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A descriptive analysis of the upper limb patterns during gait in individuals with cerebral palsy

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ABSTRACT

Patients with cerebral palsy (CP) are characterized by a large diversity of gait deviations; thus, lower limb movements during gait have been well-analyzed in the literature. However, the question of upper limb movements and, more particularly, arm movements during gait has received less attention for CP patients as a function of the disease type (Hemiplegic, HE or Diplegic, DI). Thus, the aim of this study was to investigate upper limb movements for a large group of CP patients; we used a retrospective search, including upper limb kinematic parameters and 92 CP patients (42 females and 50 males, mean $\pm$ standard deviation (SD); age: 15.2 ± 6.7 years). The diagnoses consisted of 48 HE and 44 DI. A control group of 15 subjects (7 females and 8 males, age: 18.4 ± 8.4 years) was included in the study to provide normal gait data. For the DI patients and CG, 88 arms and 30 arms were analyzed, respectively. For the HE patients, 48 affected arms and 48 non-affected arms were analyzed. The kinematic parameters selected and analyzed were shoulder elevation angles; elbow flexion angles; thorax tilt and obliquity angles; hand vertical and anterior–posterior movements; and arm angles. Several gait parameters were also analyzed, such as the gait profile score (GPS) and normalized speed. Statistical analyses were performed to compare CG with the affected and non-affected upper limbs of HE patients and with the two upper limbs of DI patients. The results show that HE and DI patients adopt abnormal upper limb movements. However, DI patients have greater shoulder, elbow, thorax and arm angle movements compared with HE patients. However, HE patients adopt different movements between their affected and non-affected arms. Thus, the patients used their upper limbs to optimize their gait more where gait deviations were more important. These observations confirm that the upper limbs must be integrated into rehabilitation programs to improve inter-limb coordination.

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1. Introduction

Understanding the role of arm movements during gait and pathological gait is necessary to fully understand gait deviations (Bonnefoy-Mazure, Sagawa, Lascombes, De Coulon, & Armand, 2013; Bonnefoy-Mazure, Turcot, Kaelin, De Coulon, & Armand, 2013; Eke-Okoro, Gregoric, & Larsson, 1997; Ford, Wagenaar, & Newell, 2007; Jaspers et al., 2009; Kaminski, 2007; Meyns, Desloovere et al., 2012; Riad, Coleman, Lundh, & Brostrom, 2011; Romkes et al., 2007). Meyns et al. reviewed the literature regarding "The how and why of arm swing during human walking?" (Meyns, Bruijn, & Duysens, 2013). The authors concluded that if it is particularly difficult to answer at the question "how", then the answers for the question "why" converged at two points: (1) the arm movement reduced the energetic cost (approximately 8%) during gait, and (2) it facilities the leg movements. For pathological gait, the two points described above can only encourage biomechanics and clinicians to consider arm movement during gait analyses of their patients. In the central neurological pathologies, such as spinal cord injury, Parkinson's disease, stroke or cerebral palsy (CP), arm movements are often directly affected (Ford, Wagenaar, & Newell, 2007; Galli et al., 2013; Huang et al., 2012; Lewek, Poole, Johnson, Halawa, & Huang, 2010; Su et al., 2014; Tester et al., 2011).

CP disease is attributed to a non-progressive disturbance during fetal or infant brain development. The main dysfunctions are related to motor disorders during posture and movement, which cause limitations in activities and societal participation. Motor disorders in patients with CP are complex; they are related to primary deficits in muscle tone, muscle weakness and a loss of selective motor control; secondary deficits can include muscle contractures and bony deformities that can affect the lower and/or upper limbs (Dietz & Michel, 2008; Riad et al., 2011; Zehr & Duysens, 2004). Different types of CP are defined based on the affected limbs' topography. In CP patients with hemiplegia (HE), one side of the body (arm and leg) is affected, while in patients with diplegia (DI), the lower limbs are more affected than the upper limbs (Dabney, Lipton, & Miller, 1997). Numerous studies have considered the lower limb abnormalities during gait (Bonnefoy-Mazure, Sagawa, 2013Bonnefoy-Mazure, Turcot, 2013; Dobson, Morris, Baker, & Graham, 2007; Gage, 2004; Perry & Burnfield, 2010; Winters, Gage, & Hicks, 1987). However, descriptive data on upper limb movement during gait in a CP population is limited (Artilheiro et al., 2013; Meyns et al., 2011). Upper limb movements (i.e., arms and thorax movements) are used differently by CP patients as a function of their disease type (HE or DI) to compensate for physical impairments and increase gait speed or to compensate for altered movements on the affected side (Meyns et al., 2011). Therefore, we expect that the pattern and deficit in the upper limb movements for DI and HE patients will be specific for each CP subgroup.

Thus, the aim of this study was to describe the arm and thorax movements during gait in a large population of CP patients with DI and HE compared with a control group.

2. Methods

2.1. Patients

A retrospective search in the Willy Taillard Laboratory of Kinesiology database was conducted to select CP patients that received gait and clinical assessments. The following inclusion–exclusion criteria were used: (1) the individuals must have had a clinical diagnosis of CP; (2) the individuals were able to walk without assistive devices; (3) the individual's age must have been in the range 5–30 years on the date of the examination; (4) the individuals must have completed a clinical exam and clinical gait analysis (CGA) on the same date; and (5) the individuals must have had no surgery one year before the CGA and no pharmacological treatments 6 months before the CGA (Graham, Harvey, Rodda, Nattrass, & Pirpiris, 2004).

Thus, 15 healthy individuals with no gait abnormalities (7 females and 8 male, mean (standard deviation, SD) age: 18.4 (8.4) years) were recruited to provide normal gait data and were used as the control group (CG) for future analyses.

2.2. Clinical Gait analysis

CGA was performed using a twelve-camera motion analysis system (VICON Mx3+; ViconPeak®, Oxford, UK) with the sampling frequency 100 Hz. During the CGA, individuals were equipped with passive reflective markers that were placed on the skin at defined anatomical and technical landmarks. The Davis protocol was used to place markers on the head, upper limbs, pelvis and lower limbs (Davis III, Ounpuu, Tyburski, & Gage, 1991). All individuals were asked to walk barefoot at a self-selected speed along a 12-meter walkway. Data were collected for at least 5 gait cycles for each individual. Kinematic curves were calculated using Nexus 1.8 software (ViconPeak®, Oxford, UK) and Matlab 2012a (MathWork, USA). For each limb, the gait cycles were averaged to generate the single angular displacement of the shoulder, elbow, arms, thorax, pelvis, hip, knee and ankle joints.

2.3. Data

To analyze the upper limb patterns, the two arms were analyzed together for the DI patients and a CG, whereas for HE patients, the affected arms and non-affected arms were differentiated and analyzed separately. The following kinematic parameters were analyzed: shoulder angles in the frontal plane, elbow angles in the sagittal plane and trunk angles in the sagittal and frontal planes.