Original Research Article

International Journal of Health Sciences and Research
Vol.12; Issue: 10; October 2022
Website: www.ijhsr.org
ISSN: 2249-9571

A Comparative Study of the Performance of Solid AFO Vis-À-Vis Dynamic AFO in Hemiplegic Patients

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DOI: https://doi.org/10.52403/ijhsr.20221004

ABSTRACT

Background and purpose: Ankle foot orthosis (AFO) has been used for hemiplegic patients for several eras to provide plantarflexion resistance during the stance phase of the gait and prevent the toe dragging in the swing phase of the gait cycle. The biomechanical efficacy of these devices positively affects hemiplegic patients, but there is a lack of clinical evidence in the Indian population regarding prescription criteria. This study compared the functional efficacy of solid AFO and dynamic AFO to provide a biomechanically sound prescription of an AFO for hemiplegic patients.
Methodology: Within the limits of inclusion criteria mentioned in the research protocol, ten patients were fitted and trained with solid Ankle Foot Orthosis (SAFO) and Dynamic Ankle Foot Orthosis (DAFO) with a specific period gap. The 30-meter walkway test measured temporospatial parameters and energy expenditure by calculating the physiological cost index (PCI) and analyzed it by Student T-Test.
Results: In this study, all the temporospatial parameters with the dynamic AFO provided increased spatiotemporal gait parameters than the solid AFO. Energy expenditure was also high in solid AFO rather than dynamic AFO.
Conclusion: This study helped in prescribing a biomechanically sound orthotic management which will help to arrest the growth of the deformity and reduce the number of patients requiring invasive treatment methods. The hemiplegic population primarily benefited from the DAFO because it provides more stability, less energy consumption, and a near-to-normal gait pattern compared to SAFO.

Keywords: Hemiplegic patient, solid Ankle Foot Orthosis (SAFO), dynamic Ankle Foot Orthosis (DAFO), Temporospatial Parameters, Physiologic Cost Index (PCI)

INTRODUCTION

Hemiplegia is one of the disorders most frequently referred for rehabilitation. The characteristic paralysis of the arm and leg is a neuromuscular functional problem caused by the occlusion or rupture of an artery that supplies the contralateral hemisphere of the brain. These patients mainly present with abnormal gait patterns (circumduction gait, hip hiking, toe dragging), altered tone, and balance impairments, leading to increased fall risk, high economic costs, and social problems (1). This group has altered muscle tone, coordination, synergy pattern, reflex, motor control, posture, and balance. In hemiplegic unstable and asymmetric, frequent fear of falling and improper weight distribution in both feet were observed because of a lack of intermuscular coordination due to the involvement of the central nervous system. Characteristics of these subjects are slow walking speed, increased double limb support time, and decreased step length and stride length times. These patients show different types of clinical features during the gait cycles. In the stance phase, some patient shows flexion of the hip or knee and hyperextension of the knee; in the swing phase, insufficient and incorrect hip and knee flexion and excessive hip abduction, excessive pelvic drop, and trunk lean on the contralateral side, equinovarus deformity in foot and ankle are common because of the spasticity of the posterior tibial muscle (2, 3). Several types of ankle foot orthosis (AFO) are there to overcome these problems, like solid ankle AFO, dynamic AFO with several joints, posterior leaf spring AFO, and flanges type of AFO. Study shows AFO provides stability to the ankle joint anteroposteriorly and mediolaterally, which enhances a near-to-normal gait pattern, affects both static and dynamic balance which, reduces the fear of falling, and improve all the temporospatial parameters of gait like walking speed, step length, stride length, cadence, and also enhances the functional recovery of the patient(4,5). This study analyzed solid ankle AFO and dynamic AFO with Oklahoma Ankle joint to determine the most appropriate prescription for hemiplegic patients.

MATERIALS & METHODS

Ten adult hemiplegic patients (six male and four female) were randomly selected with the inclusion criteria between 20 to 50 age groups followed at All India Institute Of Physical Medicine And Rehabilitation, Mumbai. These patients were free from severe spasticity and fixed deformity at the hip, knee, and ankle joints. Each participant was under ongoing physical therapy sessions and participated in our study. Every patient had to visit four times to the Institute for the fitment of two varieties of AFOs, i.e., SAFO and DAFO, with a one-month interval for each AFO. The patients and their attendants signed an informed consent letter for participation in the study.

AFO FABRICATION

Custom fabricated AFO mould was prepared to manufacture the two types of AFOs (fig.-1). In the first phase of the treatment, solid ankle foot orthosis (SAFO) was given to the patient. Then in the second phase, the Oklahoma Ankle joint was aligned over the ankle axis to fabricate the dynamic ankle foot orthosis (DAFO), which allows the patient dorsiflexion but stops the plantar flexion movement when fitted to the patient. The same orthotist mainly carried out these procedures.

Fig.1: Illustration of Solid Ankle Foot orthosis (SAFO) and Dynamic Ankle Foot orthosis (DAFO) with OKLAHOMA joint.

MEASUREMENTS

Temporospatial gait parameters and energy expenditure were assessed with these two types of orthoses.

GAIT ANALYSIS

Three methods were adopted here to determine the outcome measures: paper walk, 30-meter walkway test, and face-to-face questionnaires. Spatiotemporal parameters like step length, stride length, the base of support, and cadence were assessed by use of the paper walk with these two types of AFOs. A 30-meter walkway test was conducted for the physiological cost index or energy expenditure and speed of both AFOs. Face-to-face questionnaires were used to assess the comfort of these orthoses.

ENERGY EXPENDITURE

The Physiological cost index was calculated with both types of orthoses for energy expenditure. It was calculated by taking the resting heart rate, and after that, the patient was asked to walk 30 meters. After each data collection session, 5 minutes of rest was given to the patient. After 30 meters walk, heart rate was calculated by using a stethoscope.

$$\textbf{PCI (beats/meter)} = \frac{\text{walking heart rate} - \text{resting heart rate}}{\text{speed}}$$

Speed was again calculated by the 30-meter distance covered by the time.

$$\textbf{Speed (meter/min)} = \frac{\text{distance covered}}{\text{time}}$$

Statistical Analysis

Mean, standard error, and standard deviation of step length, stride length, cadence, BOS, PCI, and speed of the SAFO were compared with DAFO and again with the normal values. All these data were compared by student T-test with the SPSS 20.0 software (Table.1). The duration of data collection was about 30 to 45 minutes.

Gait Parameters	SAFO		DAFO		t-value	Remark
	Mean	SD	Mean	SD		
Step length (meter)	0.31	0.09	0.46	0.10	6*	P- 0.0001 P < 0.05
Stride length (meter)	0.65	0.17	0.90	0.15	9.6*	P- 0.0001 P < 0.05
Cadence (steps/ minute)	67.8	14.6	80.8	15.9	6.7*	P- 0.0001 P < 0.05
Speed (meter/second)	0.38	0.16	0.56	0.18	8.5*	P- 0.0001 P < 0.05
Base of Support (BOS) (meter)	0.15	0.45	0.19	0.31	4.09*	P- 0.0029 P < 0.05
Physiological Cost Index (PCI) (beats/meter)	29.4	20.6	14.1	7.7	3.1*	P- 0.013 P < 0.05

Table.1: p-value of spatiotemporal parameters in the analysis of the efficacy of SAFO (Solid Ankle Foot Orthosis) and DAFO (Dynamic Ankle Foot Orthosis) with mean and standard deviation at 95% confidence interval (* significant at p<0.05)

RESULT

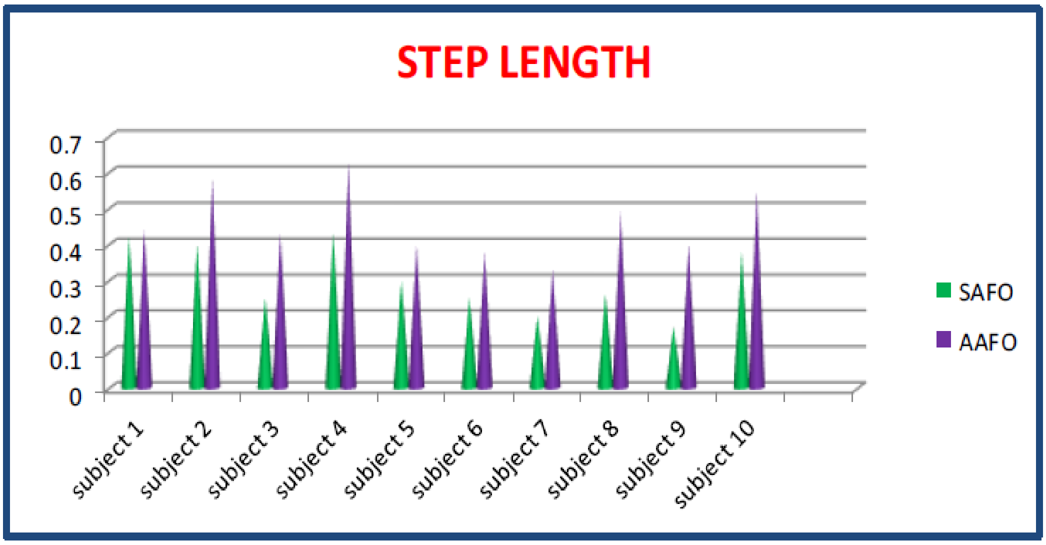
Spatiotemporal parameters were the basic quantitative measures for gait movement. Data with DAFO showed a vast cadence difference when compared with the SAFO. The DAFO aligned with the Oklahoma ankle joint for 0° plantar flexion and 15° to 25° dorsiflexion. This dorsiflexion range provided ground clearance during the terminal stance of the gait cycle. So the patients could easily clear the ground and take more steps in a minute with a safe gait. Increased cadence (Fig. 4) helped in increased speed (Fig.5), and that leads to fast walking of the patient with a good amount of step length (Fig.2) and stride length (Fig.3) in support of DAFO. The base of support was also increased by using the DAFO compared to the SAFO (Fig.7). It provided more stability and decreased fear of falls.

Stability was directly proportional to the balance. The physiologic cost index also showed a positive result in favour of the DAFO (Fig.6). While comparing the AFOs with a paired t-test, more energy expenditure was seen in SAFO. During the conversation regarding the use of orthosis and the level of satisfaction, the patients gave different statements. Most of the patients felt confident, safe, and stable while walking with the DAFO because of the restoration of the smooth tibia progression over the foot in the different stages of the gait cycle. The restricted movement in SAFO gave a sense of heavy weight and tiredness. However, in the first phase of the treatment plan, SAFO provided safety and stability to the patient as it prevented the foot drop movement. During the ascending and descending stairs, they were uncomfortable with SAFO. During the visual analysis of gait with an articulated AFO, it was observed that the patient lands with heel instead of toes, replicating normal walking. A dorsiflexion moment was created in the midstance to push off phase, which helps the patient with the forward propulsion. Patients also stated that they feel more comfortable and stable and require less energy while walking with DAFO. It provided smooth ascending and descending of stairs.

A patient could walk without fear with this orthosis. Also, they felt that DAFO is more lightweight than SAFO. They could cover the same distance in less time and achieve more degrees of freedom. The patient could replicate the functional mobility near the standard of a normal human being

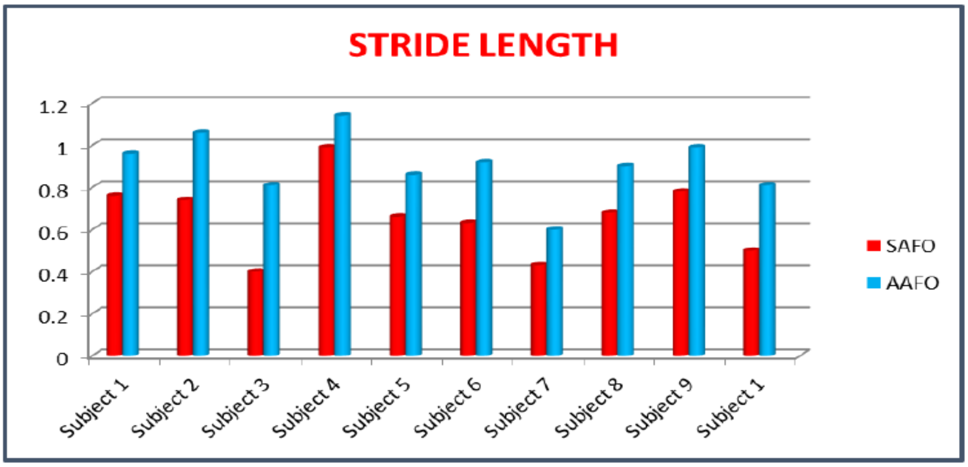
This orthosis helped in restoring all three rockers of the gait phases. During the heel rocker or the first rocker, the heel strike was restored, during the second rocker or ankle rocker, the dorsiflexion moment was initiated from the midstance to the push-off phase, and the toe rocker or third rocker, which involved the heel-off and toe-off phase, was also restored by the metatarsal break area. It helped in reducing knee hyperextension during the stance phase.

Fig.2: This chart signifies the effective role of DAFO in contrast to SAFO in the step length gait variable.



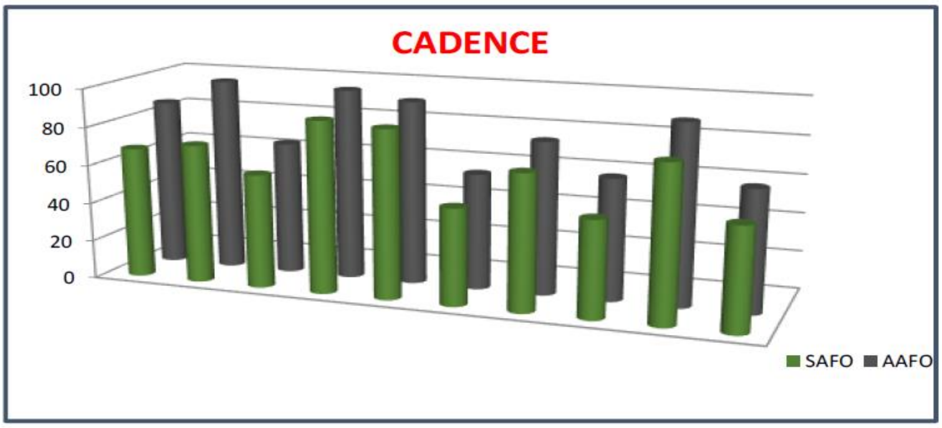
- X-Axis: Number of subjects
- Y-Axis: Step length (meter) with SAFO (Solid ankle foot orthosis) and DAFO (Dynamic ankle foot orthosis) at a comfortable walking speed.

Fig.3: This chart signifies the effective role of DAFO in contrast to SAFO in the stride length gait variable at comfortable walking speed because spasticity reduced the stride length parameter in the gait cycle with SAFO.



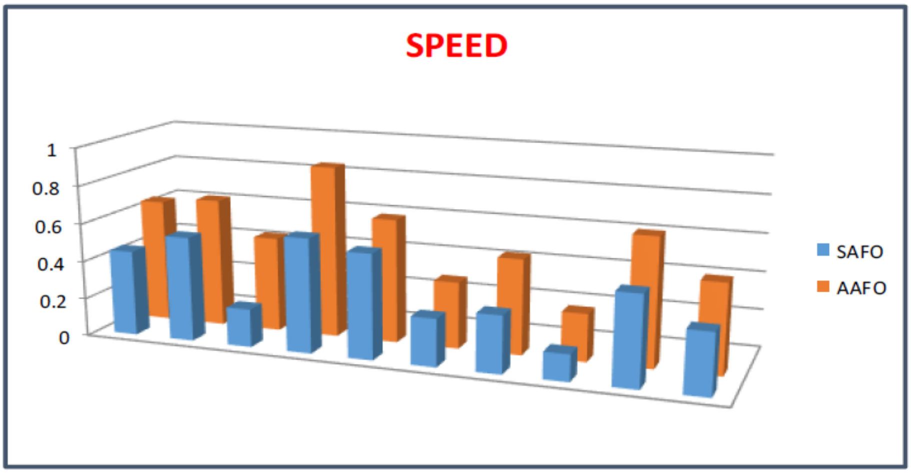
- X-Axis: Number of subjects
- Y-Axis: Stride length with SAFO (Solid Ankle Foot Orthosis) and DAFO (Dynamic Ankle Foot Orthosis) at a comfortable walking speed.

Fig. 4: This chart signifies increased cadence because of ease of ground clearance in DAFO (Dynamic Ankle Foot Orthosis).



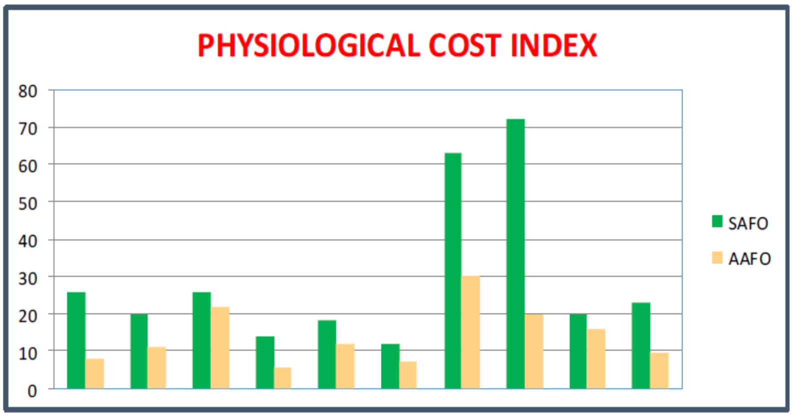
- X-Axis: Number of subjects
- Y-Axis: Cadence with SAFO (Solid ankle foot orthosis) and DAFO (Dynamic ankle foot orthosis) at a comfortable walking speed.

Fig.5: This chart signifies that increased cadence enhanced the speed in DAFO.



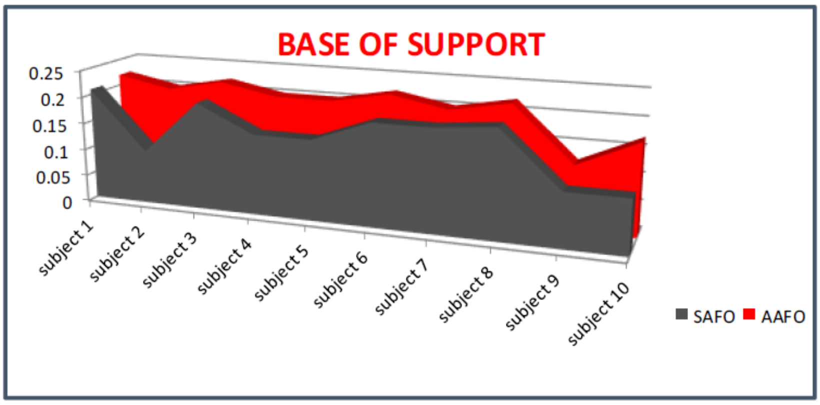
- X-Axis: Number of subjects
- Y-Axis: Speed with SAFO (Solid ankle foot orthosis) and DAFO (Dynamic ankle foot orthosis) at a comfortable walking speed.

Fig.6: This chart of PCI (Physiological Cost Index) signifies less energy consumption in DAFO (Dynamic Ankle Foot Orthosis) because it provides motion at the ankle joint.



- X-Axis: Number of subjects
- Y-Axis: PCI (Physiological Cost Index) with SAFO (Solid ankle foot orthosis) and DAFO (Dynamic ankle foot orthosis) at a comfortable walking speed.

Fig. 7: Chart of BOS (Base of Support) shows the increased BOS in DAFO (Dynamic Ankle Foot Orthosis) at a comfortable walking speed.



- X-Axis: Number of subjects
- Y-Axis: Base of Support with SAFO (Solid ankle foot orthosis) and DAFO (Dynamic ankle foot orthosis) at a comfortable walking speed.

DISCUSSION

Stroke patients showed gait abnormalities like slower walking speed, decreased step length, and stride length. Additionally, foot-dragging, circumduction, and high steppage gait were also evident due to weakened dorsiflexion of the ankle, extensor spasticity in the affected lower extremity, and compensation for the foot-dragging consequently. The result of the present study shows a high impact of DAFO in the hemiplegic population over the SAFO. DAFO showed an improved step length and stride length compared to the SAFO at a comfortable walking speed, and this finding was consistent with other studies (13, 12, and 14).

The use of DAFO allowed the patient 10°-15° of dorsiflexion with plantarflexion stop, which enhanced the heel-to-toe gait, restored the initial contact phase of the gait cycle, improved the symmetry, and gave a smooth normal gait pattern(6). Because of the aligned dorsiflexion movement in the Oklahoma joint, the function of the tibialis anterior muscle was increased instead of the tibialis posterior. It made the tibia translation over the foot much easier with the mediolateral stability of the ankle. This particular movement helped in less oxygen intake in the patients, so the energy consumption was low, and this was significant as per $P<0.005$(6, 17).

The base of support was also increased using the DAFO compared to the SAFO.

The increased base of support enhanced stability. So there was decreased fear of falls. Stability was directly proportional to the balance. Some authors found that an AFO provides a near-to-normal base of support (7, 8). The orthosis showed an essential change in the locomotors' gait pattern, which optimized stability to the hemiplegic side in the stance phase of the gait cycle. Similarly, other authors also concluded that using AFO, especially the DAFO, could provide good stability to the hemiplegic patient; simultaneously, this stability reduced the risk of falling.

When calculating the speed with both orthoses, we found that the DAFO provided increased speed. Increased speed leads to fast walking of the subject. Hence, the increased speed automatically achieves a near-to-normal cadence using DAFO. The result showed a less cadence calculation in the SAFO (16, 18). From all these above analyses and the patient's point of view, it was clear that the DAFO produces a more efficient effect on the hemiplegic patient. During the discussion with the patients regarding the use of AFOs and the level of satisfaction, we found that all ten patients feel confident, safe, and stable while walking with the DAFO.

CONCLUSION

Comparing the performance of the SAFO and the DAFO in hemiplegic patient gait parameters gave us a clear idea about the effectiveness of DAFO. This study was essential to help in prescribing biomechanically sound orthotic management, which helped to arrest the growth of the deformity and reduced the number of patients requiring invasive treatment methods. So the study aimed to understand the efficiency of Ankle Foot Orthosis in managing hemiplegia and make a definitive prescription of an orthotic device for the same. During the research question, we hypothesized that there was no difference in functional ambulation between the SAFO and DAFO. Still, by the data analysis and observation, we found that the DAFO provided a significant difference in spatiotemporal parameters in the gait of hemiplegic patients.

Based on the results of this study, we concluded that DAFO could significantly improve the gait pattern of hemiplegic patients. In this respect, it might be helpful to prescribe DAFO for a hemiplegic patient rehabilitation program.

Acknowledgement: We are deeply grateful to all the patients who participated in the study. The authors thank Dr. Anil Kumar Gaur, Director of the Institute for permitting to conduct of this study in the Institute. The authors wish to thank Mr. Devidas Thakre and Mr. Ajay Sonavane for their insightful and valuable comments on the draft version of the manuscript.

Conflict of Interest: None

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How to cite this article: Priyadarsini Monalisha Dash, Manoj Kumar Tiwari, Deepak P.Prabhu. A comparative study of the performance of solid AFO vis-à-vis dynamic AFO in hemiplegic patients. *Int J Health Sci Res.* 2022; 12(10):30-37.
DOI: *https://doi.org/10.52403/ijhsr.20221004*

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