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The influence of hip abductor weakness on frontal plane motion of the trunk and pelvis in patients with cerebral palsy

Britta K. Krautwurst, Sebastian I. Wolf, Daniel W.W. Heitzmann, Simone Gantz, Frank Braatz, Thomas Dreher *

Heidelberg University Clinics, Department for Orthopedics and Trauma Surgery, Schlierbacher Landstraße 200a, 66118 Heidelberg, Germany

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ABSTRACT

Trendelenburg walking pattern is a common finding in various disorders, including cerebral palsy (CP), where it is seen in children and adults. Clinically, this deviation is viewed as a consequence of hip abductor weakness resulting in pelvic obliquity. Trunk lean to the ipsilateral side is a common compensatory mechanism to counteract pelvic obliquity and to maintain gait stability. However, no published investigations objectively address pelvic and trunk motions in the frontal plane or examine the correlation with hip abductor weakness in patients with CP. We selected 375 ambulatory (GMFCS I–III) patients with spastic bilateral CP and 24 healthy controls from our gait laboratory database. They had all undergone a standardized three-dimensional analysis of gait, including trunk motion, and a clinical examination including hip abductor strength testing. Selected frontal plane kinematic and kinetic parameters were investigated and statistically tested for correlation (Spearman rank) with hip abductor strength. Only a weak ($r = 0.278$) yet highly significant correlation between trunk lean and hip abductor strength was found. Hip abductor weakness was accompanied by decreased hip abduction moment. However, no significant differences in pelvic position were found between the different strength groups, indicating that the pelvis remained stable regardless of the patients' strength. Our findings indicate that weak hip abductors in patients with CP are accompanied by increased trunk lean to the ipsilateral side while pelvic position is preserved by this compensatory mechanism. However, since this correlation is weak, other factors influencing lateral trunk lean should be considered. In patients with severe weakness of the hip abductors compensatory trunk lean is no longer fully able to stabilize the pelvis, and frontal pelvic kinematics differs from normal during loading response. The results indicate that the stable pelvic position seems to be of greater importance than trunk position for patients with CP. Further studies are needed to investigate other factors influencing lateral trunk lean.

1. Introduction

1.1. Trunk and pelvis movements in the frontal plane

The Trendelenburg walking pattern is commonly seen in patients with cerebral palsy (CP) (Gage, 2004; Gage & Novacheck, 2001; Metaxiotis, Accles, Siebel, & Doederlein, 2000; Miller, 2004). Hip abductor weakness may result in pelvic

* Corresponding author at: Department for Orthopaedics and Trauma Surgery, Heidelberg University Clinics, Schlierbacher Landstraße 200a, D-66118 Heidelberg, Germany. Tel.: +49 6221 26718; fax: +49 6221 26725.
E-mail addresses: thomas.dreher@med.uni-heidelberg.de, thomas_dreher@hotmail.com (T. Dreher).

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obliquity (Trendelenburg sign) and may be compensated by leaning of the trunk to the ipsilateral side to maintain gait stability (Trendelenburg, 1895). However, the patterns of frontal plane pelvic and trunk motions and their underlying pathologies have been addressed only rarely (Metaxiotis et al., 2000). Hence, there is a pressing need to further evaluate the influence of hip abductor weakness in the frontal plane of kinematics and kinetics. Metaxiotis et al. (2000) reported increased lateral trunk lean in combination with contralateral pelvic drop during walking (Trendelenburg gait) in children with unilateral and bilateral CP diagnosed with ipsilateral hip subluxation. Furthermore, they reported that the described pattern could hardly be influenced by surgical intervention. Westhoff, Petermann, Hirsch, Willers, and Krauspe (2006) studied patients with Legg-Calvé-Perthes disease with special regard to their frontal plane gait patterns and differentiated patients with pelvic drop to the swinging limb and trunk lean to the supporting limb from patients with a trunk lean toward the supporting limb in combination with a stable pelvic position or even elevated pelvis on the swinging side. Furthermore, a reduction of abduction moment was reported in patients with Perthes disease with lateral trunk lean gait. These studies indicate that enhanced lateral trunk lean is an essential compensatory mechanism in patients with hip abductor weakness.

In patients with CP lateral trunk lean is more obviously recognized than a pelvic drop. However, investigations addressing pelvis and trunk motion in the frontal plane in patients with CP are rare. Since pelvic obliquity and trunk lean have an important influence on different gait parameters and the transfer of energy during gait (Inman, 1966), these parameters have to be considered when planning treatment in such patients. To date there is only limited evidence (Metaxiotis et al., 2000) for the relationship of hip abductor weakness and abnormal pelvic and trunk movement in the frontal plane since, to the best of our knowledge, no studies have addressed this problem with adequate patient numbers.

1.2. Aim of the study

The purpose of this study was to investigate the correlation of hip abductor muscle strength with frontal plane pelvic and trunk kinematics and kinetics.

2. Methods

2.1. Subjects

Conventional instrumented three-dimensional gait analysis and clinical examination are routinely performed in our hospital when planning the treatment of patients with CP. We selected from our gait laboratory database 375 patients with bilateral CP (age 4–55 years, mean 16 years) and 24 healthy controls (6–32 years, mean 11 years). These patients were examined between one and five times at intervals of at least 1 year, yielding a total of 629 patient analyses and 24 reference analyses. Basic data are presented in Table 1.

The inclusion criteria were a diagnosis of bilateral CP, ability to walk a few steps without walking aids to enable instrumented gait analysis [levels I–III of Gross Motor Function Classification System (GMFCS)] and documented hip abductor muscle strength [Medical Research Council (MRC) scale] (John, 1984).

2.2. Methods

A 12-camera Vicon® 612 system (Oxford Metrics, Oxford, United Kingdom) capturing data at 120 Hz and three force plates (Kistler Instruments, Winterthur, Switzerland) were used for the instrumented three-dimensional gait analysis. Fifteen skin-mounted markers were applied to bony landmarks according to the Plugin-Gait marker set (Oxford Metrics, Oxford, United Kingdom) for the analysis of the lower extremity. Four additional markers on the subjects' shoulder girdle (processus spinosus of the 7th cervical vertebra, left and right acromion, and incisura jugularis) were used to observe trunk motion in relation to the global reference frame. The subjects walked barefoot along a 7-m walkway at a self-selected speed. At least five valid trials were captured and averaged. Relevant hip and trunk kinematics and kinetics were calculated

Table 1
The participants' basic characteristics. Age, body height and body weight are presented as mean (range).

	MRC 1	MRC 2	MRC 3	MRC4	MRC 5	Norm
Number	11	48	351	176	43	24
Gender (m/f)	5/6	37/11	218/133	104/72	23/20	11/13
Age (years)	16 (10–35)	15 (4–38)	14 (4–47)	19 (4–55)	22 (8–48)	11 (6–32)
Height (cm)	150 (130–169)	150 (109–191)	148 (100–187)	158 (102–185)	165 (121–189)	145 (113–175)
Weight (kg)	48 (29–79)	48 (20–116)	44 (14–102)	52 (8–109)	60 (20–111)	38 (20–62)
GMFCS I	0	4	105	52	24	–
GMFCS II	4	26	176	77	14	–
GMFCS III	6	12	28	13	1	–
GMFCS IV	0	0	0	0	0	–
GMFCS V	0	0	0	0	0	–
Undefined	1	6	42	34	4	–