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Utilization and efficacy of computational gait analysis for hamstring lengthening surgery☆

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ABSTRACT

A retrospective analysis of computational gait studies performed in a single lab over a 12 year period was undertaken to characterize how recommendations to perform or not to perform hamstring lengthenings were utilized by physicians and the effect on outcomes. 131 Subjects were identified as either having hamstring lengthening considered by the referring surgeon, recommended by gait analysis data, or performed. A subset of this data meeting inclusion criteria for pre- and post-surgical timeframes, and bilateral diagnosis was further analyzed to assess the efficacy of the recommendations. There was initial agreement between planned procedures and recommended procedures in just 41% of the cases. Including the cases where there was agreement, gait analysis altered the initial procedure in 54%. In the cases where the initial plan was not supported by gait data, surgeons followed gait recommendations in 77%. In subjects who underwent hamstring lengthening, when surgeons followed or agreed with gait recommendations, patients were 3.6 times more likely to experience a positive outcome.

1. Introduction

Previous research has demonstrated that even in centers of expertise that routinely treat complex pediatric neurological musculoskeletal conditions, the additional information provided by computational gait analysis (CGA) often alters initial treatment planning. Deluca et al. found that in patients with cerebral palsy (CP), the addition of gait analysis altered decisions in 52% of patients [1]. In similar groups, Cook et al. found a 40% alteration rate, with soft tissue procedures more likely to be changed than bone surgery [2] and Lofterød et al. found a 70% alteration rate with a 13% reduction of procedures [3]. In a slightly more diverse cohort, Kay et al. found that treatment plans were altered 89% of the time [4]. In a clubfoot population, Sankar et al. found that CGA altered 63% of preoperative plans [5].

Further research has shown that following the recommendations resulting from CGA leads to improved outcomes. Chang et al. compared a group of patients with CP that followed CGA recommendations to a matched group that did not and found that the group following recommendations were 3.68 times more likely to have a positive outcome [6]. Filho et al. compared groups of patients with CP according to the percentage of CGA recommendations followed and demonstrated improved outcomes associated with compliance to CGA recommendations [7]. Wren et al. determined that a group of subjects undergoing femoral rotational osteotomy recommended based on CGA improved more than a similar group who were not provided recommendations [8].

Lengthening of the hamstring tendons is a commonly performed procedure in children who lack knee extension with the hip flexed (popliteal angle) and exhibit crouched gait patterns. The goal of the surgery is to improve both knee extension in stance and range of motion. CGA can be a useful tool in recommending hamstring lengthening (HL) by quantitative assessment of joint kinematics. Limited knee extension in stance, reduced range of motion of knee flexion, a posterior sagittal pelvic position, excessive range of motion of the pelvis, and reduced hamstring muscle-tendon lengths at initial contact and terminal swing are all possible indicators of hamstring tightness despite the presence of limited popliteal angle. Contraindications for HL surgery include adequate or excessive knee extension, increased anterior pelvic tilt,

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and normal or elongated muscle-tendon lengths. A multifactorial analysis of these variables as well as other concomitant joint pathomechanics and planned treatments is necessary to assess the need for surgery. CGA can also be used to assess the outcomes of the surgery by evaluating the changes that occur in these same variables.

In the current study, the use of CGA for HL was investigated. The utilization of CGA recommendations are reported for children for whom HL was considered by their orthopaedic surgeon or HL was recommended after a multidisciplinary review of CGA results. The hypothesis of the study was that the group of children for whom CGA recommendations were followed would have significantly better outcomes following HL than the group in which recommendations were not followed. An additional goal of the study was to determine how often CGA altered whether or not HL were performed and how often the CGA recommendations were followed.

2. Methods

IRB approval was obtained for this retrospective data analysis. A laboratory database was searched from 2004 through 2014 for all subjects who underwent CGA. In 2004, a custom muscle-tendon length model based on the work of Delp et al. began to be used as part of the clinical decision making process [9]. CGA reports for each subject were then manually searched to determine if HL were 1) considered by the referring surgeon, 2) recommended based on CGA, and 3) subsequently performed. These conditions were then cataloged to assess how often 1) CGA agreed or disagreed with initial consideration of HL, and 2) surgeons followed the recommendations of the CGA in all patients.

A subgroup of patients was then identified for quantitative assessment of the outcomes of HL surgery. These subjects all had a diagnosis of bilateral cerebral palsy except for two patients with previous histories of transverse myelitis and two with meningitis, had undergone either unilateral or bilateral hamstring lengthening, and had CGA both within 18 months prior to surgery and 36 months following surgery. Follow-up CGA included studies performed as late as February 2016. To assess the efficacy of the HL surgery, the sagittal knee data were evaluated to categorically rank each limb as Improved, Unchanged, or Worse. The gait variable score (GVS) of knee flexion was selected as a measure of overall knee function [10]. A change of greater than one standard deviation from the mean (2.19°) based on the laboratory typically developing data set was considered significant. A decrease greater than one standard deviation was considered a positive outcome (Improved), an increase greater than one standard deviation a negative outcome (Worse), and a less than one SD change was considered Unchanged.

This subgroup of patients was then divided into two groups: the HLRx group consisted of subjects who had HL recommended following CGA and the HLNRx group had HL despite not being recommended following CGA. Odds ratios of both positive outcomes (Improved versus Unchanged or Worse) and negative outcomes (Worse versus Unchanged or Improved) were computed. The knee flexion GVS was also statistically compared between the two groups using the generalized estimating equation (GEE) using limb side as a within subject effect. An alpha level of 0.05 was considered significant.

3. Results

The database search for inclusion criteria screened 2015 gait studies from 1266 subjects. 131 subjects were identified who either were considered for HL by their surgeon prior to CGA or were recommended to have HL following CGA. 74 subjects subsequently underwent HL. Table 1 has a breakdown of the conditions considered.

3.1. Alterations in treatment planning and compliance

Of the 131 subjects, there were just 53 agreements between initial plans and CGA recommendations (41%), meaning that CGA indicated that the initial plan was not supported by quantitative data in 59% of the cases. When HL were both recommended and considered (Group A), surgery was performed in 33 of 39 cases (85%). When recommended but not previously considered (Group B), surgery was performed in 17 of 25 cases (68% compliance with recommendations). When HL was considered but not recommended (Group C) it was performed in 10 of 53 cases (19%, 81% compliance with recommendations). A final group of 14 cases was identified in which HL was neither considered nor recommended, yet was performed (Group D). Combining Groups B and C, CGA changed the initial consideration in 60 of 78 cases (77% compliance with recommendations). Considering all cases with the exceptions of those where the surgical decision did not match despite agreement between the initial consideration and the CGA recommendation, CGA altered the plan in 60 of 111 (54%) subjects.

3.2. Outcomes by recommendation status

48 subjects met the inclusion criteria for quantitative assessment (diagnosis, surgery, and time frames for both pre- and postoperative CGA). 35 subjects (65 limbs) had HL when recommended by CGA, 13 subjects (25 limbs) had HL against CGA recommendations. One subject in each group had a diagnosis transverse myelitis, one had meningitis, and the remainder had bilateral cerebral palsy. Changes in knee flexion GVS for each limb are presented in Fig. 1. Values of categorical outcome classifications are given in Table 2 and are presented as percentages in Fig. 2. The odds ratio for a positive outcome (Improved) when surgeries were recommended compared to not recommended were 3.6:1. Odds ratio for a negative outcome (Worse) when surgeries were not recommended compared to recommended were 3.8:1. The knee flexion GVS of the group with recommended HL improved by 7.8° (±8.4°) and the group with HL not recommended improved by 1.3° (±5.7°). The difference between groups as determined by GEE was significant ($p < 0.001$) and exceeded the minimal clinically significant difference of this parameter (3.4°) by more than double [11].

4. Discussion

Several studies have reported that CGA alters initial treatment planning between 40 and 89%. All previous studies of treatment planning alterations looked at multiple procedures. In this study, for hamstring lengthening procedures only, CGA altered the initial treatment plan 77% of the time when there was not agreement between the CGA recommendation and initial plan, and in 54% of all cases where HL were performed, considered, or recommended based on CGA. In 53 cases, HL was considered but not

Table 1
Subjects identified in whom hamstring lengthenings were either considered prior to gait analysis, recommended after gait analysis or performed.

Group	Recommended	Considered	HL Performed	HL NOT Performed
A	Yes	Yes	33	*6*
B	Yes	No	**17**	8
C	No	Yes	10	**43**
D	No	No	*14*	

HL = Hamstring Lengthening. Bold numbers indicate cases in which CGA altered plan, italicized numbers indicate a surgical decision contrary to agreement.