Do static or dynamic AFOs improve balance ?

Running Title: Effect of AFOs on posture and gait

Cardini R*, Marazzini F*, Crippa A*, Cattaneo D*

*Don Gnocchi Foundation I.R.C.C.S.; Onlus – MILANO-. V. Capecelatro 66 – 20148 MILANO, ITALY

Address for Correspondence: Davide Cattaneo, Via S. Mirocle 2, 20138 MILANO - ITALY.

Tel: 0039245401666; Fax: 0039240308498; eMail: cattaneo.davide@tin.it

Key Words: AFO, Balance, Rehabilitation, Multiple Sclerosis

Objective: The aim of this study was to verify if partial or total limitation of degrees of freedom at ankle joints could help patients with balance disorders in standing and walking.

Design: A cross-over design has been chosen. Patients with multiple sclerosis (MS) were tested in three experimental conditions**:** bare footed, wearing ankle foot orthoses (AFOs), and wearing AFOs that allowed plantar flexion.

Setting: Neurorehabilitation unit in a rehabilitation center

Subjects: We recruited 14 patients suffering from MS with mild strength problems and balance disorders that required them to use walking aids outside.

Main outcome measures. Tests inferring static and dynamic skills were carried out in the three experimental conditions described above.

Results. Improvements were obtained in static balance tests especially wearing dynamic AFOs; the number of patients who were able to pass Items on balance in upright position such as "standing with feet together, head extended" increased from 3 to 9. Dynamic balance was impaired especially with static AFOs; the time spent walking 10 metres with these orthoses increased of 172% with respect to bare foot; less difference (113%) has been reported wearing dynamic AFOs .

Conclusion. Static and dynamic AFOs improved static balance, while dynamic balance was impaired especially by static AFOs; less negative influence on dynamic balance has been found while wearing dynamic AFOs.

INTRODUCTION

Orthoses are prescribed in neuromuscoloskeletal disorders to assist, control and maintain the desired position of body parts.

Studies on Patients with stroke[1] have demonstrated that AFO improved postural alignment, lateral weight shift and weight bearing on the affected limb; other authors[2,3] reported a decrease of body sway in standing position, and an increase in walking speed.

Control of ankles is important to achieve a correct static balance by so called “ankle strategy”[4] in which body is considered as a rigid mass pivoting about the ankle joints. Sensibility, neuromuscular control and strength of muscles around the ankle are fundamental to perform this strategy. Some patients with balance disorders loose the control of ankle joints. Therefore restriction of degrees of freedom at ankle joints may improve static balance.

Some studies have focused the attention on the effect of AFOs on the gait cycle[5].

Balmaseda[6] et al. have demonstrated that the use of orthoses in normal subjects cause an alteration in normal body mechanism; they have found a significant reduction in the duration of the stance phase due primarily to the significant reduction during midstance. AFOs also increased the magnitude of the vertical force at the end of push-off. The impact of the heel was more posterior and the trajectory of the COP (Center of Pressure) was more lateral than normal.

Despite the alterations caused in normal gait cycle AFOs have been prescribed in different clinical approaches[7 8 9].

Winter[10] stressed the attention on the double contact period that is essential for dynamic balance. In order to minimize the reduction of the total area of support surface during this phase of the gait cycle, we modified the classical AFO allowing 20 degrees of plantar flexion. The plantar flexion movement of the AFOs would allow an early contact of the sole of the foot on the ground right after heel strike.

We chose not to use standard dynamic AFOs because they allow dorsiflexion movement. Infact the use of these AFOs led the patient to push the calf muscle on the leg section of the AFOs in order to stabilize the oscillations of the body. This movement shifts the baricentre backward where the area of support is smaller than forward. No study reports the effect of AFOs on postural stability, static functional tasks such us axial strategy[11] and dynamical stability in patients with MS.

The aim of the study was to verify if Patients suffering from multiple sclerosis (MS) improved standing and dynamic balance wearing Ankle Foot Orthoses (AFOs), or modified AFOs that allowed plantar flexion.

METHODS

18 patients were recruited from extended care ward of Don Gnocchi Hospital in Milan.

To be eligible to the study, patients had to satisfy the following criteria:

Walking indoor without aids for 20 meters and outdoor with a cane or walker;

Having mild-moderate strength problems; We assessed the strength impairment by asking the patients to stand on tiptoe and to stand up from a chair with minimal support. Finally, we did not recruited patients that were able to stand in upright position, eyes closed, head extended. We did not recruited patients who already used AFOs.

4 patients were dropped out because they could not wear AFOs; The sample was of 6 men and 8 women; the mean age of the subjects was 37.2 +/- 22.8 (SD) years; the onset of the pathology was 13.3 +/- 12.7 (SD) years before.

Patients were assessed barefooted and wearing a pair of static and dynamic AFOs. Static orthoses were pair of pre-fabricated AFOs made of polypropylene that did not allowed ankle joints movements; we called these AFOs “Static AFOs”. A pair of custom designed AFO, “dynamic AFOs”, have been developed on the basis of pre-fabricated AFOs; they allowed plantar flexion of almost 20 degrees pivoting about ankle joints (Figure 1). Both “static and dynamic” AFOs allowed patients to have their toes on the floor.

Patients did not wear shoes during the assessment section. In order to increase the grip between the ground and the AFOs a rubber surface was fixed on AFOs sole.

The order of experimental conditions were randomized. Several minutes of rest was given among trials.

To evaluate patients we chose 4 tests: 2 tests for dynamic balance (PedriÖ Test and Timed Walking Test) and 2 tests for static balance (CranioCorpoGraphy and Equiscale).

The craniocorpography[12] is an instrumental test. It gives us information about position and movement of head and trunk. We reported information about speed of oscillations of the head and trunk in standing position.

The equiscale[13] test is a clinical test created ad hoc to evaluate equilibrium problems in patients with MS. It allows to discriminate mild to moderate patients with balance disorders as regards to static functions and functional little movements.

Each Item is rated 0 (impossible to perform), 1 or 2 (best score) according to the description given in each item. The overall score is 16 points that means perfect balance.

In order to assess gait speed the Timed Walking Test[14] [15] has been performed. This test originates to evaluate the walking ability for every kind of patients. We recorded the time each patient spent to cover 5, 10 and 20 meters without aids.

We repeated each trial 3 times for each experimental condition and then we calculated the mean value.

Finally, the "Pedriö" test is a custom designed test to evaluate dynamic balance problems. We asked patients to walk inside a path 1.20 meters wide at the beginning and got narrower till 0.22 meters. We measured the width of the path at the point where the patient exited from the margin.

We repeated each trial 3 times for each experimental condition, and then we calculated the mean value.

A descriptive statistic for the collected data has been carried out in order to determine the distribution and to consider the need for transformations.

Because of the data in Equiscale and PedriÖ Test were not normally distributed, the paired Friedman test has been chosen to check statistical differences among experimental conditions. The criterion level of significance was set at $P< 0.05$; $\alpha/2$.

In order to assess repeatability of Pedriö test Friedman paired test has been carried out across the three trials assessed for each subjects.

Analysis of variance for repeated measures has been carried out for Timed Walking Test.

RESULTS

Static balance was evaluated by Equiscale test and Craniocorpography.

The comparisons were shown in Table 1. The overall score in equiscale showed little improvement with dynamic AFOs with respect to bare foot (12.1 vs10.2 points; $P<0.01$); static AFOs decreased the overall score to 9.8 points. The difference between static and dynamic AFOs were statistically significant ($P<0.05$).

The Items 2 (stand with eyes closed) and 3 (stand with eyes closed, head extended) of equiscale showed an improvement of balance in upright position. The number of patients who were able to perform Item 3 perfectly improved from 3 to 9. Axial strategy[11] (Item number 5: pick up a pen placed on the floor) was worse with static AFOs with respect to dynamic AFOs. Static AFOs produced a decrease in the performance when we asked patient to rise from a chair (Item 1).

Craniocorpography assessment showed a decrease in the speed of sways in open eyes condition (Figure 2). Because of technical problems, only 7 patients were assessed with this system; so the reduced sample made comparison among experimental conditions problematic; data showed can be considered just as a trend. Best performances were achieved wearing static AFOs; in fact the sways speed decreased in right and left directions (respectively 25 and 16% less than bare footed condition). The sway speed also decreased in forward an backward directions (respectively 18 and 10% less than bare footed condition.

In contrast, in eyes closed (Figure 3) we obtained an increase of the oscillations with dynamic AFOs (e.g. increase of 46% in forward direction).

Dynamic balance was evaluated by Timed Walking Test and Pedriö test.

Data obtained from Timed Walking Test (Table 1) showed that the time needed to walk for 5 meters increased of 180% with static AFOs with respect to bare foot; a sharp increase of 172% and 157% has also been obtained for respectively 10 and 20 meters tests.

With dynamic AFOs we had an improvement in performances with respect to static AFOs: the time needed to walk for 5 meters was reduced from 180% to 134% with respect to barefooted condition. We had a further improvement for 20 meters test where the difference was smallest. Dynamic AFOs had always best performances with respect to static AFOs.

Pedriö test showed a good repeatability; no statically difference has been found among the three consecutive trials performed on each subject. Spearman correlation coefficient between Pedriö test and Timed Walking Test was 0.38. Spearman correlation coefficient between Pedriö test and Equisclae Test was 0.39

Performing Pedriö test Patients increased their stability with dynamic AFOs compared to static AFOs, even if they had to decrease their walking speed. They were able to reduce the width of support surface from 0.36 to 0.27 meters (Table 1). With dynamic AFOs some patients could walk with feet placed in tandem position.

DISCUSSION

The Main findings of this study were that static balance was improved by static and dynamic AFOs. Conversely dynamic balance was worst wearing static AFOs; Dynamic AFOs had a minor impact on dynamic balance.

Overall score in Equiscale test showed statistical difference between barefoot and dynamic AFOs. Dynamic AFOs had better performances with respect to static AFOS. Balance in upright position was improved both with static and dynamic AFOs. In fact Equiscale test showed an improvement of standing balance with head extended that was clinical relevant and better performance has been found with dynamic AFOs with respect to static AFOs. Also cranicorpography with eyes open showed a decrease of speed of trunk/head oscillations in upright position, especially with static AFOs. Best stabilization was achieved in right and left directions. Those findings are in agreement with those of Mojica[2] who found a significant reduction of body sway. In closed eyes condition an increase of the speed of the oscillations has been observed; it may be due to a lack of cues both from visual and somatosensory information from sole feet and ankle joints.

Axial strategies were improved just by dynamic AFOs. During axial strategy the movements of ankles and the movements of other joints are coupled. Coupled movements are necessary in order to keep the center of mass inside the support surface. Static AFOs did not allowed these coupled movements**.** The restriction of ankle movements was critical also to achieve tasks such as “rise from a chair” (Item number 1); both Static and dynamic AFOs did not allow dorsiflexion movement, then patients could not transfer the center of mass inside of a new support surface.

The dynamic balance was impaired as demonstrated by Timed Walking Test. Patients who wore AFOs decreased the gait speed. This finding are in contrast with those of Hesse,[16] Mojica[2] and Lehemann.[5] They studied the effect of AFO on hemiparetic patients. They found an increased waking speed, cadence and stride length. In our study patients were not able to change the gait pattern according to the constraint due to the AFOs. The initiation of gait seemed to be the most critical phase: in fact trial with dynamic AFOs showed more differences compared with bare foot in 5m test with respect to 20m test.

In spite of these difficulties the improvement of static balance allowed patients to reduce the width of the support surface, as showed by Pedriö test.

Several limitation of the study should be considered in interpreting our result. First the use of pre-fabricated AFOs did not allowed a prefect fit of AFOs on patient’s feet. Second patients did not wear their shoes; it is possible that use of shoes could have effect on the study results. Third no gait analysis procedure was performed in order to clarify motor changes between AFOs conditions and bare foot condition.

ACKNOWLEDGMENTS

The authors tanks Dr. L. Pugnetti, Dr. C. Carniti, Dr. D. Alpini and R. Carabolona for their support and assistant to this project. We also thank the AISM Milan Association for its valuable assistance and the people with MS who volunteered to participate in this investigation.

CLINICAL IMPLICATION

- Patients who have already lost the ability to walk without aids but need to improve their static balance, seem to be the best candidates for orthoses.
- Clinicians must to consider the constraint of AFOs on different tasks such us standing from a chair.
- Training on gait skills seems necessary in order to improve patients' confidence with those orthoses.

Table 1. Score obtained in Equiscale test, Timed Walking Test and Pedriö test

	Barefoot	Static AFOs	Dynamic AFOs
EQUI 1	1.78	1 *	1.35
Sit to Stand	(0.42)	(0.55)	(0.63)
EQUI 2	1.21	1.71	1.75 ^
Stand e.c.	(0.89)	(0.61)	(0.57)
EQUI 3	0.28	0.78	1.08 ^
Stand e.c. head extended	(0.61)	(0.89)	(0.73)
EQUI 4	1.71	1.79	2.00
Lean forward	(0.61)	(0.42)	(0.00)
EQUI 5	1.14	0.85	1.75 +
Pick-up	(0.86)	(0.94)	(0.57)
EQUI 6	1.57	1.79	1.83
Push	(0.64)	(0.42)	(0.36)
EQUI 7	1.21	0.93	1.25
Rotate	(0.69)	(0.73)	(0.57)
EQUI 8	1.07	1	1
Tandem	(0.47)	(0.67)	(0.78)
EQUI TOT	10.2	9.8	12.1^^+
	(3.1)	(2.5)	(1.9)

TWT 5m (s)	10.7	20.2*	14.4
	(5.4)	(14.5)	(7.4)
TWT 10m (s)	22.4	38.7*	25.6
	(12.7)	(22.1)	(12.5)
TWT 20m (s)	46.6	73.5*	51.4
	(25.5)	(46.9)	(25.6)
PEDRIÖ (m)	0.33	0.36	0.27+
	(0.16)	(0.13)	(0.07)

EQUI: Items of Equiscale test; mean score and (SD);The score for each test ranges between 0 and 2, best score = 2. (Friedman Paired Test).

EQUI TOT: Overall score in Equiscale test. Best Score=16. (Friedman Paired Test).

TWT: Timed Walking Test; Mean Time in seconds and (SD) needed to cover 5, 10, 20 (ANOVA test).

PEDRIÖ: Pedriö test; Width of support surface in meter (SD) (Friedman Paired test)

* Comparison between Barefoot and Static AFOs; P< 0.05

^ Comparison between Barefoot and Dynamic AFOs; P< 0.05

^^ Comparison between Barefoot and Dynamic AFOs; P< 0.01

$^{+}$Comparison between Static AFOs and Dynamic AFOs; P< 0.05

Figure n. 1: dynamic AFO

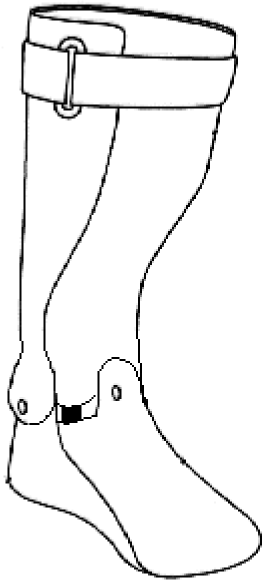
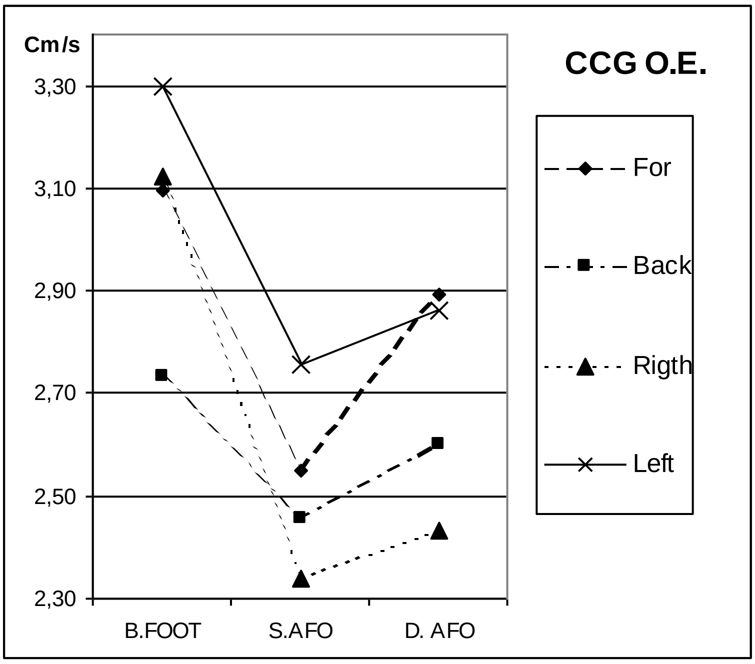
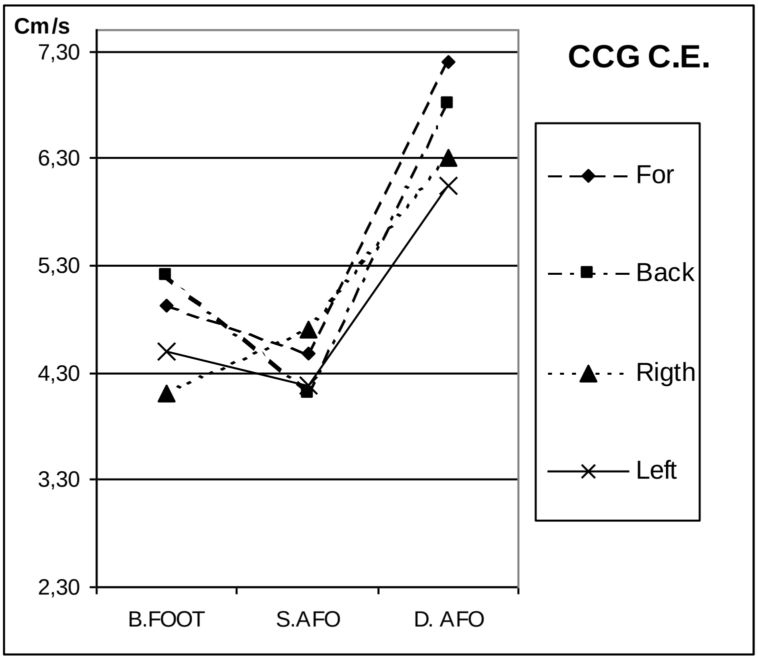


Figure n 2 Craniocorpography Test; Eyes open



Sway speed of the head in Forward, Backward, Right and Left directions; open eyes condition. B. FOOT = Bare foot; S. AFO= static AFOs ; D. AFO= dynamic AFOs.

Figure n. 3 Craniocorpography Test; Eyes Closed



Sway speed of the of the head in Forward, Backward, Right and Left directions in closed eyes condition. B. FOOT = Bare foot; S. AFO= static AFOs ; D. AFO= dynamic AFOs.

[1] Chen C-L, Yeung K-T, Wang C-H, et al. Anterior ankle-foot orthosis effects on postural stability in hemiplegic patients. Arch Phys med rehabil; 1999; 80: 1587-92

[2] Mojica JA, Nakamura R, Kobayashi T, et al. Effect of ankle-foot orthosis (AFO) on body sway and walking capacity of hemiparetic stroke patients. J Exp Med 1988;156:395-401

[3] Lehmann JF, Condon S, Price R, deLateur BJ; Gait abnormalities in Hemiplegia: They correction by ankle-foot orthoses. Arch Phys med rehabil; 198;76: 763-771.

[4] Horak F, Nashner L. Central programming of postural movements adaptations to altered support surface configuration. J Neurophysiol 1986; 55:1369-1381

[5] Lehemann JF, Ko MJ, de Lateur BJ. Knee moment: origin in normal ambulation and they modification by double-stopped ankle-foot orthoses. Arch Phys med rehabil; 1982; 63: 345-351.

[6] Balmaseda M-T, Koozekanani SH, Fatehi MT, et al: Ground reaction forces, center of pressure, and duration of stance with or without ankle-foot orthosis. Arch Phys Med Rehabil 1988; 69: 1009-1112.

[7] Abel MF, Juhl GA, Vaughan CL, Damiano DL. Gait assessment of fixed ankle-foot orthoses in children with spastic diplegia. Arch Phys Med Rehabil 1998;79:126-33

[8] Park TS, Owens JH. Surgical management of spastic diplegia in cerebral palsy. New Engl Med 1992;32: 745-9

[9] Harris SR, Riffle K. Effects of inhibitive ankle-foot orthoses on standing balance in a child with cerebral palsy. Phys Ther; 1986; 66: 663-667

[10] Winter D A. Human balance and posture control during standing and walking. Gait & Posture:1995; 3: 193-214, December

[11] Crenna P, Frigo C, Massio j, Pedotti A. Forward and backward axial strategies in man. Exp Brain Res; 1987; 65:538-548

[12] Alpini D, Cesarani A. Vertigo e Dizziness rehabilitation, the MCS method, Springer, 2000

[13] Tesio L, Perucca L, Franchiglion PF, Battaglia MA. A short measure of balance in multiple sclerosis: validation through rasch analysis. Functional neurology 1997;12:255-65

[14] Rossier P, Wade DT. Validity and Reliability comparison of 4 measures in patients presenting with neurologic impairment. Arch Phys Med Rehabil; 2001; 82: 9-13

[15] Wade D.T. Measurement in neurological rehabilitation. Oxford University Press: 154-56, 1995

[16] Hesse S, Luecke D, Jahnke MT, Mauritz KH. Gait function in spastic hemiparetic patients walking barefoot, with firm shoes, and with ankle-foot orthosis. Int J Rehabil Res 1996;19:133-41