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Predictors for anterior pelvic tilt following surgical correction of flexed knee gait including patellar tendon shortening in children with cerebral palsy

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ABSTRACT

Introduction: Patellar tendon shortening procedure within single event multilevel surgeries was shown to improve crouch gait in Cerebral Palsy (CP) patients. However, one of the drawbacks associated to the correction of flexed knee gait may be increased pelvic anterior tilt with compensatory lumbar lordosis.
Research question: Which CP patients are at risk for excessive anterior pelvic tilt following correction of flexed knee gait including patellar tendon shortening?
Methods: 32 patients with CP between 8 and 18 years GMFCS I&II were included. They received patellar tendon shortenings within multilevel surgery. Patients with concomitant knee flexor lengthening were excluded. Gait analysis and clinical testing was performed pre- and 24.1 (SD = 1.9) months postoperatively. Patients were subdivided into more/less than 5° increase in anterior pelvic tilt. Preoperative measures indicating m. rectus and m. psoas shortness, knee flexor over-length, hip extensor and abdominal muscle weakness and equinus gait were compared between groups. Stepwise multilinear regression of the response value increase in pelvic tilt during stance phase was performed from parameters that were significantly different between groups.
Results: 34% of patients showed more than 5° increased pelvic anterior tilt postoperatively. Best predictors for anterior pelvic tilt from preoperative measures were increased m. rectus tone and reduced hip extension during walking that explained together 39% of the variance in increase of anterior pelvic tilt.
Discussion: Every third patient showed considerable increased pelvic tilt following surgery of flexed knee gait. In particular patients with preoperative higher muscle tone in m. rectus and lower hip extension during walking were at risk and both features need to be addressed in the therapy.

1. Introduction

Patella alta is frequently found in 61–93% of walking children with Cerebral Palsy (CP) [1,2]. It is characterized by a superior patellar position relative to the trochlear groove of the femur [3]. This condition has been associated clinically with patellofemoral dysfunction [4] that is demonstrated as an active knee extension lag that contributes to a flexed knee gait in CP [5]. In addition, patella alta increases patellofemoral joint stress (force per unit area) that is believed to lead to articular cartilage degeneration [6,7] and subsequent pain [8]. Therefore, a patellar tendon shortening procedure (PTS) may be important to improve flexed knee gait and avoid patellofemoral joint degeneration and knee pain in adulthood [2]. PTS within single event multilevel surgeries was shown to improve flexed knee gait in CP patients [5,9]. In particular patients that received additional PTS showed less recurrence of flexed knee gait after two years following multilevel surgery [26]. Therefore, the current standard for the correction of flexed knee gait is to include PTS. However, one of the drawbacks associated to the correction of flexed knee gait including PTS may be increased anterior pelvic tilt with compensatory lumbar lordosis [5,9], as shown in Fig. 1. This compensatory lumbar hyperlordosis may later be associated with spondylosis and back pain [10] and therefore impairs mobility.

Abbreviations: CP, cerebral palsy; PTS, patellar tendon shortening procedure; MAS, modified Ashworth scale; PT, group with excessive increase in anterior pelvic tilt following surgery; PN, group with no increase in anterior pelvic tilt following surgery; TD, typically developed peers.

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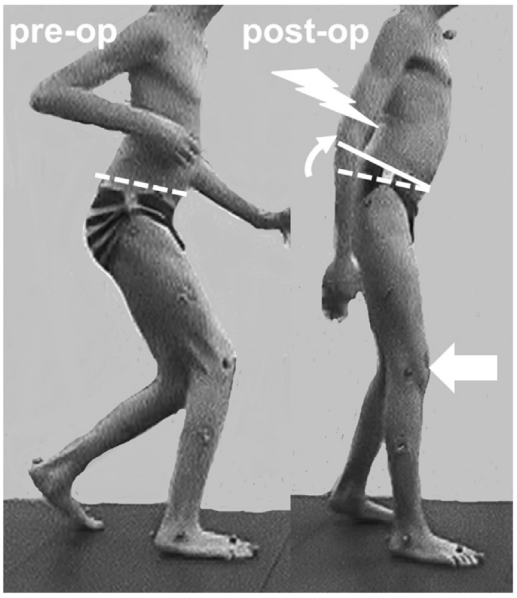

Fig. 1. Patient with increased pelvic anterior tilt and compensatory lumbar hyperlordosis, following surgical correction of crouch gait.

Different reasons for anterior pelvic tilt during walking have been suggested: spasticity and subsequent contractures of m. psoas and m. rectus femoris were shown to pull the pelvis anteriorly [11–14]. Weakness and excessive length of biarticular hamstrings and weakness of hip extensors may reduce posterior stabilisation of the pelvis [14–18]. Additionally, weakness of m. rectus abdominis may lead to anterior pelvic tilt [19]. Equinus results in an anterior position of the ground reaction force vector that requires advancing the centre of mass by tilting the pelvis anteriorly [20]. In addition, a fixed deformity of the spine may also affect pelvic tilt [21]. All etiologies mentioned above would likely increase anterior pelvic tilt when the knee is extended by surgical correction. Hereby the femur is more vertically aligned and more muscular effort is required to stabilize the pelvis compared to the flexed knee position. The counteracting anterior pull of the m. psoas and m. rectus femoris must be compensated by the posterior hip extensor muscles and m. rectus abdominis. Therefore, preoperative muscular contractures and weaknesses may result in an increase of anterior pelvic tilt postoperatively. In particular PTS in addition to other procedures (extension and or rotation osteotomies of the distal femur) may further increase the tension within biarticular m. rectus femoris that further exaggerates the anterior pull to the pelvis.

Therefore, the aim of the study is to find the main causative factors for an increased anterior pelvic tilt following the correction of flexed knee gait including PTS in children and adolescents with CP. The goal is to find which CP patients are at risk preoperatively for excessive anterior pelvic tilt postoperatively and to draw further therapeutic conclusions.

2. Methodology

2.1. Patients and surgical interventions

This study was a retrospective review of all patients diagnosed with spastic bilateral CP who were treated with multi-level surgeries at a single institution between 2010 and 2014. The inclusion criteria used for patient selection were: PTS procedures and supracondylar osteotomy for femoral derotation or extension or both. Instrumented gait analysis and clinical assessment was performed no longer than 3 months before and between 20 and 28 months after surgery. Age between 8 and 18 years, GMFCS I and II and crouch gait. If both sides were treated, only the side with more crouch gait was included in the analysis. This was selected by the peak knee extension angle during stance phase of gait.

Excluded were patients with fixed deformities of the spine and patients with concomitant knee flexor lengthening procedures. The reasons were because fixed deformities of the spine result in pelvic coronal and sagittal plane decompensations [22], and knee flexion procedures were shown to increase anterior pelvic tilt [15] and were not useful in addition to PTS [17].

Participants provided written consent, as approved by the local ethics committee.

Thirty-two typically developed peers (TD) within the same age range provided reference values for gait and clinical tests.

2.2. Data collection and evaluation

Kinematic and kinetic data were collected using the Vicon Plug-in-Gait marker set on an 8-cameraVicon system (Vicon, Oxford, UK) and two force plates (AMTI, Watertown, MA, USA). Muscle lengths were calculated based on kinematic data [23,24]. To compare muscle lengths between patients of different body heights, muscle lengths and velocities were scaled on femur or shank lengths determined from the Plug-in-Gait model during a standing trial.

Patients were subdivided into those with more/less than 5° increase in pelvis anterior tilt named pelvic tilt (PT)/pelvic no tilt (PN) group. This threshold was defined as 1 SD of pelvic tilt of TD peers of 4.7°, rounded to the next integer value that we suggest as clinically relevant and noticeably above the mean difference of pelvic tilt between sessions of 1.3°, determined in our gait laboratory [25].

Six possible preoperative reasons for anterior pelvic tilt were investigated: 1. m. rectus femoris shortening, 2. m. psoas shortening, 3. knee flexor excess length, 4. hip extensor insufficiency, 5. abdominal muscle weakness and 6. equinus gait. The associated gait and clinical parameters to each item are listed in Table 2. Stepwise multilinear regression of the response value postoperative increase in mean pelvic tilt during stance phase was performed from parameters that were significantly different between PT and PN groups. Henze–Zirkler's multivariate normality test was used to test the requirements for the multiple regression analysis [26]. The calculation was carried out using the function 'stepwisefit' of the MatLab 6.2 statistics toolbox (The Mathworks Inc., Natick, USA). The maximum p-value for a term to be added was $p = 0.05$. The minimum p-value for a term to be removed was $p = 0.10$.

Although the effect of surgeries on knee extension is not a preoperative measure, it was additionally correlated to the amount of anterior pelvic tilt. This was done, since the amount of correction of flexed knee gait may intensify the effects of muscular short- and weakness.

To statistically describe the outcome of the surgery and the preoperative baseline parameters a two factors ANOVA with factors group (PT, PN) and intervention (pre, post) including post-hoc t-tests were performed on all parameters investigated.

3. Results

3.1. Surgical outcome on gait and clinical parameters

Thirty-five patients fulfilled the inclusion criteria, of those one patient was excluded because of an additional knee flexor lengthening procedure and two because of fixed deformities of the spine. This results in a total of 32 patients that were analyzed.