INTRODUCTION

For children with cerebral palsy, AFOs are prescribed to prevent deformity at the ankle, promote a stable base during locomotion and improve the dynamic efficiency of gait. Although AFOs have been found to improve locomotion, their limitation of ankle motion is thought to adversely affect the ability of the child with cerebral palsy to ascend and descend stairs. The purpose of this study was to determine whether a specific AFO configuration (hinged, posterior leaf spring (PLS), or solid) produced biomechanical compensations which inhibited the ability of the child with hemiplegia to ascend or descend stairs.

REVIEW AND THEORY

Stair locomotion is an important functional activity. In order to ascend and descend stairs the ankle requires 30-40 degrees of both plantar and dorsiflexion to control the forward progression of the body. Restriction of ankle motion by an AFO has been shown to produced compensatory movements at the pelvis and hip in children with normal neurological systems. Children with cerebral palsy often have difficulty with stair ambulation due to poor motor control and balance, spasticity and contractures. Despite the difficulty posed by stairs, no information exists regarding the kinematics of stair locomotion in children with cerebral palsy and the subsequent biomechanical compensations required by the child when orthotic devices are utilized.

METHODS

Nineteen children with a diagnosis of spastic hemiplegia, cerebral palsy with a mean age of 9.3 years (range 6.3-15.3 years) were evaluated during stair ambulation. Each child participated in the study for one year which consisted of three months of no AFO wear followed by a randomized AFO sequence. Each AFO was worn for three months with assessments performed at the completion of each wearing period. Each child ascended and descended a series of four stairs using a reciprocal stepping pattern. Stair locomotion data were collected with a six camera motion measurement system (Vicon 370, Oxford Metrics) and analyzed using Vicon Clinical Manager (VCM). Only data from stairs 1 to 3 during ascent and 3 to 1 during descent for both the involved and noninvolved sides were used in the analysis. Velocity and single limb stance times were assessed during stair ascent and descent. Maximum and minimum values were evaluated at the pelvis over the entire cycle (sagittal, coronal, transverse planes), hip (sagittal, coronal planes) knee and ankle (sagittal plane) during stance and swing. Data were analyzed using univariate repeated measure ANOVAs with linear contrasts. P values ranged from .008-.025 using a Bonferonni correction.

RESULTS

During stair ascent on the involved side no differences were found at the pelvis or hip in any plane. Knee extension during stance was
greater barefoot compared to hinged \( p = .003 \) AFO wear. Ankle motion during stance showed greater dorsiflexion when the hinged AFO was worn in comparison to barefoot \( p = .0001 \) and solid \( p = .0004 \) AFO wear. Velocity was fastest with the PLS AFO in comparison to barefoot \( p = .004 \) and solid \( p = .007 \) AFO wear. The involved limb showed increased single limb stance times during hinged \( p = .017 \) and PLS \( p = .006 \) AFO wear in comparison to barefoot. The only biomechanical compensation by the non involved limb at the ankle was a decrease in plantarflexion during stance when a hinged \( p = .008 \) AFO was worn on the contralateral side. No differences in gait parameters were found.

During stair descent, the involved side allowed greater plantarflexion during stance barefoot \( p = .0001 \) in comparison to all AFOs. During swing, the hip \( p = .0003 \) and knee \( p = .0026 \) showed an increase in flexion while the ankle had greater plantarflexion \( p = .0001 \) and less dorsiflexion \( p = .0001 \) during barefoot in comparison to AFO trials. No differences in gait parameters were found. On the non involved side, no kinematic compensations were seen at the pelvis, hip, knee and ankle during stance or swing. Single limb stance times were greater \( p = .016 \) when AFOs were worn in comparison to barefoot.

**DISCUSSION**

During ascent and descent, the majority of differences were seen at the ankle between barefoot and all AFOs with minimal differences occurring between the AFOs. During stair ascent the increase in dorsiflexion offered by the hinged AFO allowed for a smooth transition of the center of mass over the foot, improving single limb stability. During stair descent in the barefoot condition, children with hemiplegia chose to minimize pelvic obliquity on the involved side by increasing hip and knee flexion to clear the plantarflexed foot during swing. Velocity during stair locomotion was slower for children with hemiplegia barefoot and in all AFOs when compared to normal children wearing a unilateral solid AFO\(^2\). During stair locomotion on the non involved side, minimal kinematic compensations were seen resulting from the AFO configuration. Maximum and minimum angles at the hip, knee and ankle were found to be similar to those of Andriacchi et al.\(^1\). Despite claims that orthotic devices are detrimental for stair ambulation in children with cerebral palsy, kinematic evaluation reveals improved stability during stance on the involved limb while no compensations were made by the non involved limb. For children with hemiplegia the hinged and PLS AFOs offer motion and stability without significant compensations at proximal joints.

**REFERENCES**


**ACKNOWLEDGEMENTS**

Research was funded by the Shriners Hospitals for Children.