height 65 cm), walk a distance of 3 meters (approximately 10 feet), turn, walk back to the chair, and sit down. No physical assistance was provided. The time taken was recorded in seconds using a stopwatch. TUG task includes diverse components different from ambulation velocity and distance. In persons with chronic stroke, the TUG test has been proven to have a high inter-rater reliability (ICC=0.95-0.96) and test-retest reliability (ICC=0.99) [21].

All the assessments were carried out under standardized conditions. All the tests were administered by the same investigator and in an identical manner under both the conditions.

Statistical analysis

Data thus collected was subjected to statistical analysis. A comparative analysis between two test conditions viz. with AFO and without AFO was performed. AFO served as an independent variable whereas postural control and functional mobility served as dependent variables.

Descriptive statistics: Mean and Standard Deviations for the quantitative variables and percentage frequencies for the categorical variables were calculated.

Inferential statistics: Normality of data was assessed using the Kolmogorov-Smirnov Test. The data passed the normality test; therefore, parametric test viz. paired t test was used for comparative analysis. Statistical significance was set at P value < 0.05 level (two-tailed).

Results

Demographic characteristics of the participants are given in **Table 1**. Results of the statistical analysis are summarised in **Table 2**.

Table 1: Sample characteristics.

Characteristics	Values
Age (years) mean ± SD	50.6 ± 9.96
Gender (M/F)	2:03
Side of hemiplegia (Right/Left)	2:03
Time since stroke (months) mean ± SD	17.2 ± 8.52
Duration of AFO use (months) mean ± SD	6.6 ± 7.65

Discussion

Postural sway during quiet stance

A statistically significant increase in sway velocity was observed with static AFOs during quiet stance under both eyes open and eyes closed condition. Similar findings have been reported by Panwalkar N and Aruvin AS [22] on modified CTSIB in healthy subjects. The researchers observed that "when active ankle joint movements were constrained by the AFOs, the center of gravity sway was significantly larger as compared to the conditions with no AFOs." This finding could be attributed to reduced proprioceptive feedback while wearing AFO thereby increasing sway velocity. Also, in the present study, sway velocity was affected more when eyes were closed than in eyes open condition. It has been reported in previous studies that patients with stroke rely more on visual feedback for their postural control [23].

Limits of stability

Maximum excursion with AFO significantly reduced in anterior direction, followed by lateral and posterior direction on the affected side. The rigid AFO may show some ankle dorsiflexion motion at weight acceptance as the polypropylene is stressed and bends slightly. However, as the subject progresses further forward, the polypropylene rebounds to its original position. Thus, while braced with rigid AFO, overall the translation of the body over a fixed base of support is blocked along with blocking the ankle strategy. Excursions may be restricted by biomechanical limitations and are indicators of motor control abnormalities which are further aggravated with AFO. In contrast, Chen et al. [14] reported significant positive effects of anterior AFO in long-term hemiplegic patients on lateral weight shifting and weight bearing through affected leg after weight shifted to the affected side and no significant effect anterior-posterior weight shifting. It is important to note that this study involved hemiplegic subjects with either acute or chronic stroke.

Table 2: Comparative analysis between 'without AFO' and 'with AFO' condition.

Test	Parameters		Without AFO		With AFO		p value
			Mean	SD	Mean	SD	
mCTSIB	COP sway velocity (deg/sec)	Eyes open	0.59	0.21	0.83	0.25	0.0197*
		Eyes closed	0.77	0.37	1.16	0.41	0.0101*
LOS	Maximum excursion (%)	Anterior	52.5	20.87	45.9	16.71	0.0213*
		Affected side-anterior	46.8	17.57	40.2	18.39	0.0385*
		Affected side	42.6	19.39	32.7	17.56	0.0493*
		Affected side-posterior	53.6	22.4	34.1	15.6	0.0455*
		Posterior	47.6	22.9	42.1	26.45	0.1033
		Unaffected side - anterior	66.2	25.99	57.8	13.33	0.2338
		Unaffected side	61.9	13.52	55.2	14.76	0.5299
		Unaffected side - posterior	59.4	18.24	58	17.48	0.851
Sit to stand	Left/Right weight asymmetry (%)		27	11.54	18.55	11.3	0.0123*
	Weight transfer time (sec)	2.29	2.32	1.85	1.71	0.0218*	
	Rising index	14	6.87	10.77	5.63	0.0443*	
	Sway velocity (deg/sec)	4.02	2.48	6.71	1.41	0.0467*	
Walk across	Step width (cm)		18.43	2.81	20.23	3.3	0.0450*
	Step length (cm)	19.74	6.18	22.07	10.99	0.0391*	
	Speed (cm/sec)	19.89	8.86	14.17	13.96	0.0567*	
	Step length asymmetry	29	33.23	32.7	19.29	0.0593*	
TUGT	Time (sec)		22.5	3.06	29.9	3.46	0.0261*

*p value < 0.05 considered as significant (two-tailed)

Sit to stand

Hemiplegic patients exhibit asymmetric posture with difficulties in the ability to transfer their weight in various directions during standing tasks, especially evident when rising from a chair [24]. This postural asymmetry is associated with impaired gait and risk of fall in stroke patients. In the present study, symmetry during sit to stand significantly improved whereas weight transfer time significantly reduced with AFO. Both these findings could be attributed to improved ankle stability with AFO by keeping the ankle joint in proper alignment and providing external support thus improving weight bearing through the affected leg. Wang et al .[15] reported improved symmetry of weight distribution with an AFO in standing whereas Kim KD, et al. [25] reported that chronic stroke patients showed wearing the AFO aided performance of various functional standing tasks through better alignment and increased weight-bearing ability on the affected side. In accordance with these studies and the results obtained AFO is thus, supposed to provide better alignment and stability at the ankle conductive to functional activities. A detrimental effect, however, was observed as sway velocity during sit to stand significantly increased. This could be due to reduced proprioceptive feedback with AFO as mentioned previously [22]. Rising index reduced with AFO which was statistically significant. Increased weight of AFO could not be taken by weak hemiplegic limb leading to increased effort for standing thereby reducing the rising index. Contrasting findings were observed in a study which showed increase in the rising index along with other balance related parameters with AFOin hemiplegic patients with less than 6 months duration [26].

Walk across

Step width significantly increased with AFO. This is also reported in study by Abe H [27] on stroke patients using plastic AFO. Author concluded that increased step width is due to widening of toe out angle while wearing AFO and not due to gait instability. Reduced proprioceptive feedback with AFO may deteriorate balance, so to maintain COG within BOS step width may increase as a compensatory mechanism.

Step length significantly improved with AFO. This is in accordance with the study performed by Stefan Hesse S [28] which concluded that the orthosis led to a more dynamic and balanced gait, with enhanced functional activation of the hemiparetic vastus lateralis muscle. Thus, AFO seems to exert a positive effect on step length. However, subjects exhibited significantly lesser symmetry in step length with AFO during gait, the reason for which is unknown.

Speed significantly reduced with AFO because of increased weight of AFO on the weak hemiplegic side. James Lewallen et al. [29] also concluded that solid AFO was shown to result in the most compromised gait when considering speed, step length, and single stance time forchronic stroke patients with a functional ambulation category of 4 or 5.

TUG test

Tug test score significantly reduced in all the participants with AFOindicating that longer time was taken to complete the mobility task with AFO. The speed during walking reduces with AFOs is also supported by study performed by James Lewallen et al. [29]. On the contrary, in favour of AFO, D CM de Wit et al. reported a change in the TUG test of 3.6 seconds which was statistically significant but too small to be clinically relevant [9]. This study included chronic stroke patients, wearing an AFO for at least six months. More familiarity with AFO could be the reason for disparity in the findings observed in the reported and present study.

The visual, proprioceptive, and vestibular systems are critical sources of afferent information that affect postural control and spatial orientation [30]. Postural control requires complex interaction between the musculoskeletal and neurological systems. It involves muscle properties, range of motion, flexibility, and biomechanical relationships between bodily regions, motor processes, sensory perception processes, and higher processing levels ranging from sensation to action with anticipatory and adaptive aspects.

Proprioception is an essential feedback required to balance body in space. AFO is suspected to block the proprioceptive inputs from the ground to the foot leading to deterioration of some balance related parameters. The modification of lower limb muscle activity may be linked to alteration in the proprioceptive input from the foot and ankle joint mechanoreceptors and feedback from the muscle/tendon stretch receptors that are caused by constraining the ankle with a rigid AFO. Further with use of AFO on one side and thus the asymmetrical somatosensory modification may impair brain's capacity to deal as compared to bilateral constrained condition [31].

Panwalkar N. &AruinAS [22] found that the use of bilateral AFOs impeded the performance of the mCTSIB, the Limits of Stability and the Functional Reach test even in healthy subjects. The researchers observed that "when active ankle joint movements were constrained by the AFOs the center of gravity sway was significantly larger as compared to the conditions with no AFOs." Simons et al. [32] in a mixed sample of acute and chronic stroke patients found no significant effects of AFOs for weight-bearing asymmetry and dynamic balance contribution of the paretic lower limb. However significant differences in favour of ankle-foot orthosis use were found for most functional balance tests including BBS and TUGT. Apparently, improvements at functional level cannot be readily attributed to a greater contribution of the paretic lower limb to weight-bearing or balance control, suggesting that AFOs influence compensatory mechanisms. Also, many other studies have demonstrated an improvement with AFO in clinical and/or functional balance tests using other measures [33]. Correct foot posture is required to maintain the kinetic and kinematic chain of the lower limb necessary to maintain balance and functional mobility. Use of rigid AFO helps in correcting the commonly found equino-varus deformity of foot thereby showing improvement in some balance related parameters.

Perry demonstrated that the range of ankle motion for normal subjects during walking is 10º of dorsiflexion to 15º of plantarflexion [34]. TheAFO's rigid posterior section are reported to lock the ankle in a functional position and block the ranges possible at the ankle joint thus reducing movement. The rigid AFO may show some ankle dorsiflexion motion at weight acceptance as the polypropylene is stressed and bends slightly. However, as the subject progresses further forward, the polypropylene rebounds to its original position. Thus, while braced with rigid AFO, overall the translation of the body over a fixed base of support is blocked along with blocking the ankle strategy. Carmick J [35] also pointed out that the disadvantage of the rigid AFO was its limitation of normal movement of the tibia forwards over the weight bearing foot resulting in decreased ankle dorsiflexion and early heel rise in stance. Thus, excursions and weight shifts may be restricted by biomechanical limitations and are indicators of motor control abnormalities which are further aggravated with AFO. To maintain balance during perturbations certain motor strategies are present at the ankle joint, such as action of plantarflexion in response to small perturbation to maintain COG within the BOS. These actions are blocked by the rigid AFO thus deteriorating balance as observed during limits of stability test. Hesse S. et al. [28] using kinesiological electromyogram found reduced activity in the paretic tibialis muscle with rigid AFO and suggested that this may lead to disuse atrophy and hence long-term dependence on the orthosis. Prolonged use of AFO has shown to cause disuse atrophy of the tibialis anterior muscle in ambulatory stroke patients [36]. Also, it has been reported that the TUG test has significant relationships with the affected-side ankle joint dorsiflexion muscular strength (r=−0.67) [37]. Thus, it can be speculated that the chronic population of stroke who participated in this study may have already developed muscle weakness due to orthotic intervention further contributing to impairment in their postural control. However, apart from these preliminary findings, it remains unclear whether the mechanical properties of the AFO affect the level of muscular activity in the lower limbs.

Wong M., et al. reviewed effects of different types of AFO on gait in hemiplegic stroke patients [38]. Unlike the solid AFO, the hinged AFO with plantarflexion stop allows the tibia to move forward over the weight bearing foot during stance resulting in more normal dorsiflexion motion. Walking with an effective roll-over may facilitate forward progression. Gok et al. reported similar positive mechanical effects of metallic and plastic AFOs on severely hemiparetic stroke patients [39]. However, metallic AFOs provided better stabilization of the ankle and dorsiflexion angle than the plastic AFO, allowing improved heel strike and push-off. Tyson et al. reported improvements in functional mobility and in some gait impairments viz. stride length of the weak and sound legs, velocity; and cadence but with hinged AFO [40]. No effect was found for step length in the weak or sound leg or symmetry.

In a prospective rehabilitation study [41] on the role of AFO on locomotion, mixed results were obtained on gait parameters such as walking speed and endurance with more than two-third showed no significant effect. A systematic literature review(Leung J., Moseley A.) [4] suggested that ankle-foot orthoses may lead to immediate kinematic and temporal improvements in gait (velocity, stride length, gait pattern and walking efficiency) in selected hemiplegic patients but their effect on the paretic lower limb muscle activity is inconclusive. This study involved hemiplegic subjects at various stages of recovery, and encompassed a broad range of orthoses and gait parameters. The review highlighted lack of well-designed and adequately powered randomised controlled trials on the use of ankle-foot orthoses by adults with hemiplegia. More recently Tyson SF et al. [16] systematically reviewed controlled trials in stroke survivors and found positive effects of an ankle-foot orthosis on gait biomechanics by improving ankle and knee kinematics and kinetics in stance phase. De Wit DC et al. [9] found that the effect of an AFO on walking speed and TUGT was statistically significant, but it was too small to be clinically relevant. However, this study population of chronic stroke patients was wearing an AFO for at least six months.

Ray YW, et al. compared the effects of an ankle-foot orthosis (AFO) on balance performance in patients with hemiparesis of short (6 months) and long duration (12 months) [15]. In subjects with hemiparesis of short duration, after wearing an AFO, they found significant improvement in static and dynamic balance evaluated using balance master and Berg balance scale and also in speed and cadence of gait; however, such effects were not observed in subjects with hemiparesis of long duration. It is important to emphasise that most of the literature cited above have involved hemiplegic stroke patients with mixed duration and studies on chronic patients have either shown no controversial effects. In view of differential effects of AFOs in acute and chronic hemiplegic patients, we recommend duration of stroke should be taken into account while prescription of AFO is made.

To summarise, AFO use on hemiplegic side has shown toincrease postural sway velocity during quiet stance and sit to stand, restrict the maximum excursion in forward, lateral and posterior direction in LOS; reduce the rising index during sit to stand; increased step width, reduced step length symmetry and speed during walk across; and increase the time taken to perform TUGT. Within test conditions variability was highest for the TUGT (100%) followed by Step width (90%) and maximum excursion in anterior direction (90%); and rising index (88%) parameters where the subjects exhibited detrimental balance with AFO showing its negative effects. Whereas, with AFO parameters of symmetry and weight transfer time during sit to stand improved showing positive effects of AFO. Mixed results obtained in this study emphasize the need for more specific guidelines for prescription of AFO in chronic stroke population. Effects of AFOs on balance are largely dependent on the design characteristics of the orthosis used, especially in the patients whose balance is already compromised. Studies have shown that articulated devices are less likely to have negative effects on balance and thus these AFOs along with some other modifications e.g. dorsiflexion assist are increasingly recommended. However, taken into consideration the economic cost and the bulkiness of some articulated AFOs, the standard rigid model is still commonly used in rehabilitation practices [42]. Despite how thin or flexible the plastic material is, one can expect a solid shell, non-articulated AFO to compromise proprioception and balance. Also, few authors reported that patients are reluctant to use rigid AFOs. In light of these findings, the design of an AFO should be further improved for better biomechanical characteristics and to make it more suitable for patients' daily usage.

One of the highlights of this study was the use of balance manager system for assessment of postural control. Instrumented tools such as force platform assessment augment clinical balance tests by providing quantitative information on postural sway, weight-bearing asymmetry and weight-shift control during balance activities. The assessments are particularly sensitive to limitations in performance resulting from deficits in lower extremity weight distribution, range of motion, and motor control. The objective data quantify the impact of impairments on a patient's ability to perform mobility tasks essential to daily living. This study provides new information and objective evidence for clinical decision-making, thereby directly impacting the treatment plan and resulting in an improved outcome.

Adaptation time permitted for AFO use can influence the study outcome and this factor needs to be taken into account while interpreting the results. As there are no prescription and/or training guidelines with AFO, this needs to be specifically explored in future studies. Also this suggests that future studies will require a longitudinal design in order to evaluate effects of AFO over time.

We hypothesize that the alterations with rigid AFO (with respect to alignment, proprioceptive inputs, range of ankle movement, etc.) as possible reasons for these observations. However, studies using kinetic and kinematic analysis e.g. using biomechanical motion analysis system, EMG, etc. will be better able to justify these findings. Also, similar study can be done using hinged AFO in chronic ambulatory stroke patients. This study included hemiplegic subjects who were able to walk, thus, results may not be applicable to patients with more severe hemiplegia. Also, we acknowledge that the number of subjects who met the selection criteria was relatively small, sample size was not estimated based on any calculations prior to the study and thus limitation in the population studied could have influenced the results. Further study can be done with larger sample so that results can be generalised.

Conclusion

In chronic ambulatory stroke patients, use of rigid AFO demonstrated significant detrimental effect on static and dynamic postural control; and functional mobility. There is a need for further well-designed randomized, controlled, clinical trials to establish better scientific evidence for the effects of AFO, especially in chronic stroke patients. In terms of clinical implications, while AFOs have significant potential benefit to treat neurologic deficits in stroke patients, practitioners should be aware of the potential shortcomings of these devices and take appropriate measures to minimize the negative effects on balance and mobility.

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