Research in Developmental Disabilities 41–42 (2015) 52–57

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Foot pressure distribution in children with cerebral palsy while standing

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ARTICLE INFO

Article history:
Received 4 December 2014
Received in revised form 5 May 2015
Accepted 21 May 2015
Available online 6 June 2015

Keywords:
Cerebral palsy
Posture
Foot
Arch Index plantar pressure
Standing
Rehabilitation

ABSTRACT

Foot deformity is a major component of impaired functioning in cerebral palsy (CP). While gait and balance issues related to CP have been studied extensively, there is little information to date on foot–ground interaction (i.e. contact area and plantar pressure distribution).

This study aimed to characterize quantitatively the foot–ground contact parameters during static upright standing in hemiplegia and diplegia.

We studied 64 children with hemiplegia (mean age 8.2 years; SD 2.8 years) and 43 with diplegia (mean age 8.8 years; SD 2.3 years) while standing on both legs statically on a pressure sensitive mat. We calculated pressure data for the whole foot and sub-regions (i.e. rearfoot, midfoot and forefoot) and average contact pressure. The Arch Index (AI) served for classifying the feet as flat, normal or cavus feet. The data were compared with those from a sample of age- and gender-matched participants (control group, 68 children). Most of the feet showed very high AI values, thus indicating a flat foot. This deformity was more common in diplegia (74.4%) than in hemiplegia (54.7%). In both diplegic and hemiplegic children, average plantar pressure was significantly increased in the forefoot and midfoot and decreased in the rearfoot ($p < 0.001$).

The present data indicate an increased load on the front parts of the foot, which may be due to plantarflexor overactivity or knee flexion, combined with an increased incidence of low foot arches. As a low foot arch does not necessarily increase forefoot load, this deformity can be regarded as secondary.

1. Introduction

Cerebral palsy (CP) is described as a group of permanent disorders of movement and posture development that causes functional limitations as well as difficulty in the activities involved in daily living. CP disorders are attributed to non-progressive alterations that occur during fetal or infant development of the brain. The most typical symptoms of CP are

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http://dx.doi.org/10.1016/j.ridd.2015.05.006
0891-4222/

disorders of movement activities to various degrees and affecting different parts of the body. Such alterations often assume the form of contractures of limb and trunk muscles, mostly of a spastic type, balance disorders and motor hyperactivity. A very common disorder is represented by restriction of walking efficiency or even an inability of the child to walk on its own. Lack of control is obvious at the ankle and foot joints in the stance phase, and results from poorly controlled muscle activity, contractures and/or bony foot deformities. In particular, foot deformities, which are very common in individuals with CP, lead to the foot resting on the ground in an unnatural way, abnormal pressure distribution and altered gait and posture (Dziuba & Szpala, 2008).

Although the literature has widely investigated the degree of functional limitation of gait and posture in children with CP using 3D movement analysis (Chang, Rhodes, Flynn, & Carollo, 2010; Cimolin, Galli, Tenore, Albertini, & Crivellini, 2007; Ferreira et al., 2014; Gage, 2004, chap. 19; Galli et al., 2007; Galli, Cimolin, Rigoldi, Tenore, & Albertini, 2010; Piccinini et al., 2007; Rojas et al., 2013; Saxena, Rao, & Kumaran, 2014; Sutherland & Davids, 1993), quantitative studies of the characterization of foot morphology and functionality in these patients are scarce.

In previous studies, pedobarography was used primarily to assess plantar pressure during walking. Femery, Moretto, Renaut, Thévenon, and Lensel (2002) reported that hemiplegic children are characterized by significant differences in load distribution under the feet of both the affected and unaffected limbs, particularly as regards the midfoot, the first metatarsal head and the hallux. Park, Park, Lee, Joo, and Kim (2008) identified characteristics of foot pressure distribution during gait in different types of foot deformity (equinus, equinovarus and equinovalgus) using a computerized insole sensor system and assessed changes after corrective surgery in children with spastic CP. Nsenga Leunkeu, Lelard, Shephard, Doutrellot, and Ahmaidi (2014) compared the extent of plantar pressure during walking in a sample of children with CP and able-bodied peers. Plantar pressure differed substantially and consistently between healthy and CP children, with increased medial heel pressure in hemiplegia, and reduced hallux and lateral heel pressure but increased lateral, medial mid-foot and first metatarsal pressure in diplegia. Pauk, Daunoraviciene, Ihnatouski, Griskevicius, and Raso (2010) assessed pressure distribution of typical feet and those of patients with deformities, including patients with CP, during static and walking conditions, with the aim of characterizing different foot deformities, such as planovalgus, clubfoot and pes planus, independently of the basic disease.

To the best of our knowledge, no study has so far focused on characterizing foot type and plantar pressure distribution during static standing in CP, as this condition was mainly investigated using a force platform to evaluate postural sway and thus static balance abilities (Rojas et al., 2013). In particular, it was noted that the postural control system of patients with spastic diplegic CP performed worse than that of patients with spastic hemiplegic CP.

The foot as the base of the body thus plays an important role, and deformities may cause difficulty in daily life (Rojas et al., 2013). The aim of the present study is quantitative characterization of foot morphology and plantar pressure patterns in children with CP (diplegics and hemiplegics) during upright standing. Foot problems are common in patients with CP; our hypothesis is therefore that children with CP demonstrate particular plantar pressure patterns with respect to healthy children.

2. Materials and methods

2.1. Participants

107 children with spastic CP in the 5–13 age range (mean age 8.6 years, SD 2.4 years), level I–II according to Palisano's classification (GMFCS: Gross Motor Functional Classification System) (Palisano et al., 1997) consecutively examined at the Movement Analysis Lab of the IRCCS "San Raffaele Pisana", Tosinvest Sanità, Roma (Italy) were recruited for the present study. Children were included in the study if they met the following criteria: (a) could stand up independently for at least 2 min unaided without losing their balance, with the entire plantar area in contact with the ground; (b) had had no previous orthopedic surgery on any of the lower limb joints; (c) had not had botulinum toxin injected into the lower limbs within 6 months or casts on these levels; (d) no associated problems that could influence their balance (mental deficiency, severe visual and sensory problems). They were classified as diplegic, right hemiplegic and left hemiplegic CP. We distinguished between right and left hemiplegic CP because the literature has documented a different gait pattern in the two groups (Galli et al., 2010). A different foot type was supposed to be present in the two hemiplegic groups. Three gender- and age-matched control groups (CG1, CG2 and CG3) of the same size were set up, consisting of unaffected children attending three primary school classes in the city of Cagliari (Italy). The main anthropometric features as well as the number of the participants for each group tested are reported in Table 1.

The study was approved by the local Ethics Committee and written informed consent was obtained from the parents of the children.

2.2. Data acquisition and post-processing

We used a pressure sensitive mat (Tekscan 5315, Tekscan Inc., South Boston, MA, USA), composed of 2016 sensing elements arranged in a 42×48 matrix and connected via USB interface to a Personal Computer. Participants were placed on the mat with the help of an assistant who, after a brief familiarization period, asked them to stand as still as possible for 5 s trials. A total of 40 temporal frames (sampled at 8 Hz) were acquired barefoot for each trial, and matrices containing the foot–ground pressure value for each element in the sensitive grid were exported for further analysis.