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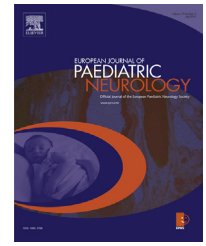

Original article

Kinematic analysis of upper limb during walking in diplegic children with Cerebral Palsy

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ABSTRACT

Movements of the lower limbs during walking have been widely investigated in literature, while quantification of arm movement during gait is scanty. The aim of the present study was to assess quantitatively the upper limb motion during gait in children with Cerebral Palsy (CP). Sixteen children with diplegic CP were evaluated using a full-body marker set, which allows assessing both the lower and upper limb kinematics. Our results demonstrated that movement of the arms was characterized by an abducted shoulder and a more flexed elbow position at the initial contact of the gait cycle with a quite physiological range of motion if compared to controls. These data showed that gait of children with diplegic CP is generally characterized by abnormal upper limb position which could be considered a strategy to keep balance and posture control during walking.

1. Introduction

Most clinical studies using quantitative analysis of walking (Gait Analysis-GA) generally focus on lower limb strategy and tend to ignore arm swing, head and trunk movement during deambulation, assuming that this unit moves as one mass. However, the first studies on gait also included detailed descriptions of arm movement during gait and some authors concluded that the arm swing during gait is not passive and driven by muscle activity.[1–4] Later studies, however, reasoned that active shoulder torques are only small, and suggested that arm swinging may be largely passive.[5,6] At the moment, however, there is consensus on the role of arm swing to reduce energetic cost during walking as much as 8%, to maintain balance (to avoid falls and postural problems), to reduce the mechanical loads on tissue (to avoid pain) and energy efficacy to improve endurance.[7,8] In addition, the efficacy of body movement in normal walking depends on upper limb swing.[9]

Several pathologies, such as for example stroke, Parkinson's disease, Cerebral Palsy and spinal cord injury, may lead to various abnormalities in arm movements during walking. It

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Table 1 – Upper limb kinematic parameters and descriptors (IC: Initial Contact).

Parameters	Description
IC T Tilt	The value of trunk angle respect to the lab reference system on the sagittal plane (Trunk Tilt plot) at IC
ROM T Tilt	The range of motion of trunk angle respect to the lab reference system on the sagittal plane (Trunk Tilt plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC T Obl	The value of trunk angle respect to the lab reference system on the frontal plane (Trunk Obliquity plot) at IC
ROM T Obl	The range of motion of trunk angle respect to the lab reference system on the frontal plane (Trunk Obliquity plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC T Rot	The value of trunk angle respect to the lab reference system on the transversal plane (Trunk Rotation plot) at IC
ROM T Rot	The range of motion of trunk angle respect to the lab reference system on the transversal plane (Trunk Rotation plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC S Fl–Ex	The value of shoulder angle on the sagittal plane (Shoulder Flex–Extension plot) at IC
ROM S Fl–Ex	The range of motion at shoulder on the sagittal plane (Shoulder Flex–Extension plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC S Ab–Ad	The value of shoulder angle on the frontal plane (Shoulder Abd–Adduction plot) at IC
ROM S Ab–Ad	The range of motion at shoulder on the frontal plane (Shoulder Abd–Adduction plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC S Rot	The value of shoulder angle on the transversal plane (Shoulder Rotation plot) at IC
ROM S Rot	The range of motion at shoulder on the transversal plane (Shoulder Rotation plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
IC E Fl–Ex	The value of elbow angle on the sagittal plane (Elbow Flex–Extension plot at IC)
ROM E Fl–Ex	The range of motion at elbow on the sagittal plane (Elbow Flex–Extension plot) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot

may therefore be expected that pathological gait is energetically more demanding not only because of the pathology with the altered function of the leg but also because of affected arm movements. Patients with Cerebral Palsy (CP) are known to experience weakness, motor control abnormalities and spasticity in the muscles of the involved arms.[10] For this condition, it was found that the arm swing amplitude of the non-hemiplegic arm exceeds that of healthy control[11,12] and diplegic children with good motor control of both arms show altered arm movements and greater variability.[13]

For rehabilitation the evidence emerges that upper and lower limb movements influence each other during locomotor-like tasks. The use of arm movements during gait seems to have a potential beneficial influence on gait rehabilitation and for several pathological states including CP.[14,15] In CP, it has been suggested in fact that normalizing interlimb coordination could improve gait pattern[14] leading to a normalization of the angular momentum.[16]

It may seem strange that there is only a limited body of work assessing arm movements during pathological gait and evaluating the potential role of arm swing in gait rehabilitation. To our knowledge, only few papers[13,11,16,17,18] evaluated quantitatively the upper body movements during gait in children with CP, and in particular only Romkes et al.[13] and Meyns et al.[14] conducted their analysis in diplegic children. In particular, both Romkes et al.[13] and Meyns et al.[11,14] evaluated upper body kinematics of arms in diplegic children using a full-body marker set (34 markers), founding important movements for compensation by the upper limbs in order to control balance[13] and to increase walking speed[11] and altered coordination.[14] Accordingly, the literature on upper limb movement during walking in diplegic children is scarce.

Recently, literature[12] proposed an experimental set-up which allows the simultaneous assessment of upper and lower limb motion during GA using a lower number of markers compared to previous researches[11,13,14,17,19] (28 markers versus 34 markers) and showed its easy appropriateness especially for the clinical application in difficult cases and in small children for the low number of additional markers.

Therefore, the aim of this study is to quantify movement of the upper limb during walking in children with diplegic CP using the proposed simplified marker set-up and to compare the obtained results with literature.

2. Materials and methods

2.1. Participants

16 children with diplegic CP participated in this study (CP group; age: $M = 11.3$ years, $SD = 3.1$ years; weight: $M = 38.5$ kg, $SD = 13.2$ kg; height: $M = 1.42$ m, $SD = 0.18$ m). All participants were community ambulators without assistive devices such as walkers or crutches. They had no history of functional upper or lower limb surgeries and of pharmacological treatments for at least one year before data collection.

A control group of 20 non-affected subjects (CG: Control group; age: $M = 9.2$ years, $SD = 5.7$ years; weight: $M = 33.5$ kg, $SD = 9.4$ kg; height: $M = 1.35$ m, $SD = 0.07$ m) was included. Selection criteria for the CG included no prior history of cardiovascular, neurological, or musculoskeletal disorders. They exhibited normal range of motion and muscle strength, and had no apparent postural or motor deficits.