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The influence of timing of knee recurvatum on surgical outcome in cerebral palsy

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ABSTRACT

Recent reports have shown that timing of genu recurvatum (GR) might be caused by different underlying factors and that equinus leads to GR especially during early stance. The purpose of this study was to investigate the reduction of GR after surgical correction of equinus in children with bilateral spastic cerebral palsy and whether the children with early and late type GR show differences in reduction of knee hyperextension after a surgery. In 24 limbs (mean age 10.3 years, GMFCS I-III) showing equinus and GR the kinematics of the knee and ankle as well as the kinetics of the knee were evaluated before and one year (mean follow up period: 12.8 months) after surgical correction of equinus. The study was approved by the local ethical committee. Limbs with early type GR showed a reduction by 11.1° ($p < 0.001$) and those with late type GR by 6.0° ($p < 0.049$) in GR after surgery. Before surgery limbs with early type GR showed increased external extending moments, which decreased significantly after surgery. In contrast limbs with late GR did not show a significant reduction of those moments. The findings of this study underline the influence of equinus on early GR as an underlying factor. As equinus is attributed to early knee hyperextension and proximal factors are more important as underlying factors in late type GR, a classification into early and late onset GR is useful to identify underlying factors and to choose adequate treatment.

1. Introduction

According to Sutherland et al. genu recurvatum gait (GR) is one of the main pathologic gait patterns of the knee in children with cerebral palsy (CP) (Sutherland & Davids, 1993). In contrast to crouch or stiff gait, recurvatum gait is less frequent and has a prevalence of eight to ten percent in children with bilateral spastic CP (Klotz et al., 2014; Wren, Rethlefsen, & Kay, 2005). GR is characterized by a knee hyperextension, which occurs in mid- and late stance phase (Sutherland & Davids, 1993). Over time it causes secondary problems like degeneration of ligaments and cartilage, which lead to pain and an impaired mobility (Simon et al., 1978). Therefore, an understanding of the primary mechanisms of GR is important for adequate treatment.

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Recent reports could show that the timing of the maximum knee hyperextension might be important to understand the underlying pathology (Klotz et al., 2014; Svehlik, Zwick, Steinwender, Saraph, & Linhart, 2010). In this context a first classification into early and late onset GR was done by Simon et al. in the 70s, who observed a different timing of knee hyperextension in children with CP. They divided the timing of GR into an early type, which occurred during the first half of stance phase and a late type which occurred during the second half and found different kinematic movement patterns (Simon et al., 1978). In 2010 Svehlik et al. analyzed kinematic differences between these two groups in children with CP. They reported an increased prevalence of dynamic equinus in early type GR while fixed equinus was observed more frequent in late type recurvatum (Svehlik et al., 2010). In another study an increased prevalence of equinus was found in limbs showing early type GR while limbs with a late type GR showed a significant increased anterior pelvic tilt with an associated reduction in hip flexion (Klotz et al., 2014). The authors concluded that early type GR is attributed to equinus and the plantar-flexion-knee-extension-couple while late type GR is caused by other factors like a weakness of the hamstrings or an increased anterior pelvic tilt (Klotz et al., 2014).

As previous studies reported a superior influence of equinus on early type GR (Klotz et al., 2014), surgical equinus correction should relevantly reduce knee hyperextension during early stance. In contrast in limbs showing late GR reduction of knee hyperextensions seems not to be expected. Therefore the purpose of this study was to assess whether children with early and late type GR show differences in reduction of knee hyperextension after a surgical correction of equinus.

2. Methods

2.1. Participants

In this retrospective study, the data of our motion laboratory data base were screened for patients with bilateral spastic cerebral palsy, who showed a maximum knee hyperextension of more than five degrees, the ability to ambulate (GMFCS I-III) and received a surgical correction of equinus. Finally, 24 limbs of 18 patients (mean age 10.3 years (SD 5.5 years)) matched the determined inclusion criteria and the kinematic data of the knee and ankle as well as the kinetic data of the knee, which was recorded by three dimensional motion analysis before and one year after the intervention (mean follow up: 12.8 months (SD 2.4 months)), was included in this study. Except two patients (2 limbs), who used a cane for support while walking (GMFCS level III), all other included patients showed a GMFCS level II (Table 1). The study was approved by the local ethical committee.

2.2. Surgical procedures

Equinus was corrected using an aponeurotic lengthening of the calf muscles (23 limbs) and a lengthening of the Achilles tendon (3 limbs). Aponeurotic lengthening of the calf muscles was performed according to Baumann et al. and Strayer et al. (Dreher, Buccoliero, et al., 2012; Saraph, Zwick, Uitz, Linhart, & Steinwender, 2000; Strayer, 1950). Lengthening of the Achilles tendon was carried out using a Z-lengthening (Yngve & Chambers, 1996) or according to Hoke et al. (Salamon, Pinney, Van Bergeyk, & Hazelwood, 2006). The surgical correction of equinus was performed during a single event multilevel surgery. Therefore, additional procedures, which are shown in Table 1, were also performed: In eight limbs an osteotomy of the proximal femur (limb 7, 8, 12–14, 18, 21, 22), in five limbs a lengthening of the psoas muscle (limb 8–10, 18, 23), in 21 limbs a transposition of the rectus femoris muscle (limb 1–4, 7–21, 23, 24), in three limbs a rectus femoris muscle recession (limb 8, 11, 18), in 15 limbs a hamstring lengthening (limb 1, 2, 7, 9, 11, 13–20, 23, 24), in seven limbs a distal femur osteotomy (limb 1, 4–6, 10, 11, 19), in three limbs a tibialis muscle tendon transposition (limb 1, 11, 20) and in eight limbs a hind foot reconstruction (limb 1, 3, 8, 9, 14, 16, 23, 24).

2.3. Three-dimensional gait analysis

Gait analysis was performed using a conventional three-dimensional motion capture (Vicon® camera system, Oxford Metrics, Oxford, United Kingdom) as reported before (Klotz et al., 2014): Skin mounted markers were applied to bony landmarks of the patients according to a standard protocol and kinematics as well as kinetics were calculated according to a standard software procedure (Plugin Gait; Oxford Metrics, Oxford, United Kingdom) based on Kadaba et al. (Kadaba, Ramakrishnan, & Wootten, 1990). Pre and Post Examinations were carried out by the same physiotherapist and study nurse with special education in pediatric neuro-developmental therapy and gait analysis. Patients were asked to walk barefoot along a 7 m walkway at self-selected speed. At least 5 representative strides were averaged for further analysis.

2.4. Classification & data analysis

The kinematic and kinetic parameters of the ankle and the knee were analyzed in the sagittal plane. The kinematics and the kinetics of the knee were classified into early and late type GR. The kinematics were analyzed during stance phase (0–60% of gait cycle) and the kinetics during single support. The classification into early onset (minimum knee flexion during first half of stance phase) and a late onset (minimum knee flexion during second half of stance phase) GR was done according to Simon et al. (Simon et al., 1978) and Svehlik et al. (Svehlik et al., 2010). To avoid a bias caused by initial contact, the kinetic