PM R XXX (2017) 1-7
www.pmrjournal.org

Original Research

Long-Term Effects of Orthoses Use on the Changes of Foot and Ankle Joint Motions of Children With Spastic Cerebral Palsy

Xue-Cheng Liu, MD, David Embrey, PhD, Channing Tassone, MD, Kim Zvara, MD, Brenna Brandsma, DPT, Roger Lyon, MD, Karin Goodfriend, MD, Sergey Tarima, PhD, John Thometz, MD

Abstract

Background: Orthoses commonly are prescribed to children with cerebral palsy (CP) to provide foot correction and to improve ambulatory function. Immediate effects of ankle foot orthosis (AFOs) have been investigated, but long-term kinematic effects are lacking clinical evidence.
Objective: To determine changes in 3-dimensional ankle and foot segment motion in pediatric patients with CP between initial and follow-up visits (18-month average time differences) in both barefoot gait and gait with their AFO. We also investigated intravisit changes between barefoot and AFO gait.
Design: A prospective cohort study.
Setting: Children's Hospital of Wisconsin, Department of Orthopaedic Surgery, Medical College of Wisconsin.
Patients: A total of 23 children with CP, mean age 10.5 years (6.2-18.1 years) were clinically prescribed either a solid ankle foot orthotic (SAFO), hinged ankle foot orthotic (HAFO), or supramalleolar orthotic.
Methods: Holes were cut in the study orthoses so that electromagnetic markers could be directly placed on the skin. A 6-foot segment model was used.
Outcome Measurements: Kinematic and kinetic data was recorded for each patient's initial and follow-up visit (18-month follow-up average, 15-20 months range).
Results: For the SAFO group (gait with AFO), a significant decrease in dorsiflexion was found between the initial and third visit ($P = .008$). Furthermore, the SAFO group (barefoot gait) had an increased eversion at the midfoot for most of the gait cycle ($P < .008$). Sagittal forefoot range of motion was reduced for all 3 groups between the barefoot and AFO groups.
Conclusion: The use of AFOs long term either maintained or improved foot deformities or dysfunction.
Level of Evidence: To be determined.

Introduction

Children with cerebral palsy (CP) usually have impaired ambulation and reduced balance compared with children who are typically developing, and orthoses often are prescribed to improve their ambulatory function. In addition, patients with CP have an altered pattern of lower limb and trunk muscle activation, particularly with a greater muscle activation rate [1]. This may lead to a repetitive loss of balance and abnormal foot position. Later, it can lead to a soft-tissue contracture and osseous deformity [2] and ultimately foot deformities. An estimated 93% of children with spastic CP have foot or ankle deformities [3]. Two of the most common foot deformities in children with CP are equinovarus and pes valgus [4,5].

Orthoses are believed to help correct abnormal gait for patients with CP by allowing for a maintenance of a neutral or slight dorsiflexion and a reduction of ankle plantarflexion during swing phase (compared with barefoot); these reduce the risk of the foot making contact with the floor during swing phase and prevents foot drop during swing [5,6]. Other gait deviations can be improved by the use of specific types of foot orthoses. For example, the supramalleolar orthosis (SMO) is prescribed primarily to control hindfoot and midfoot

1934-1482/$ - see front matter
http://dx.doi.org/10.1016/j.pmrj.2017.08.438

varus/valgus and is thought to have a limited influence in the sagittal plane control during stance phase [5,7,8]. Hinged ankle foot orthoses (HAFOs) are prescribed to reduce foot equinus during gait to improve ankle dorsiflexion in mid-stance and to prevent foot drop during the swing phase [6].

However, there are concerns that in some cases the HAFO allows excessive dorsiflexion and may promote overstretching of the gastrocnemius [7]. Solid ankle foot orthoses (SAFOs) often are prescribed to help provide foot and ankle stability. SAFOs also control excessive ankle plantarflexion while preventing excessive dorsiflexion.

Although most SAFOs allow some ankle dorsiflexion, some have proposed that HAFOs provide a more natural kinematic and kinetic function [6,9]. Our previous study investigated the immediate effects of orthoses and confirmed that SAFO constrained forefoot range of motion (ROM) and did not control excessive plantar flexion [10]. Contrary to previous reports, the SMO showed no effects in the coronal plane. However, our study demonstrated immediate effects of an orthosis intervention [10].

There are few studies that have investigated the effect of orthoses on patients with CP over an extended period of time [11]. One study followed 12 children with CP over a 2-year period and discontinued their AFO use for 4 weeks [12]. Q3 The investigators found that during these time periods, ROM and overall gait deteriorated. Furthermore, a retrospective study examined 2 gait analysis results (average 18 months apart) of 18 patients with CP [13]. Although AFOs were not analyzed as a factor affecting gait, 16 of the subjects in this study used or had used AFOs. Findings showed subjects with CP had worsened spatiotemporal parameters and decreased joint motion at the latter gait analysis [13].

In addition to orthoses affecting a patient's gait, evidence shows that shoes by themselves can affect gait in patients with CP. A study comparing barefoot gait, shod gait, and shod gait with orthoses found that the use of shoes significantly alters gait in children with spastic hemiplegia. This study found that the significance in gait kinematic and kinetic changes when orthoses were worn varied depending on whether the subjects were barefoot or shod [14]. Studies in healthy children also found that shoes could have an impact on gait parameters [15,16].

For this study, we investigated the long-term effects of HAFOs, SAFOs, or SMOs on kinematic function between the initial patient visit and final visit (18 months). Measurements were collected by the use of direct foot markers directly on the skin and specially constructed orthoses. In most studies that examine the gait of children with CP with orthoses, investigators attach markers to the outside of the orthoses and/or the shoe to track movement. Although markers placed in this manner may measure movement of the orthosis or shoe, they do not measure underlying foot motion. We hypothesized that a long-term (18 month) application of HAFOs, SAFOs, and SMOs would demonstrate improvements in ankle joint and foot segment motion, although the SAFO improvements may be less evident. Particularly, improvements are most evident by reducing dorsiflexion at the forefoot during the third rocker (terminal stance phase, or 40%-60% of gait cycle) [17].

Methods

Study Recruitment

For the initial visit, 23 patients were recruited. Before the final visit, 2 patients discontinued the study. The institutional review board approved this study, and all families signed informed consent before their participation.

AFO Assessment

The mean time between the initial and final visit was 18 months (15-20 months). All participants used clinically prescribed HAFOs, SAFOs, or SMOs and were divided into groups according to the orthoses prescribed. During the first visit, 7 participants were diagnosed as hemiplegic and the other 16 were diagnosed with diplegia; 2 patients with diplegia dropped out of the study by the final visit. There were 9 participants in the SMO group, with 3 using SMOs bilaterally and 6 unilaterally. Initially, 5 participants were in the SAFO group, with all participants using them bilaterally; 1 subject dropped out before the final visit. Initially, 10 participants were in the HAFO group, with 6 using them bilaterally and 4 unilaterally; 1 bilateral HAFO user dropped out before the final visit. A participant who wore a right HAFO and a left SMO was assigned to both the HAFO and SMO groups. During the initial and final visit, the average age was 8.6 years (range 4.5-16.6 years) and 10.5 years (range 6.2-18.1), respectively. All Q4 participants had their function classified using the Gross Motor Function Classification System (GMFCS) by a physical therapist. At the final visit, 10 participants were level 1, 5 participants were level 2, 4 participants were level 3, and 2 participants were level 4. A participant with level 1 GMFCS and a participant with level 3 GMFCS from the initial visits discontinued the study.

During the initial visit, a pedorthotist constructed the clinically prescribed orthosis (with holes for data collection) for each participant, which was used at the initial and final visits. The dorsiflexion of the ankle in the HAFOs and SAFOs are set up at plantigrade (0° of dorsiflexion) or 1-5° of dorsiflexion, depending on the individual cases. Orthoses without holes were constructed (using the same molds) for everyday wear by the subjects in the study. Slip-resistant material was used to modify the study orthosis and to provide