Gait & Posture 37 (2013) 165–171

Contents lists available at SciVerse ScienceDirect

Gait & Posture

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

Walking deterioration and gait analysis in adults with spastic bilateral cerebral palsy

A. Opheim [a,b,*], J.L. McGinley [c,d], E. Olsson [a], J.K. Stanghelle [b,e], R. Jahnsen [b,f]

[a] Karolinska Institutet, Stockholm, Sweden
[b] Sunnaas Rehabilitation Hospital, Nesoddtangen, Norway
[c] University of Melbourne, Melbourne, Australia
[d] Clinical Research Centre for Movement Disorders and Gait, Southern Health, Melbourne, Australia
[e] Faculty of Medicine, University of Oslo, Norway
[f] Oslo University Hospital, Rikshospitalet, Oslo, Norway

ARTICLE INFO

Article history:
Received 4 September 2011
Received in revised form 18 June 2012
Accepted 30 June 2012

Keywords:
Cerebral palsy
Adults
Gait analysis
Walking
Gait
Spastic CP
Gait pattern
Walking deterioration

ABSTRACT

Walking deterioration occurs frequently in adults with spastic bilateral cerebral palsy (CP), but their gait characteristics are largely unknown. The study aims were (1) to compare selected gait analysis variables between those reporting and those not reporting walking deterioration, and (2) to characterise the overall gait deviations and classify the gait patterns. Participants ($N = 16$) were recruited from a follow-up study, had spastic bilateral CP, <40 years in 2006, GMFCS levels I–III, and could walk at least 10 m without support. Eight reported walking deterioration (cases) and eight did not (controls). A theoretical framework linking work of walking, fatigue and deterioration in walking was developed. It was hypothesised that higher energy requirements during gait and larger gait deviations would be associated with deterioration in walking. Three-dimensional gait analysis was used to obtain centre of mass work, mechanical joint work, lower limb kinematics, movement analysis profile (MAP), and gait profile scores (GPS). There were no differences between the cases and controls in centre of mass work, joint work, or in the GPS. The largest MAP deviations were seen in sagittal pelvis, hip, and knee angles and foot progression. Crouch and asymmetric gait were common patterns. Walking deterioration could not be explained by these work and kinematic variables. An individual's perception of deterioration in walking is subjective, and may be experienced and interpreted differently across people. Larger, longitudinal studies on the natural history of walking in spastic CP are needed. Qualitative studies on the subjective experiences of walking deterioration are also warranted.

1. Introduction

In cerebral palsy (CP), the development of mobility is delayed [1–3], and walking is often impaired and energy demanding [4]. Mobility is found stable from 2 to 21 years in people at Gross Motor Function Classification System (GMFCS) levels I and II, while people at levels III, IV and V show a decline [5]. Recent studies show that an increasing number of people with CP experience reduced gross motor function in early and middle adulthood [6–8]. Furukawa et al. [9] found reduced subjective well-being among those with deteriorated physical function. Factors associated with deterioration included musculo-skeletal pain, fatigue, late onset of walking debut, and severity of motor impairments [6,10]. Our seven year follow up study from 1999 to 2006 on adults with spastic CP in Norway, found a considerable increase in the proportion of people aged 35–40 years reporting walking deterioration, especially in spastic bilateral CP [11]. This was associated with higher levels of pain and fatigue, and higher GMFCS levels. Deterioration in walking was regarded as a result of impaired balance by 65% of participants and by reduced muscle strength by 33% [11].

To know more about factors associated with walking deterioration in the participants of our follow-up study, we decided to study walking in greater detail, using 3-dimensional gait analysis (3DGA). Few studies have focused on the natural history of walking in children and young adults with CP. Negative changes in kinematic and tempo-spatial variables in children with CP were reported by both Johnson et al. [12] and Bell et al. [13]. Gannotti et al. [14] found that the Gillette Gait Index was stable for most subjects 10–15 years after surgery. Two longitudinal studies >17 years after selective dorsal rhizotomy showed improved or

* Corresponding author at: Sunnaas Rehabilitation Hospital, 1450 Nesoddtangen, Norway. Tel.: +47 66969000; fax: +47 66912576.
E-mail addresses: arvei.opheim@sunnaas.no, ai-ophei@online.no (A. Opheim).

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http://dx.doi.org/10.1016/j.gaitpost.2012.06.032

unchanged preoperative values, and stability thereafter [15,16]. The relationship between self-reported walking deterioration in adults with spastic bilateral CP, and kinematic and kinetic gait variables has to our knowledge not been examined.

The aims of the study were: (1) to compare selected kinematic and kinetic gait variables between those reporting, and those not reporting walking deterioration in this group of adults with spastic bilateral CP. (2) To characterise the overall gait deviations, and classify the gait patterns.

2. Methods

2.1. Ethical approval and consent

The study was approved by the Regional ethics committee for medical research in South-Eastern Norway, and by the Commissioner for the protection of privacy in research. All participants provided written informed consent.

2.2. Design

A case–control design was used.

2.3. Setting

The Motion Analysis Laboratory at Sunnaas Rehabilitation Hospital, Nesodden, Norway, 2009.

2.4. Participants

Participants were recruited from a follow-up study on adults with spastic CP [11]. All persons with spastic bilateral CP, who were under 40 years in 2006, with GMFCS levels I–III, and who could walk at least 10 m without support were invited. The age cut-off of 40 years was chosen because this age was found critical for the onset of walking deterioration [11].

2.5. Procedure

Self-reported walking deterioration was assessed in an interview before the 3DGA with the questions: "Has your walking function changed since the end of adolescence? Deteriorated, unchanged or improved?" The causes for deterioration were recorded. Passive range of motion (ROM), muscle tone, strength and selective motor control (SMC) were assessed clinically and leg length (Anterior Superior Iliac Spine through the knee to medial malleolus) measured. Self-reported falls over the last month were recorded (Table 1). Fatigue severity scale (FSS) Norwegian version [17] scores were obtained from the survey in 2006.

2.5.1. Gait analysis

3DGA was conducted with six infrared MX13 cameras (Vicon Motion Systems, Oxford, UK) and two AMTI OR6-7 force plates (AMTI, Watertown, USA). Retro-reflective markers were placed according to the Plug-in-Gait model (Vicon Motion Systems,

Table 1
Characteristics of the study group of 16 adults with spastic bilateral CP ($N = 16$).

	Cases ($n = 8$)	Controls ($n = 8$)
Females/males, *n*	5/3	6/2
Age (years), median (min–max)	39 (29–42)	36 (29–39)
GMFCS II/III, *n*	8/0	7/1
FMS 5 metre		
(score 6)	0	1
(score 5)	8	6
(score 4)	0	1
FMS 50 metre		
(score 5)	8	7
(score 2)	0	1
FMS 500 metre		
(score 5)	6	6
(score 4)	1	0
(score 1)	1	2
Muscle strength[a] (0–5), median (min–max)	4 (2–5)	4 (3–5)
MAS[b] (0–5), median (min–max)	1+ (1–3)	1+ (1–2)
FSS[c] (1–7), median (min–max)	4.7 (2.3–5.9)	3.6 (1.4–4.8)
Falls last month, *n*		
0	3	4
1–2	2	2
3–8	2	2
20	1	0

	Cases ($n = 8$)		Controls ($n = 8$)	
	Left	Right	Left	Right
Hip extension[d] (°), median (min–max)	−5 (−20 to 10)	0 (−20 to 10)	0 (−15 to 20)	0 (−10 to 20)
Unilat pop. angle[d,e] (°), median (min–max)	48 (30 to 70)	43 (30 to 65)	55 (35 to 65)	53 (40 to 65)
Ankle DF[d], knee 0° (°), median (min–max)	0 (−5 to 15)	0 (0 to 10)	0 (−10 to 10)	0 (−10 to 10)
SMC[f], ankle DF (0–4), median (min–max)	4 (2 to 4)	3 (2 to 4)	3 (2 to 4)	2.5 (2 to 4)

GMFCS: Gross Motor Function Classification Scale; FMS: Functional Mobility Scale: 6: independent on all surfaces, 5: independent on level surfaces, 4: uses one crutch or two sticks, 3: uses two crutches, 2: uses walker or rollator, 1: uses wheelchair; DF: dorsiflexion.

[a] Muscle strength in hip flexors, extensors and abductors, knee flexors and extensors and ankle plantar and dorsiflexors were assessed bilaterally with the 0–5 grade Manual Muscle Test scale, and the median score was reported. *Note*: Manual muscle strength testing in persons with spastic CP may be affected by spasticity and therefore may not fully reflect the active, voluntary muscle function in the individual.

[b] Modified Ashworth Scale, were assessed bilaterally in triceps surae, rectus femoris, hamstring and adductor muscle groups, and the median score is reported; higher score is more resistance to passive movements.

[c] Fatigue severity scale; higher score indicates more fatigue, the information is from the 2006 survey.

[d] Passive range of motion was measured with a goniometer.

[e] Unilateral popliteal angle.

[f] Selective motor control; higher scoring indicates better ability to isolate tibialis anterior activity.