Gait & Posture 37 (2013) 494–499

Contents lists available at SciVerse ScienceDirect

Gait & Posture

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

Spatial rotational orientation ability in standing children with cerebral palsy

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ARTICLE INFO

Article history:
Received 22 February 2012
Received in revised form 26 June 2012
Accepted 31 August 2012

Keywords:
Spatial orientation
Turning platform
Perception
Motor control
Gait
Hemiplegia
Cerebral palsy

ABSTRACT

This study quantified perception and reorientation ability after passive horizontal rotations in thirteen children with cerebral palsy (CP). They stood barefoot on a platform in front of a fixed reference point (static posture task, *SPT*) and were then blindfolded and passively rotated with six velocity profiles (maximum angular velocity: 57°/s; rotation amplitudes: ±90°, ±180° and ±360°). After the perturbation, the blindfolded children were asked to point to the fixed reference point with their preferred hand (pointing task, *PT*) and to step back to the initial position on the stationary platform (reorientation task, *RT*). In order to gain further insight into rotational attitude, the results were comparatively examined with body segment rotations determined using standardized gait analysis (gait task, *GT*).

The kinematic evaluations were conducted using an optoelectronic system: for *SPT*, *PT* and *RT* we confined the analysis, in the horizontal plane, to the head and upper pointing arm of the subject and to the platform; for *GT* a full body analysis was performed.

When CP children were passively rotated towards their more affected side, they overestimated the imposed angle in *PT* but under-reproduced it in *RT*. A higher variability emerged in left-hemiplegic children, confirming that the spatial disorganization is predominantly related to right brain lesion. Patients tended to rotate in *GT* towards the more affected side while in *RT* they showed an opposite trend.

1. Introduction

The control of orientation and navigation in space is a crucial function in humans and animals and is based on the fusion of visual, vestibular, and somatosensorial inputs. Due to the higher accuracy required in large scale rotatory movements compared to translatory ones [1], several studies investigated in humans the perception and reproduction of imposed rotations in both sitting and standing positions, and found slight differences in angular perception between the two test conditions [2]. It has also been demonstrated in healthy adults [2–7] and children [7,8] that small differences in angle estimation can be related to age, while not significant differences in orienting themselves in both hemispaces emerged. Results of research on adult patients with vestibular disorders using the Barany chair revealed lower estimation accuracy when the rotation was towards the affected side [9] while in locomotion task the patients made large errors in angle reproduction [10].

Previous studies focusing on children with cerebral palsy (CP) have attempted to determine how the perception of passive rotation affects the active rotation. Ducrouquet et al. [11] highlighted the essential role of pelvic rotation in the horizontal plane to maintain dynamic stability during locomotion; the role of pelvic rotation was also further explored, either blocking the pelvic rotation during walking [12] or imposing steady sinusoidal horizontal rotations for standing subjects [13]. Clinical experience suggested that: (i) the impairment affects the sensory-motor system, assumed to be a single functional unit, and (ii) the movement specifies the sensory information driving the movement itself. Furthermore, an overall examination of balance control in dynamic posturography and during locomotion was recommended by Evans and Krebs [14] because subjects were likely to use a wider set of compensatory mechanisms.

We therefore decided to study in children with CP the self orientation and reproduction tasks in comparison to gait characteristics in order to gain information on sensory–motor integration which would assist therapeutic decision-making. Hence, the aim of the study was to evaluate the relationship between angle perception and angle reproduction after horizontal

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http://dx.doi.org/10.1016/j.gaitpost.2012.08.022

Nomenclature

Notations

A	platform rotation amplitude [°]
CP	cerebral palsy
GT	gait task, 4th task
PT	pointing task, 2nd task
RT	reorientation task, 3rd task
SPT	static posture task, 1st task
TD	typically developed children
α_p	perceived angle measured in *PT* trials evaluated in the horizontal plane [°]
α_{plat}	platform angle [°]
α_r	reproduced angle measured in *RT* trials evaluated in the horizontal plane [°]
ω	platform angular velocity [°/s]

passive rotations when vision is suppressed, and to compare these angles to gait rotations in the horizontal plane in eyes open condition.

2. Methods

2.1. Subjects

The aims of the study and procedure were explained to the children and their parents before the experiment started; parental consent was obtained after presentation of oral and written information. The protocol was approved by the Ethics and Medical Board of "Bambino Gesù" Children's Hospital.

Fifteen children with CP, recruited from the outpatient and inpatient populations of the Neurorehabilitation Department of "Bambino Gesù" Children's Hospital, participated in this study. Table 1 summarizes the patient descriptive data. Nuclear magnetic resonance analysis in all the subjects revealed a periventricular leucomalacia subsequent to brain damage at birth. The children were enrolled after standard neurological examinations. Exclusion criteria were the presence of seizures, arousal problem, as well as cognitive and gross sensorial deficit. Inclusion criteria were orientation and pointing skills tested before the trials; the children were asked to point to a target, i.e. a puppet used in the protocol, five times. The more affected side of children with diplegia was determined by gait analysis data and clinical examination. Clinical assessment was completed by administration of the Gross Motor Function Classification System (GMFCS) and the Gillette Functional Assessment Questionnaire (GFAQ).

The patients were naïve to the experimental procedures. Two children with diplegia, with left prevalent affected side, were excluded from data analysis because they were not able to complete the protocol.

2.2. Equipment

The equipment and most of the procedures have been described in earlier papers [7,8,13] and are briefly recalled here for clarity. Children stood at the center of an in-house developed rotating platform, driven by a servo-motor under computer-control.

The Vicon Plug-in-Gait marker set was used to generate kinematic data collected at 200 Hz and with an RMS error of ~1 mm in calibration volume (1 m × 1 m × 2.5 m); five additional markers were placed on the moving base to define its position as a function of time. In the trials conducted with the rotating platform, the kinematic analysis was confined to the subject's head and upper pointing arm evaluated in the horizontal plane. All the trials were video-recorded in frontal and lateral planes.

2.3. Protocol

The experimenter performed the trial himself, demonstrating the procedure to each child separately. The children were asked to get on the platform and to orient themselves towards a puppet placed at two meters distance and at eye level, with feet parallel and arms by their sides. They were then asked to point towards the puppet, first with eyes open and then blindfolded. The period of familiarization with the platform motion also permitted verification of their ability to perform the task.

The children completed three successive experimental sessions on the platform. A therapist was close by at all times to reassure them and, if necessary, to help them keep their balance. Kinematic data were collected in standing static posture with eyes closed (static posture task, *SPT*) in order to assess subjective rotational biases. The children, always blindfolded, were asked to prepare themselves and, after a few seconds, were rotated by the platform;

Table 1
Children descriptive data.

ID	Sex	Age (years)	Height (mm)	Body mass (kg)	Diagnosis (more affected side)	GMFCS[a]	GFAQ[b]
CP#1	M	9	1140	19.6	H(R)	2	9
CP#2	F	9	1320	32.4	D(L)	–	–
CP#3	F	10	1550	46.5	H(R)	1	10
CP#4	M	9	1310	27.1	H(R)	1	10
CP#5	M	7	1220	20	H(L)	2	9
CP#6	F	6	1260	31.1	H(R)	2	9
CP#7	M	8	1230	25.1	H(L)	2	9
CP#8	M	10	1360	41.5	H(L)	1	10
CP#9	M	10	1360	32.1	D(R)	2	8
CP#10	F	6	1240	40.8	H(R)	1	7
CP#11	M	10	1320	27	H(L)	1	10
CP#12	F	6	1040	18.2	D(R)	2	8
CP#13	M	7	1130	19.1	D(R)	2	9
CP#14	F	9	1120	26	D(L)	–	–
CP#15	M	7	1020	18.8	H(R)	2	9
Mean ± SD		8 ± 2	1241 ± 138	28 ± 9			

Subjects CP#2 and CP#14, highlighted in gray, are discarded because they are unable to complete the experimental session. M, male; F, female; H, hemiplegia; D, diplegia; R, right; L, left.

[a] From 1 (child is completely able to walk) to 5 (child is not able to walk).

[b] From 1 (child is not able to step) to 10 (no assistance to walk, run, climb on uneven terrain).