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Effects of ankle-foot orthoses on hemiparetic gait

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Objective: Ankle-foot orthoses (AFOs) are widely used to provide optimal ambulation in people with hemiplegia. In this study we evaluated the mechanical effects of metallic and plastic AFOs on severely hemiparetic stroke patients.
Methods: Twelve hemiparetic patients were analysed on a Vicon 370 Motion Analysis System. Spatiotemporal, kinematic and kinetic parameters were measured.
Results: The two types of orthoses generally had similar positive effects on hemiplegic gait parameters, increasing cadence, walking speed, single and double step length, ankle dorsiflexion angle at heel strike and swing. The metallic AFO was better at increasing the ankle dorsiflexion angle than the plastic AFO.
Conclusion: Hemiplegic gait was improved by both orthoses. However, metallic AFOs provided better stabilization of the ankle, allowing improved heel strike and push-off.

Introduction

Ankle-foot orthoses are commonly used to control ankle motion and provide optimal ambulation in patients with hemiplegia. The Seattle design plastic AFOs and metallic AFOs are the most widely prescribed AFOs in hemiplegic patients, presumably due to their good mediolateral stability, toe clearance and dorsiflexion resistance.[1,2] Comparison of the effects of different AFOs on hemiplegic gait pattern have not been documented before.[2–4] The aim of this study was to evaluate and compare the mechanical effects of plastic and metallic AFOs on the same patient with hemiplegia.

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Methods

Twelve hemiparetic stroke patients (3 women, 9 men), who had no ankle control on the hemiplegic side while walking, participated in the study after giving their consent. Mean age of the group was 54 (39–65) years; mean time since stroke was 67 days (30–270). Patients were using either a single-point or three-point cane. None had fixed deformity at the ankle. Three patients had a moderate degree of spasticity in plantar flexors (Modified Ashworth grade 2–3). None of them had neglect phenomenon, communication problems or proprioceptive sensory impairment.

Both a Seattle-type polypropylene AFO and a metallic AFO were specially moulded and fitted for each patient. During manufacture of the metallic AFO a rigid sole plate extending to the head of the metatarsals was attached to a Blücher shoe and a stirrup assembly was riveted to the

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sole plate. This was attached to two metal uprights which were fixed with a rigid posterior calf band and leather closure. The dorsiflexion angle of the AFOs was adjusted to 90 degrees. All the patients had an opportunity for walking practice with each orthosis before gait analysis to ensure proper fitting and to allow necessary adjustments to be made.

The Vicon 370 Motion Analysis System was used for gait analysis. Ground reaction forces (GRF) were collected using two force plates (Bertec, Columbus, OH, USA) with simultaneous measurement of the limb position. All the gait data of a patient was collected on one day to avoid any changes due to recovery. Each subject was instructed to walk without any orthosis then an AFO on the same session, at a self-selected speed. The order of testing was randomized. Spatiotemporal (cadence, walking speed, step time, step length and double support time), kinematic (ankle dorsiflexion at heel strike and mid-swing), and kinetic parameters (knee flexion moment, GRFs) were measured at each condition. Practice trials were performed by each subject until they could consistently and naturally contact both of the force plates. Statistical Package for the Social Sciences (SPSS for Windows v.901) was used for statistical evaluation. Pairwise comparisons of gait parameters were done within the same group using the Wilcoxon signed ranks test.

Results

There were no significant differences in cadence, double support time, single step time and step length with the two types of AFOs. A significant increase in walking speed was observed with the metallic AFO. Ankle dorsiflexion at heel strike and mid-swing showed an increase with both types of AFO. The metallic AFO provided more dorsiflexion in these phases than the plastic AFO (Table 1). Maximum hip and knee flexion–extension angles showed no significant differences. The metallic AFO caused a greater decrease in knee flexion moment compared with bare walking and the plastic AFO. There were no significant differences in mean hip flexion–extension moments, knee extension, valgus moments, ankle plantar flexion moment, total ankle power or first vertical force peak. The shape of the vertical force curves showed a plateau pattern instead of normal double peak pattern in almost all of the cases during bare walking. We observed the change of plateau pattern to normal double peak pattern in six patients during walking with AFOs.

Discussion

Hemiplegia due to stroke impairs an individual's ability to walk and frequently causes severe disability. Inadequate ankle dorsiflexion during swing, mediolateral ankle instability and insufficient push-off during late stance frequently disturb normal walking patterns, causing slower walking speed, shorter step length and foot drag.

Table 1 Gait parameters measured in three walking conditions (mean ± SD)

Parameters	Without orthosis (a)	Plastic AFO (b)	Metallic AFO (c)	*p* a x b	*p* a x c	*p* b x c
Cadence (steps/min)	62.33 ± 20.56	65.00 ± 19.27	67.33 ± 17.45	NS	NS	NS
Walking speed (m/s)	0.32 ± 0.13	0.37 ± 0.14	0.41 ± 0.16	NS	<0.05	<0.05
Single step time (s)	1.20 ± 0.52	1.12 ± 0.41	1.03 ± 0.33	NS	NS	NS
Double support time (s)	1.04 ± 0.69	0.90 ± 0.53	0.79 ± 0.31	NS	NS	NS
Single step length (m)	0.33 ± 0.08	0.36 ± 0.08	0.37 ± 0.08	<0.05	<0.05	NS
Ankle[a] dorsiflexion (degrees)	–16.18 ± 10.84	–6.48 ± 6.21	–0.37 ± 4.37	<0.05	<0.05	<0.05
Ankle[b] dorsiflexion (degrees)	–12.38 ± 13.04	–1.29 ± 5.72	3.44 ± 5.76	<0.05	<0.05	<0.05
Knee flexion moment (N/m)	0.36 ± 0.25	0.32 ± 0.24	0.20 ± 0.16	NS	<0.05	<0.05

[a]Stance phase.
[b]Swing phase.
NS, nonsignificant.

Clinical messages

- A more rigid metallic ankle-foot orthosis improved gait more than a plastic AFO in patients with long-term hemiparesis and slow walking.

An AFO is thought to be the most suitable lower-limb orthosis to overcome any gait deficit related to ankle instability.[5]

Walking speed, cadence, step length usually decrease in hemiparetic gait pattern.[6] The mean walking speed of subjects was very slow (0.3 m/s) compared with men aged over 60 who have a walking speed of 1.18 m/s.[7] Normal walking speed in healthy women 64 years of age and older is 0.96 m/s.[8] Although both AFOs increased the walking speed of patients, the mean value was still low compared with that of healthy people.

Hemiplegic patients usually have less dorsi-flexion during heel contact and mid-swing due to loss of motor control, spasticity of the gastrocnemius-soleus group and ankle contracture. Although mean plantarflexion of the hemiparetic patients during swing was excessive, both orthoses decreased plantarflexion adequately for toe clearance. Better toe clearance provided by the metallic orthosis was most likely due to its greater resistance to plantarflexion compared with polypropylene orthosis.

Knee stability is considerably affected by loss of ankle control and use of AFOs. The lack of forward movement of the centre of pressure on the ankle produces a markedly increased knee flexion moment in midstance when body weight is supported by the paralysed limb.[9] Both AFOs limited the excessive plantarflexion, forming a potential for dynamic knee instability. It is suggested that the greater the plantarflexion resistance of AFO, the greater the external bending moment at the knee.[2] In accordance with this, we noted a greater decrease in internal knee flexor moment with metallic orthosis. Lehman *et al.* observed a decrease in flexor moment with use of metallic AFO, however, they used AFOs set at 5° plantarflexion.[6]

Usually, heel strike and push-off phases are inefficient in hemiparetic gait due to decreased weight bearing and consequent shorter stance duration, mediolateral instability, striking on the ground with toes or sole of the foot and weak or absent plantarflexors.[10] Both AFOs changed the plateau pattern of curve to the usual double peak pattern in six subjects. This observation was presumably due to better stabilization of ankle joint medio-laterally and significant plantarflexion resistance offered by AFOs, allowing better heel strike and more effective push-off.

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