International Journal of Advances in Medicine
Uppal H et al. Int J Adv Med. 2019 Dec;6(6):1924-1929
http://www.ijmedicine.com
pISSN 2349-3925 | eISSN 2349-3933

DOI: http://dx.doi.org/10.18203/2349-3933.ijam20195252

Original Research Article

Comparative study of anterior support ankle foot orthosis and posterior ankle foot orthosis in foot drop patients

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Received: 06 November 2019
Accepted: 15 November 2019

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ABSTRACT

Background: Anterior Support Ankle Foot Orthosis (A-AFO) is a fairly recent approach. There is dearth of studies relating to comparison of metabolic efficiency of A-AFO and P-AFO. Objective was to study the efficacy of A-AFO compared to P-AFO in foot drop patients, using gait and metabolic analysis.
Methods: It was a cross over study, included foot drop patients who could walk with/ without orthosis. Patients having spasticity more than grade 2 (Modified Ashworth Scale) were excluded. The metabolic parameters measured were volume of Oxygen consumed at Standard Temperature and Pressure in l/min (VO_2), Dry in l/min, Rate of Oxygen consumption (MET), Volume of Carbon dioxide produced in litre/min (VCO_2). Along with various gait parameters, questionnaire about patient's preference after 4 weeks was also incorporated.
Results: A-AFO was significantly better than P-AFO in terms of VO_2 and VCO_2 (p value = 0.02 and 0.009 respectively) as well as in terms of subjective preference.
Conclusions: A-AFO is comparable to P-AFO in terms of energy efficiency, gait parameters and subjective preference, hence should also be prescribed.

Keywords: Ankle foot orthosis, Energy consumption, Foot drop, Gait analysis, Metabolic equivalent, Orthotic devices

INTRODUCTION

Ankle-foot orthoses (AFOs) are intended to improve toe clearance during swing and ankle position at initial contact (IC) and midstance.[1] AFO significantly improved self-selected speed, stride cycle, stance and double support and reduced energy cost of walking without affecting cardiorespiratory response.[2]

It has been proved through many studies that AFOs have been widely used in stroke patients to assist in safe, energy-efficient walking.[3-5] and improve gait in hemiplegics. However, most of these AFO studies focused on the effects of Posterior AFOs (P-AFO).[2,4,6-8]

Recently, an Anterior Ankle Foot Orthosis (A-AFO) has been invented for correcting Foot Drop and similar conditions. Specifically, it includes an anterior support which is adapted to be placed in a position extending generally from the dorsal portion of the foot along the shin to a point below the knee. This permits the heel portion of the foot to be unobstructed and allow the patient to wear standard shoes, eliminating the expense and obviousness of the modified footwear. It is compatible with barefoot walking. More particularly, the foot movement and foot support more closely conform to the muscular and tendon structures of the ankle joint, resulting in a greater degree of comfort and energy conservation during ambulation as well as a more normal gait.

Many people in some Asian countries including in India walk with bare feet indoors because of the hot weather, and P-AFO is not suitable under such conditions.[9,10] In Taiwan, a low-temperature customized molded plastic A-AFO, which could be worn barefoot indoors as well as with shoes, is the principal orthosis for post stroke foot drop patients.[5,10-13] It has been well documented that A-AFOs are light, easy to use, and suitable for indoor barefoot walking.[11] There is scarcity of research studies relating to A-AFOs which have been invented fairly recently.

Despite its widespread usage, I have come across only seven studies related to ambulation-related effects of A-AFO.[11,12] Most of these studies focused on gait analysis, subjective preference and postural stability. To the best of my knowledge, studies comparing the Anterior and the Posterior AFO in terms of subjective preference and metabolic efficiency are lacking so far. The A-AFO which was used in our study extended from the dorsal portion of the foot along the shin to a point about 4 inches above the ankle. We have called the orthosis as “Anterior Support Ankle Foot Orthosis”. A-AFO and P-AFO has been shown in the figures 1 and 2 respectively.

The objective of the study was to compare the efficacy of A-AFO and P-AFO using metabolic and gait analysis in foot drop patients. It was hypothesized that A-AFO should be as efficient or more efficient than P-AFO.

METHODS

The duration of the study was 21 months from January 2011 to September 2012. The study was conducted in the Department of Physical Medicine and Rehabilitation (PMR), All India Institute of Medical Sciences (AIIMS), New Delhi. Patients of ‘Foot Drop’ irrespective of any age and sex who attended the Outpatient Department (OPD) of the Department of PMR at AIIMS, New Delhi by themselves and satisfied the inclusion criteria were included in the study. Author included 22-foot drop patients and these patients were controls for themselves. Hence the study was a Cross Over Study. Ethical approval was taken from the institute’s Ethical Committee before commencing the study and research was conducted in accordance with the Declaration of the World Medical Association.

Inclusion criteria

- Patients who could walk with or without orthosis or with any other external support e.g. walking cane, walker, crutches.
- The ability to follow simple verbal commands or instructions.

Exclusion criteria

- Those excluded from the study were patients having any upper motor neuron lesion leading to foot drop with spasticity more than grade 2 (Modified Ashworth Scale) as well as non-ambulatory patients.[14,15]

After taking a detailed history and examination and confirming the diagnosis and cause of foot drop and ensuring that the patient satisfied the inclusion criteria, the test protocol was explained to the subjects, and they were given the opportunity to ask questions. Prior to testing, written informed consent was obtained and schedule of the study was explained. Each patient was prescribed both A-AFO and P-AFO. There were two sequences of intervention that is, testing with A-AFO followed by P-AFO (sequence 1) and testing with P-AFO followed by A-AFO (sequence 2). For each patient sequence of intervention was randomized. The patients were assigned random numbers from the random number table as a method of randomization. Before starting with the test run, patients were allowed to get familiarized with the orthosis for about 30 minutes by making them walk with the respective orthosis.[9]

Patients in sequence 1 were first made to walk with A-AFO on Day 1(Period 1). Metabolic analysis was done using the ‘Portable Metabolic Analysis System - START 2000M ®’ initially. Each patient was made to walk for 6 minutes at a comfortable speed for each metabolic analysis, 6 minutes’ walk was deemed sufficient to establish ‘steady state’ values of O_2 consumption in this population.[15-17] Three readings were taken, which were averaged to get the final reading.[18] Patients were given 15 minutes rest period in between each test so that the metabolic parameters returned to the basal values which was confirmed by again doing the metabolic analysis.19 After finishing with the metabolic analysis a rest period of 15 minutes was given to the patient followed by Gait Analysis using the ‘Zebris Gait Analyses System®. Patients were made to walk 10 meters at a comfortable speed.[9,20,21] Three readings were taken which were averaged to get the final value. They were allowed to take rest for 5 minutes in between the tests.[9] On Day 2, (Period 2) the same patients were made to repeat the whole of the above-mentioned procedure with the P-AFO. So, the wash out period was 1 day. The washout period is defined as the time between the 2 interventions to remove the effect of the intervention given initially to affect the second intervention. Patients in sequence 2 were made to undergo the above-mentioned procedure with P-AFO on day 1 (Period 1) and with the A-AFO the following day (Period 2).

The metabolic parameters measured were Volume of Oxygen consumed at Standard Temperature and Pressure, Dry in l/min. (VO_2), Rate of Oxygen consumption, which is a metabolism unit (MET). MET and VO_2 were the primary outcome measures of the study.

The gait analysis parameters measured for the study were velocity, stride length, stride duration, stance duration, swing duration, cadence.

Subjective assessment of the patient was done by a structured questionnaire on telephone after 4 weeks.

RESULTS

There were 22 subjects who met the selection criteria, of these, eighteen were men and four were women. The mean age of subjects included was 33 years. Of these subjects, thirteen had right hemiparesis whereas nine had left hemiparesis, and the mean duration of onset was 4 years. 18 patients, i.e. 82% had no spasticity in any of the muscle groups while the remaining 4 patients, i.e. 18% had spasticity; 3 out of these 4 having spasticity grade 1 according to the Modified Ashworth Scale, whereas 1 patient had grade 2 spasticity.

Metabolic analysis

There was a significant difference in the primary outcome i.e. VO_2 and the secondary outcome, VCO_2; between patients wearing the A-AFO and the P-AFO. The value of VO_2 was significantly lower in patients wearing A-AFO (0.45±0.13) as compared to those wearing the P-AFO (0.50±0.16). (Treatment Effect (p value) = 0.02, Period effect = 0.33, Treatment Period Interaction = 0.5). In our study the treatment effect (p = 0.02) was significant i.e. there was a significant reduction of VO_2 with the A-AFO as compared to the P-AFO. Period effect as well as the treatment period interaction were not significant i.e. the effect of the intervention did not depend on the order of the intervention (Table 1). Metabolic Equivalent i.e. the rate of O_2 consumption was lower in patients wearing A-AFO as compared to those wearing the P-AFO. (Treatment Effect (p value) = 0.08, Period effect = 0.88, Treatment Period interaction = 0.5) However the treatment effect, period effect and the treatment period interaction were not significant. VCO2 was also significantly lower in patients wearing A-AFO as compared to those wearing P-AFO (Table 4). (Treatment Effect (p value) = 0.009, Period effect = 0.19. Treatment Period Interaction = 0.5) Period effect and Treatment Period Interaction were not significant. However, treatment effect was significant (Table 2).

Table 1: Comparison of VCO_2 in ml between anterior support AFO and posterior AFO.

Intervention	Period 1 (Day 1)	Period 2 (Day 2)	Mean
Anterior Support AFO (n=22)	0.51±0.15 l/min	0.52±0.15 l/min	0.51±0.14 l/min
Posterior AFO (n=22)	0.6±0.14 l/min	0.54±0.17 l/min	0.57±0.16 l/min
Difference (95%CI)			-0.05(-0.09-0.01)

Treatment Effect (p value): 0.02; Period Effect: 0.33; Treatment Period interaction: 0.5

Table 2: Comparison of metabolic equivalent between anterior support AFO and posterior AFO.

Intervention	Period 1(Day 1)	Period 2 (Day 2)	Mean
Anterior Support AFO (n=22)	2.43±0.8 METs	2.26±0.57 METs	2.34±0.68 METs
Posterior AFO (n=22)	2.43±0.57 METs	2.58±0.89 METs	2.51±0.73 METs
Difference (95% CI)			-0.16 (-0.35 - 0.02)

Treatment Effect (p value): 0.08; Period Effect: 0.88; Treatment Period Interaction: 0.58

Table 3: Comparison of gait parameters between anterior support AFO and Posterior AFO.

Gait parameters	Anterior Support AFO Mean (n = 22)	Posterior AFO Mean (n=22)	Difference	Treatment effect (p value)	Period effect
Velocity (km/ hr)	3.99	4.10	-0.11	0.5	0.36
Stride length (cm)	110.41	109.2	1.205	0.65	0.9
Stride duration(sec)	1.05	0.93	0.11	0.33	0.16
Stance duration (%) affected	62.44±1.43	61.89±1.91	0.54	0.79	0.66
Stance duration (%) unaffected	66.09±2.14	67.19±2.50	-1.09	0.68	0.34
Swing duration (%) affected	37.53±1.43	38.75±1.89	-1.212	0.54	0.44
Swing duration (%) unaffected	33.40±1.90	33.12±2.43	0.284	0.9	0.18

The gait parameters studied were Velocity, Stride Length, Stride Time, Double Support Time, Cadence. Velocity data revealed that there was no significant difference between the two orthoses. There was no significant period effect as well. The respective means and p values have been shown in the (Table 3) for all above mentioned gait parameters. Stride Length also showed no significant difference between the two orthoses (p = 0.65). Similarly stride duration data didn't differ significantly between the two orthoses, (p = 0.16, period effect = 0.33). Interpreting the stance and swing phase duration data, statistically there was no significant difference between patients wearing either of these two orthoses, p value of the stance phase duration of the affected lower limb and that of unaffected lower limb being 0.79 and 0.68 respectively, p value of swing phase duration of the affected and unaffected lower limb being 0.54 and 0.9 respectively.

Figure 1: Anterior ankle foot orthosis.

Figure 2: Posterior ankle foot orthosis.

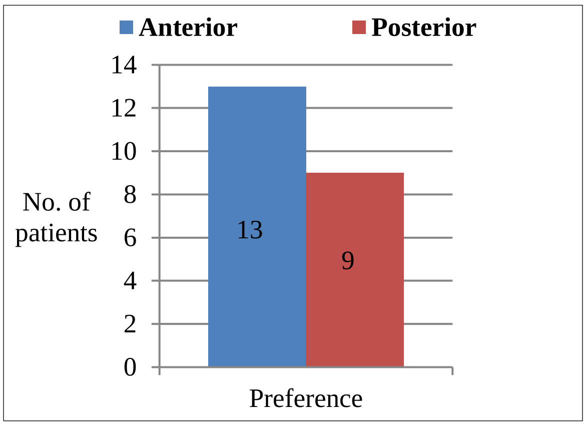

Figure 3: Subjective preference between anterior support Ankle Foot Orthosis and posterior ankle Foot Orthosis.

Subjective preference

Statistically 13 (59%) patients out of the 22 preferred the A-AFO; as compared to 9 patients (41%) who preferred the P-AFO (Figure 3). In terms of cosmetic preference; 17 patients (77.3%) preferred the A-AFO while 5 patients (22.7%) preferred the P-AFO. In terms of donning and doffing 12 patients (54.54%) and 8 patients (36.36%) preferred the A-AFO and P-AFO respectively while 2 patients (9.09%) didn't have any problem with either of the 2 orthoses.

In terms of Activities of daily Living; 15 (68.18%) and 7 (31.8%) patients liked the A-AFO and the P-AFO respectively (Figure 4).

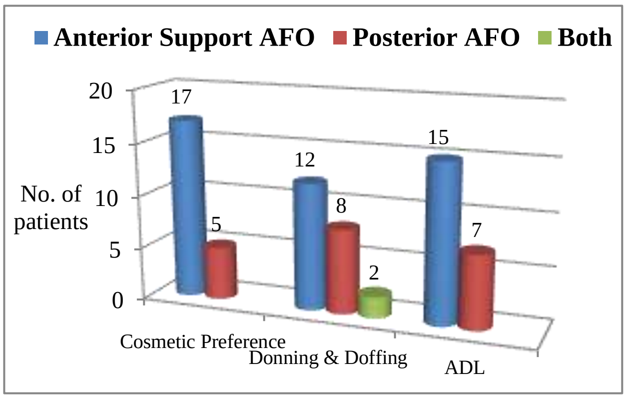

Figure 4: Preference in terms of cosmesis, donning and doffing, ADL (activities of daily living) between anterior support AFO and posterior AFO.

P-AFO was rejected by patients as reasoned out by them that it was heavy according to 6 patients, while 5 of them found the P-AFO to be obstructive while walking, 7 of them had difficulty climbing stairs and maneuvering on uneven surfaces with the Posterior AFO, 2 patients were unhappy with the posterior AFO as they couldn't manage barefoot walking wearing the P-AFO. 7 patients rejected the A-AFO as it hurt them on the dorsum of the foot; while 6 found it to be unsuitable as it didn't provide stability at the ankle.

DISCUSSION

Metabolic analysis data revealed that VO_2 (primary outcome) was significantly lower when patients wore A-AFO as compared to when they wore P-AFO. (Treatment Effect (p value) = 0.02, Period effect = 0.33, Treatment Period Interaction = 0.5) Treatment effect denotes the difference in the concerned parameter (VO_2 in this case) with the two interventions. (A-AFO and P-AFO) Since the treatment effect is lesser than 0.05, it is statistically significant. The Period effect was used to compare the differences between the periods in the two groups of patients. In the absence of treatment period interaction, a patient's average response to the two treatments would be the same regardless of the order in which they are received. We can deduce that wearing A-AFO is more or as energy efficient as wearing P- AFO since MET, VO_2, VCO_2 and VO_2/kg represent energy consumption and metabolic efficiency as is also evidenced by Dufek et al.[21] This could possibly be due to the facts that when using unilateral P-AFO, there could be difference in the length of the limb making the centre of gravity have more excursion; secondly patients trying to adjust their limb inside the P-AFO since the contact area of the P-AFO is different compared to the natural foot while making contact with the ground, hence the patient consumed more energy.

Thirdly the improved biomechanical effectiveness of A-AFO as compared to the P-AFO as by attaching the A-AFO to the dorsal area of the foot, the foot movement and foot support more closely conform to the muscular and tendon structures of the ankle joint, resulting in a greater degree of comfort and energy conservation during ambulation. Fourthly many patients have found A-AFO to be lighter than the P-AFO and the same can be taken as one of the reasons for patients requiring less energy when using the A-AFO. This has been supported by Janet S Dufek et al, who concluded that mechanically adding mass to any system will require greater energy to perform work; i.e. to move the body/system.[21] This fact is in accordance with the Newtonian relationship of Work=Force X Distance. In itself, this is a simple and straight forward argument against using a heavier support system for correction of lower limb dysfunction.[21,22]

Federica Menotti et al, have concluded that gait spatio-temporal parameters were higher with A- AFO than with P- AFO or shoes only.[23] Walking energy cost per unit of distance was lower with anterior than posterior ankle-foot orthosis or shoes only (3.53±1.00 vs 3.94±1.27 and 3.98±1.53 J·kg-1·m-1 respectively; $p < 0.05$) and level of perceived comfort was higher with anterior (8.00±1.32) than with posterior ankle-foot orthosis (4.52±2.57; $p < 0.05$). This study also conforms to the above findings.

Comparing the gait analysis of patients wearing A-AFO and P-AFO in our study we found that there was no significant difference in terms of velocity, stance duration, swing duration, stride length and stride duration. There was no significant difference (p value = 0.5) between the two orthosis in terms of velocity which is in accordance with the results of other authors18 In terms of Stride Length (p value = 0.65) and Stride Time (p value = 0.33) the 2 orthoses did not show a significant difference. But it was observed that, with A-AFO, there was increased stride length as compared to P-AFO though the difference was not significant.

The Stride Time also decreases in the second period irrespective of the orthosis but not significantly, (p value = 0.33). This can be explained by the fact that as patient gets accustomed to the orthosis, the velocity increases as already mentioned and the stride time decreases. Similar results were found by Park et al, who observed increased walking speed, stride length and velocity with both ankle foot orthoses i.e. Anterior and Posterior AFO as compared to barefoot walking.[9] ($p < 0.05$) However there was no significant difference between the two, and hence they concluded that wearing Anterior AFO was as useful as Posterior for correcting hemiplegic gait which is same as the findings of this study. Chen et al, and Wong et al, further confirmed the above results that A-AFO was as effective as P-AFO for improving gait in patients with hemiplegia.[11,12]

A-AFO is comparable to P-AFO in terms of proprioception and balance related requirements as is evident in our Subjective Questionnaire results and the same has been documented by a few Japanese studies.[9-11]

Hence the hypothesis stating that A-AFO is comparable in energy efficiency and various gait parameters to P-AFO was supported in the study.

The strengths of the study were appropriate methodology and statistics, low number of dropouts and loss to follow up. The limitations of study not testing without any orthosis and lack of blinding.

CONCLUSION

A-AFO is as good as the P-AFO in terms of energy consumption as documented by the results of VO2, MET, VO_2/kg and VCO_2. However, there is no significant difference between Anterior and Posterior AFO in terms of the various gait parameters we measured with the exception of double support time which showed a decrease with the A-AFO. Functionality wise, A-FO is as good as the Posterior AFO.

A-AFO is better than the Posterior one in terms of cosmesis, ADL, donning and doffing as shown by subjective preference.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Uppal H, Handa G, Singh U, Wadhwa S, Yadav SL. Comparative study of anterior support ankle foot orthosis and posterior ankle foot orthosis in foot drop patients. Int J Adv Med 2019;6:1924-9.