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The effect of a hinged ankle foot orthosis on hemiplegic gait: objective measures and users' opinions

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Objective: To assess the effect of a hinged ankle foot orthosis (AFO) on functional mobility and gait impairments in people with a severe hemiplegia undergoing rehabilitation, and to investigate the patients' views of the hinged AFO.
Design: With/without group comparison, and face-to-face questionnaire.
Subjects and setting: Twenty-five subjects over 18 years, with a hemiplegia following cerebrovascular accident (CVA) undergoing rehabilitation in a regional rehabilitation unit.
Outcome measures: Functional Ambulation Categories as a measure of disability. Paper walkways to measure gait impairments – stride length, step length, symmetry, cadence and velocity. Face-to-face questionnaire to determine the users' opinion of the hinged AFO.
Results: Comparison of gait with and without the hinged AFO showed significant improvements in functional mobility ($p = 0.000$) and in some gait impairments; stride length of the weak ($p < 0.005$, 95% CI –8.1, –1.6) and sound legs ($p < 0.014$, 95% CI –8, –1), velocity ($p = 0.00$, 95% CI –0.1, –0.03) and cadence ($p < 0.002$, 95% CI –15.1, –3.8). No effect was found for step length in the weak or sound leg or symmetry. The subjects' response was positive, 24 (96%) felt they walked better with the AFO and found it comfortable. Twenty-three (92%) were unbothered by the appearance and 16 (64%) could doff and don it.
Conclusion: The hinged AFO improved objective measures of gait impairments and disability and patients were positive about it.

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Introduction

The re-education of walking is a primary goal for people following stroke and the physiotherapists treating them. An ankle foot orthosis (AFO) is sometimes prescribed to assist retraining hemiplegic gait. The rationale for this is that the AFO provides medio-lateral stability in stance by limiting ankle and subtalar movement, and facilitates toe clearance and heel strike in swing phase. A number of studies have looked at the effects of AFOs on hemiplegic gait and generally found a positive effect.[1–8] In the main, these have selected subjects with a chronic hemiplegia, who were not receiving physiotherapy and could already walk, and have concentrated on gait impairments such as step length, or velocity rather than function. Although the designs varied, all used an AFO with a fixed ankle joint. This limits plantar flexion to prevent foot drop and ensure heel strike during swing phase, but it also prevents dorsiflexion and so impairs forward weight transfer during stance phase and other activities such as descending stairs. This problem can be overcome by using an AFO with a hinged ankle joint, which allows dorsiflexion but limits plantar flexion to a neutral position. However the efficacy of a hinged AFO has not previously been evaluated. The aim of this study was to examine the effect of a hinged AFO on hemiplegic gait in a common clinical situation in which an AFO is prescribed for people with severe impairments during rehabilitation (as short-term or long-term measure).

Method

A with/without group comparison design was used to study the effects of a hinged AFO on gait impairments and functional mobility, and subjects were surveyed about their opinion of the AFO using a face-to-face questionnaire. Data were collected by a physiotherapist not involved in the subjects' treatment (HT) one month after the hinged AFO was fitted. Subjects were all over 18 years, had a hemiplegia following stroke, were able to weightbear and step with the weak leg (but may not have a functional gait pattern), and had sufficient range to obtain plantargrade in both heels. They were recruited from patients of the Regional Rehabilitation Unit at Northwick Park Hospital. Ethical approval was obtained from Harrow Research Ethics Committee and Brunel University Ethics Committee.

The orthosis

A hinged AFO was made for each subject by an orthotist using 4 mm polypropylene with a metal ankle joint and adjustable plantar flexion stop which was set to prevent plantar flexion but allowed full dorsiflexion. It enclosed the malleoli to give rigidity and medio-lateral stability, the sole plate extended the full length of the toes to prevent weight-bearing on an edge and toe-clawing, and it was moulded to preserve the arches of the foot as described and recommended by Edwards.[9] Each AFO cost approximately £250, and follow-up time to check and revise the fit as necessary was estimated at £120.

Gait measurements

The subject's gait was assessed as they walked with and without the hinged AFO (the order of testing was randomized). They wore ordinary shoes and were encouraged to rest as often as they needed during data collection. Physical support was not given during gait testing. All data was collected on one day to avoid any changes due to recovery. Functional Ambulation Categories were used to assess the effect on functional mobility. This simple 5-point scale assesses independence when walking[10–12] (Table 1) and has established reliability and validity. Paper walkways were used to assess several gait impairments – step and stride length of the weak and sound leg, symmetry of step length, velocity and cadence (step frequency). This simple, cheap method is suitable for use in the clinical situation and has previously been found to be reliable, accurate and valid.[10,11,13] A 7 m length of paper is divided into a 5 m walkway with a metre at each end for the start and finish line. Small stickers (orthopaedic felt with an adhesive backing and soaked in ink) were attached to the subjects' shoes at the apex of the heel. The subject walked along the walkway leaving a trail of inky footprints. Stride length for the left and right legs was measured as the distance between successive ipsilateral ink marks. Step length was measured as

the distance between contralateral ink marks, and symmetry was calculated by dividing the values for the sound step length by the weak step length. One or two walkways were completed so that there were data for at least 10 strides and mean values for the stride length, step length and symmetry of each leg were calculated, and an extra four 5 m walk tests were performed to assess velocity and cadence. The 5 m walk was timed using a stopwatch and the number of steps counted, these were converted into metres/s (velocity) and steps/min (cadence).

The questionnaire

Finally, the subjects' opinions of the hinged AFO were sought. Two main issues were considered: the effect of the AFO on gait and the subject's views of the AFO itself. These were developed into a questionnaire using a mixture of open and closed questions and Likert scales. It was piloted with three physiotherapists and four patients already using the AFO. Subjects were questioned about key aspects of function, including their ability to lift their toes, swing their leg forwards, take weight through their leg and the effect on their confidence, perceived safety, speed, and distance they could walk. Then they were asked what effect, if any, the hinged AFO had on these aspects of walking. They were also asked about the comfort and weight of the hinged AFO, putting it on and taking it off, and their thoughts on its appearance and whether they found this off-putting.

The authors wished to assess the effect of the hinged AFO on quality of movement as physiotherapists are often reluctant to prescribe AFOs as they are thought to have a detrimental effect on 'quality of movement'.[14] No accepted or widely used definitions of 'quality of movement' currently exist, so for this study it was interpreted as 'walking without a limp'. In order to consider the relative importance of 'quality of movement' and function, patients were asked to choose between function (walking quickly with a hinged AFO) or quality (walking without a limp or a hinged AFO, even if it meant walking slowly).

Analysis

As the data were distributed normally, the effect of the AFO was assessed by comparing each parameter with and without the AFO using paired *t*-tests, the FAC with and without the splint were compared using Wilcoxon's signed rank test. The questionnaire was analysed using descriptive statistics.

Results

Twenty-five subjects were recruited with a mean age of 49.9 (SD 1) years. There were 16 (64%) men and nine women, 16 (64%) had a right hemiplegia and nine had a left hemiplegia. The mean duration of hemiplegia was 8.3 months (SD 5.5).

Effect on function

The frequency of FAC scores is shown in Table 1. Function improved when using the hinged AFO. Without the hinged AFO the median FAC score was 2 (needs continuous support, range 1–4), with the hinged AFO the median score was 4 (able to walk independently on even ground, range 1–5). This difference was highly significant ($p = 0.00$).

Effect on gait impairments

A comparison of the mean values of each gait parameter with and without the hinged AFO and the *p*-values for the comparison are shown in Table 2. There were significant improvements in stride length of the sound and weak legs, cadence and velocity gait impairment when using the hinged AFO, but not for step length of the weak or sound leg, nor symmetry.

Table 1 Functional Ambulation Categories with and without AFO

Level	Without AFO	With AFO
1 Continuous support	7 (28%)	1 (4%)
2 Intermittent support	8 (32%)	0 (0%)
3 Supervision	7 (28%)	3 (12%)
4 Independent on level ground only	3 (12%)	19 (76%)
5 Independent anywhere	0 (0%)	2 (8%)

Table 2 Mean values (and standard deviation) for each gait parameter, with *p*-values (and 95% CI) for comparison with and without AFO

	Without AFO	With AFO	*p*-value (95% CI)
Weak stride length* (cm)	39.4 (14.3)	44.3 (14.1)	0.005 (–8.1, –1.6)
Sound stride length* (cm)	39.3 (13.7)	43.8 (14)	0.014 (–8, –1)
Weak step length (cm)	21.7 (9.5)	23.7 (11.7)	0.303 (–5.7, 1.9)
Sound step length (cm)	19.4 (9.9)	20.8 (9.6)	0.334 (–4.2, 1.5)
Step symmetry	2.6 (4.9)	3 (7.8)	0.653 (–2.2, 1.4)
Cadence* (steps/min)	53.1 (16.8)	62.5 (17.2)	0.002 (–15.1, –3.8)
Velocity* (m/s)	0.18 (0.1)	0.25 (0.1)	0.000 (–0.1, –0.03)

*Indicates a significant difference.

Subjects' views on the hinged AFO

The subjects were very positive about the hinged AFO. Twenty-four (96%) felt they walked better or much better with the hinged AFO, and one felt it made no difference. Nobody felt that it made their walking worse. Subjects were questioned about the key impairments and aspects of function that the hinged AFO might alter (listed in the Method section). Whether the hinged AFO altered the subjects' ability is shown in Table 3, and how it was altered is shown in Table 4. The majority of subjects found that the hinged AFO improved these aspects of gait.

Most patients ($n = 24$, 96%) found the hinged AFO comfortable or very comfortable to wear, although six (24%) felt that it was too heavy. Sixteen (64%) found it easy to put on and take off, and 14 (56%) were able to do this independently.

Table 3 Did the AFO change . . .

	Yes	No	Not a problem
Lifting your toes?	16 (64%)	8 (32%)	1 (4%)
Swinging your leg forwards?	20 (80%)	5 (20%)	0
Taking weight through your foot?	14 (56%)	10 (40%)	1 (4%)
Your confidence?	22 (88%)	2 (8%)	1 (4%)
Your safety?	23 (92%)	1 (4%)	1 (4%)
The distance you can walk?	19 (74%)	4 (16%)	2 (8%)
Your speed?	19 (74%)	4 (16%)	2 (8%)

Table 4 What effect did it have?

	Much improved	A little improved	A little worse	Much worse
Lifting my toes is . . . ($n = 16$)	8 (50%)	8 (50%)	0	0
Swinging my leg forward is . . . ($n = 20$)	11 (55%)	8 (40%)	1 (5%)	0
Taking weight through my foot is . . . ($n = 14$)	10 (71%)	4 (29%)	0	0
My speed is . . . ($n = 19$)	9 (47%)	10 (37%)	0	0
My confidence is . . . ($n = 22$)	9 (41%)	13 (59%)	0	0
My safety is . . . ($n = 23$)	18 (78%)	5 (22%)	0	0
The distance I can walk is . . . ($n = 23$)	14 (61%)	9 (39%)	0	0

Only five (20%) found it unattractive, while 23 (92%) were either not bothered by the appearance or felt that the benefits were more important than the appearance. Finally, they were asked about the relative importance of function and quality of movement. Twenty-four (96%) chose function (to walk fast with a splint) over quality of movement (walking without a limp or AFO although it may be slower).

Discussion

The results of this study show that a hinged AFO can significantly improve functional mobility, and some gait impairments – velocity, cadence and stride length showed significant improvements but not step length or symmetry. This is may be due to high intersubject variability in step length (particularly weak step length when the AFO was used) and therefore symmetry.

Users were very positive about the hinged AFO. The majority found it comfortable and felt it improved their walking, particularly the functional aspects such as safety, confidence, speed and distance. They were either unworried by the appearance or felt that the benefits outweighed any reservations. Despite their severe impairments most were able to learn how to put it on and take it off independently.

The functional significance for patients and the rehabilitation process was marked. Without a hinged AFO 88% of patients needed support or supervision to walk but with the hinged AFO 84% were able to walk independently. Using the AFO enabled an increase in walking practise during physiotherapy and on the ward. This is critical factor in acquiring motor skill,[15] and may be how the hinged AFO enabled independence. This study has looked at the short-term effect during rehabilitation, a longitudinal study would be required to discover the longer term effects of the hinged AFO.

Clinical messages

- A hinged AFO significantly improved functional mobility and stride length, cadence and velocity, but not step length or symmetry.
- Users were positive about the hinged AFO. They found it effective and comfortable. Reservations about appearance were outweighed by the benefits. Patients valued function over quality of movement.

Each hinged AFO costs approximately £250 – the cost of one day's stay at the regional rehabilitation unit. Yet by speeding the acquisition of functional independence, the hinged AFO could reduce length of stay and level of support, and therefore the cost of rehabilitation and aftercare. A full cost/benefit analysis of the short- and long-term effects of using a hinged AFO as a rehabilitation aid is needed to allow more informed decisions to made about the provision of rehabilitation.

Users' opinion of AFOs has received little attention to date but difficulties with comfort, fit and donning and doffing the AFO have been reported in studies using fixed, 'off-the-shelf' AFOs.[1,5,16] This study reports greater satisfaction with comfort and fit and ability to don and doff the AFO, possibly because each hinged AFO was specifically moulded and fitted for each subject, and their rehabilitation specifically targeted putting the hinged AFO on and off.

The positive perception of the hinged AFO could have been biased as the subjects were inpatients in the unit supplying the AFO when questioned. Several measures were taken to minimize possible bias however. First the person administering the questionnaires was not actively involved in treating the patients, or in prescribing or fitting the hinged AFOs. Secondly, the subjects were encouraged to be frank and honest in their answers, as the information would be used to improve the clinical service. An anonymous written questionnaire was considered in the early stages of the project but was rejected as many subjects had communication or cognitive problems that prevented written replies.

A notable finding was the value patients attached to regaining functional mobility even if it was at some cosmetic cost. Physiotherapists have traditionally emphasized retraining 'quality of movement' in the belief that this would deliver the best functional outcome and that patients put a premium on cosmetically 'normal' movement patterns,[17,18] and that using an AFO would have

a detrimental effect on quality of movement.[14] These beliefs are not supported by the results of this study. Patients' perceptions of their motor impairments and disabilities and their priorities for different aspects of recovery have received little attention to date. Further work is clearly indicated on this issue and the relationship between 'quality of movement' and function so that both therapists and patients can make more informed choices about rehabilitation goals.

In summary, a hinged AFO improved functional mobility and some gait impairments. The majority of users found it beneficial, were able to put it on and take it off independently, found it comfortable to wear and felt that the benefits outweighed any reservations about its appearance. Further study is needed to examine the longer term effects and the cost-effectiveness of prescribing a hinged AFO for people with stroke.

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