Gait & Posture 38 (2013) 1038–1043

Contents lists available at SciVerse ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

The relationship between clinical measurements and gait analysis data in children with cerebral palsy

Małgorzata Domagalska [a,*], Andrzej Szopa [a], Małgorzata Syczewska [b], Stanisław Pietraszek [c], Zenon Kidoń [c], Grzegorz Onik [a]

[a] Faculty of Health Sciences, Medical University of Silesia, Katowice, Poland
[b] Paediatric Rehabilitation Department, The Children's Memorial Health Institute, Warszawa, Poland
[c] Institute of Electronics, Silesian University of Technology, Gliwice, Poland

ARTICLE INFO

Article history:
Received 7 December 2012
Received in revised form 20 May 2013
Accepted 27 May 2013

Keywords:
Cerebral Palsy
Clinical assessment of spasticity
Accelerometer
Gait
Gillette Gait Index

ABSTRACT

Spasticity is a common impairment that interferes with motor function (particularly gait pattern) in children with cerebral palsy (CP). Gait analysis and clinical measurements are equally important in evaluating and treating gait disorders in children with CP. This study aimed to explore the relationship between the spasticity of lower extremity muscles and deviations from the normal gait pattern in children with CP. Thirty-six children with spastic CP (18 with spastic hemiplegia [HS] and 18 with spastic diplegia [DS]), ranging in age from 7 to 12 years, participated in the study. The children were classified as level I ($n = 24$) or level II ($n = 12$) according to the Gross Motor Function Classification System. Spasticity levels were evaluated with the Dynamic Evaluation of Range of Motion (DAROM) using the accelerometer-based system, and gait patterns were evaluated with a three dimensional gait analysis using the Zebris system (Isny, Germany). The Gillette Gait Index (GGI) was calculated from the gait data. The results show that gait pathology in children with CP does not depend on the static and dynamic contractures of hip and knee flexors. Although significant correlations were observed for a few clinical measures with the gait data (GGI), the correlation coefficients were low. Only the spasticity of rectus femoris showed a fair to moderate correlation with GGI. In conclusion, the results indicate the independence of the clinical evaluation and gait pattern and support the view that both factors provide important information about the functional problems of children with CP.

1. Introduction

Various treatment strategies are used to improve motor function in children with cerebral palsy (CP). Clinical examination combined with gait analysis is often used to assess the effectiveness of various treatment methods [1–8]. The most popular methods of clinical muscle tone assessment are subjective scales, including the Ashworth Scale (AS), the Modified Ashworth Scale (MAS), the Tardieu Scale (TS), and the Modified Tardieu Scale (MTS) [2,8]. In children with spastic CP, there is a strong correlation between the range of motion (ROM), the velocity of movement, and the position in which the tested muscle reacts to stretching [2,9–13].

The Dynamic Evaluation of Range of Movement (DAROM) is an assessment that considers spasticity, dependence on movement velocity, and the position of adjacent joints. The instrument was introduced by Reimers and Jóźwiak [9–11]. The reliability of the Ashworth Scale has been questioned [8]. The MTS and the DAROM (a simplification of the MTS), which uses at least 2 different velocities of passive muscle stretching, have reported satisfactory intra- and inter-rater reliability [2,8]. However, these assessments are not objective tests. The DAROM, similar to the MTS, defines the ROM as slow and fast passive stretching to determine a dynamic component of muscle contracture [2,10,11]. In contrast with a standard clinical examination, the DAROM identifies a "range of motion deficit" (DROM), defined as a value from the minimal muscle stretch position. In this test, two joint angles are measured: DROM I, defined as the PROM deficit following a slow velocity stretch, and DROM II, defined as the angle of catch (AOC) after a fast velocity stretch. The difference between DROM II and DROM I indicates the examined muscle group's level of contracture and is called the angle of spasticity (ASO) [2,10–13]. The DAROM, again like the MTS, specifies three velocities that can be applied to the

* Corresponding author at: Faculty of Health Sciences, Medical University of Silesia, Medyków 12, 40-752, Katowice, Poland. Tel.: +48 601 516 725; fax: +48 322088712.
E-mail addresses: mdomagalska@sum.edu.pl (M. Domagalska), aszopa@sum.edu.pl (A. Szopa).

0966-6362/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gaitpost.2013.05.031

muscle [12]: V1, as slow as possible; V2, the speed of the body segment falling freely under gravity; and V3, as fast as possible. In the DAROM, the precise measurement of a limb's position during testing is essential [9–11].

Currently, one of the most commonly used methods for assessing motor deficits in children with CP is objective, instrumented gait analysis. An algorithm called bridge therapy is often used: in this algorithm, spasticity and contracture are managed simultaneously using orthotic devices [3–7,13–16]. However, while most gait analysis reports are based on selected gait parameters [3–7], many gait parameters are interdependent. Moreover, improvements in selected gait parameters are not always equal to global gait pattern enhancement. To overcome these problems, an index for quantifying deviations from normal gait, called the Gillette Gait Index (GGI) and, previously, the Normalcy Index (NI) [17], was introduced. This index is a global measure of gait pattern based on 16 selected gait parameters taken from objective gait analysis. However, data comparing the spasticity determined via quantitative clinical examination with the results of objective gait analysis are scarce in the literature.

Therefore, the purpose of this study was to explore the relationship between spasticity in the muscles of the lower extremities, assessed with the DAROM method, and deviations from normal gait in children with CP.

2. Methods

The research protocol was approved by the Bioethics Committee of the Medical University of Silesia in Katowice, Poland. The parents/guardians signed an informed consent form prior to the subjects' enrolment into the study.

2.1. Subjects

Thirty-six children with CP, 18 with hemiplegia (HS) and 18 with diplegia (DS), were included in the study. All of the participants were independently functioning outpatients (Level I or II of the Gross Motor Function Classification System [GMFCS]) [18] at local paediatric rehabilitation centres. The inclusion criteria were a diagnosis of the predominantly spastic type of CP, the ability to walk without assistive devices, age 7 to 12 years, sufficient cooperation to enable accurate clinical assessment and three-dimensional gait analysis, no surgeries within 18 months, and no inhibiting casts or botulinum toxin treatment 6 months before the evaluation. The HS group consisted of 6 girls and 12 boys; deficits occurred on the right side in 12 patients and on the left side in 6, and the mean age was 8 years and 2 months (range: 7 years, 4 months to 12 years, 2 months). The DS group consisted of 8 girls and 10 boys; the mean age was 10 years and 4 months (range: 8 years, 3 months to 12 years, 2 months). A group of 18 healthy children (6 girls and 12 boys) with no known neurological or orthopaedic problems and mean age of 8 years and 8 months (range: 7 years, 5 months to 12 years, 3 months) was recruited as a reference group (Ref). These children underwent only gait analysis.

2.2. Testing procedure

Each child with CP underwent a clinical examination, including DAROM, of the four muscle groups in each leg. The testing positions and standardisation procedures for all measurements are shown in Table 1. All of the measurements were performed at the functional testing lab of the University of Silesia. All of the participants were examined three times (on consecutive days) by the same well-trained physiotherapist. The child was instructed to hold onto a couch in both sitting and lying positions, and the pelvis was stabilised to minimise compensatory movements. The therapist moved the segment of the lower limb from the starting position towards the final position at two velocities (V1 and V3), holding the limb at the end of the available range while testing with the slow velocity (DROM I) or at the position of the AOC (DROM II) while testing with the fast velocity.

2.3. Data collection and analysis

The DROM I and DROM II angles were measured (in degrees) using an accelerometer-based system with ZK software (Institute of Electronics of Silesian University of Technology) [19]. The limb segment coordinates were defined by external markers. The results from the three trials were averaged to obtain the DROM I and DROM II values. The ASO value was calculated as the difference of DROM II − DROM I [3]. Angular velocity was measured using an accelerometer system.

2.4. Three-dimensional instrumented gait analysis

After clinical examination, objective gait analysis was performed using the Compact Measuring System for 3D Real-Time Motion Analysis (CMS- HS 3D) with WinGait software (Zebris Medizintechnik GmbH, Germany). The CMS HS 3D system is based on 15 active ultrasonic markers (five triplets of ultrasound markers).[20]

Before gait analysis, the following anatomic landmarks were identified with an instrumented pointer: hip joint centre, knee rotation centre (internal and external), ankle rotation centre (internal and external), forefoot landmark (between the second and third metatarsals), and rear foot (heel). Gait data were recorded while the subjects walked on an Alfa XL treadmill (Kettler, Germany). Prior to data collection, all subjects had the opportunity to practice walking on the treadmill. The children walked without shoes and without assistive devices. Markers were attached to the skin with double-sided adhesive tape and placed bilaterally. Depending on each subject's walking abilities, five to

Table 1
Accelerometer placement and stabilisation for dynamic assessment of range of motion (DAROM tests).

Test	Testing position	Position of accelerometer	Stabilisation
T1 Deficit of hip extension in the Thomas test	Supine, the contralateral extended leg resting on a support	10 cm proximal to the lateral epicondyle femur, parallel to the long axis of the femur	Pelvis
T2 Pelvis elevation angle in the Duncan-Ely test	Prone, both lower limbs extended resting on a support	10 cm distal to the trochanter major, parallel to the long axis of the femur	Without stabilisation
T3 Popliteal angle	Supine, hip and knee of tested leg flexed 90°, ankle in neutral position, contralateral flexion leg resting on support	Anterior, 5 cm proximal to the lateral malleolus, parallel to the long axis of the fibula	Pelvis
T4 Deficit of knee extension	Supine, hip of tested leg in neutral position in all planes and knee flexed 90°, off the table with the ankle in a neutral position contralateral extended leg resting on support	Anterior, 5 cm proximal to the lateral malleolus, parallel to the long axis of the fibula	Pelvis