Differences in implementation of gait analysis recommendations based on affiliation with a gait laboratory

Tishya A.L. Wren a,b,*, Koorosh J. Elihu c, Shaun Mansour a, Susan A. Rethlefsen a, Deirdre D. Ryan a,b, Michelle L. Smith a, Robert M. Kay a,b

a Children’s Orthopaedic Center, Children’s Hospital Los Angeles, Los Angeles, CA, United States
b Keck School of Medicine, University of Southern California, Los Angeles, CA, United States
c School of Medicine & Public Health, University of Wisconsin, Madison, WI, United States

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A B S T R A C T

This study examined the extent to which gait analysis recommendations are followed by orthopedic surgeons with varying degrees of affiliation with the gait laboratory. Surgical data were retrospectively examined for 95 patients with cerebral palsy who underwent lower extremity orthopedic surgery following gait analysis. Thirty-three patients were referred by two surgeons directly affiliated with the gait laboratory (direct affiliation), 44 were referred by five surgeons from the same institution but not directly affiliated with the gait laboratory (institutional affiliation), and 18 were referred by 10 surgeons from other institutions (no affiliation). Data on specific surgeries were collected from the gait analysis referral, gait analysis report, and operative notes. Adherence to the gait analysis recommendations was calculated by dividing the number of procedures where the surgery followed the gait analysis recommendation (numerator) by the total number of procedures initially planned, recommended by gait analysis, or done (denominator). Adherence with the gait analysis recommendations was 97%, 94%, and 77% for the direct, institutional, and no affiliation groups, respectively. Procedures recommended for additions to the surgical plan were added 98%, 87%, and 77% of the time. Procedures recommended for elimination were dropped 100%, 89%, and 88% of the time. Of 81 patients who had specific surgical plans prior to gait analysis, changes were implemented in 84% (68/81) following gait analysis recommendations. Gait analysis influences the treatment decisions of surgeons regardless of affiliation with the gait laboratory, although the influence is stronger for surgeons who practice within the same institution as the gait laboratory.

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1. Introduction

A comprehensive clinical gait analysis test typically involves physical examination, videotaping, and instrumented quantification of lower extremity motions, forces, and muscle activity during walking. The results are presented in a report that includes both the gait analysis data and treatment recommendations from a gait laboratory physician trained to interpret the data. Previous research has shown that treatment recommendations in a gait analysis report are followed over 85% of the time when the referring surgeon is affiliated with the institution operating the gait laboratory [1,2]. However, since gait laboratories are often located in academic or major medical centers [3], many referrals may come from outside the institution. It is not known how often outside physicians adopt the surgical recommendations of the gait laboratory. One recent study has suggested that outside physicians may follow gait analysis recommendations much less frequently [4].

The current study examined the extent to which gait analysis recommendations are followed by orthopedic surgeons with varying degrees of affiliation with the gait laboratory. We hypothesized that gait analysis recommendations would be followed most closely by surgeons most closely affiliated with the gait laboratory. We also investigated the influence of gait analysis on specific surgical procedures to identify when gait analysis is most useful and when it has the greatest impact on surgical decisions.

2. Materials and methods

This study examined retrospective data from children with cerebral palsy (CP), ages 3–18 years, who underwent preoperative gait analysis at our institution between January 1, 2005 and March 1, 2010. Patients were eligible for the study if they had surgery by their referring surgeon within 18 months of their gait analysis

* Corresponding author at: Children’s Hospital Los Angeles, 4650 Sunset Blvd., #60, Los Angeles, CA 90027, United States. Tel.: +1 323 361 4120; fax: +1 323 361 1310.

E-mail address: twren@chla.usc.edu (Tishya A.L. Wren).

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test and if their surgical records could be accessed under the protocol approved by our institutional review board (IRB). The primary reason records could not be accessed was lack of permission to access the records due to inability to contact the patient or the patient’s decision. Records could not be accessed for 69 patients referred by physicians from an outside institution (internal referrals received a consent exemption). Demographic characteristics did not differ between the outside patients whose records could be accessed and those whose records could not be obtained.

Subjects were grouped according to the degree of affiliation of their referring surgeon to the gait laboratory. Of 95 total subjects, 33 were referred by two surgeons directly affiliated with the gait laboratory (direct affiliation), 44 were referred by five surgeons practicing at the same institution but not directly affiliated with the gait laboratory (institutional affiliation), and 18 were referred by 10 surgeons not affiliated with the gait laboratory or gait laboratory institution (no affiliation). None of the surgeons had any direct or indirect financial interest in the gait laboratory.

The study collected data from three sources: (1) referral by the referring surgeon before gait analysis, (2) recommendations by the gait laboratory surgeons after gait analysis, and (3) operative notes from the surgery conducted. Adherence to the gait analysis recommendations was calculated by dividing the number of procedures where the surgery followed the gait analysis recommendation (numerator) by the total number of procedures initially planned, recommended by gait analysis, or done (denominator). For example, if the referring surgeon initially planned bilateral hamstring and tendo-achilles lengthenings, the gait laboratory recommended bilateral hamstring lengthenings and rectus femoris transfers without tendo-achilles lengthenings, and ultimately only bilateral hamstring lengthenings were done, the denominator would be 6 (bilateral hamstring lengthenings, tendo-achilles lengthenings, and rectus femoris transfers), and the numerator would be 4 (hamstrings done as recommended by gait analysis, tendo-achilles dropped as recommended by gait analysis, but rectus transfers not done despite recommendation by gait analysis). Procedures were counted separately for each side and included psoas lengthening, hip adductor lengthening, hamstring lengthening, rectus femoris transfer, triceps surae (gastrocnemius or tendo-achilles) lengthening, femoral derotation osteotomy, tibial derotation osteotomy, bony correction for varus foot, bony correction for valgus foot, posterior tibialis lengthening or transfer, and anterior tibialis lengthening or transfer.

Statistical comparisons between groups were performed using analysis of variance (ANOVA) for continuous variables chi-square or Fisher’s exact tests for categorical variables. Bonferroni post hoc tests were also performed when appropriate.

### Table 1

<table>
<thead>
<tr>
<th>Affiliation with gait laboratory</th>
<th>Direct, N=33</th>
<th>Institutional, N=44</th>
<th>No affiliation, N=18</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10.3 (3.9)</td>
<td>11.6 (4.2)</td>
<td>10.9 (3.7)</td>
<td>0.21</td>
</tr>
<tr>
<td>Female</td>
<td>9 (27%)</td>
<td>19 (43%)</td>
<td>5 (28%)</td>
<td></td>
</tr>
<tr>
<td>GMFCS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>N (%)</td>
<td>24 (73%)</td>
<td>25 (57%)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9 (27%)</td>
<td>16 (36%)</td>
<td>9 (50%)</td>
<td>0.53</td>
</tr>
<tr>
<td>3</td>
<td>3 (9%)</td>
<td>13 (30%)</td>
<td>3 (17%)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>6 (14%)</td>
<td>1 (6%)</td>
<td></td>
</tr>
<tr>
<td># procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planned before GA</td>
<td>Mean (SD)</td>
<td>4.5 (2.6)</td>
<td>3.0 (2.1)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Recommended by GA</td>
<td>Mean (SD)</td>
<td>5.4 (3.4)</td>
<td>5.3 (2.9)</td>
<td>0.97</td>
</tr>
<tr>
<td>Done</td>
<td>Mean (SD)</td>
<td>5.0 (3.2)</td>
<td>4.5 (2.4)</td>
<td>0.63</td>
</tr>
</tbody>
</table>

GA: gait analysis; GMFCS: gross motor function classification system.

* P = 0.03 for direct vs. institutional, 0.08 for direct vs. no affiliation, 1.00 for institutional vs. no affiliation.

### Table 2

<table>
<thead>
<tr>
<th>Affiliation with gait laboratory</th>
<th>Direct, N=33</th>
<th>Institutional, N=44</th>
<th>No affiliation, N=18</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence %</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Patients with 100% adherence</td>
<td>97 (6)</td>
<td>94 (15)</td>
<td>77 (23)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Procedures added %</td>
<td>82% (27/33)</td>
<td>75% (33/44)</td>
<td>28% (5/18)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Procedures dropped %</td>
<td>98% (48/49)</td>
<td>87% (78/90)</td>
<td>77% (17/22)</td>
<td>0.02**</td>
</tr>
</tbody>
</table>

* P = 0.001 for non-affiliated vs. others; P > 0.58 for direct vs. institutional.

** P = 0.03 for direct vs. institutional; P = 0.01 for direct vs. non-affiliated; P = 0.32 for institutional vs. non-affiliated.

### 3. Results

Patient characteristics were similar among the three groups (Table 1). Although more procedures were initially planned in the direct affiliation group (P ≤ 0.08), a similar number of procedures was recommended by the gait laboratory and ultimately done in all groups (P > 0.6). This suggests that the three groups of patients were comparable, with a similar level of involvement across all groups.

As might be expected, adherence with the gait analysis recommendations increased with closer affiliation to the gait laboratory (Table 2). Surgeons associated with the gait laboratory followed an average of 97% of the gait analysis recommendations. Surgeons from the same institution followed 94%, while outside surgeons followed 77%. In addition, adherence with the gait laboratory increased the likelihood that a surgeon would follow all of the gait analysis recommendations for a patient. Surgeons with direct and institutional affiliation followed all recommendations for ≥75% of their patients, compared with 28% of patients for surgeons from other institutions (P < 0.001).

Of the 95 patients, 81 had specific surgical plans prior to gait analysis. The gait laboratory recommended changes in the surgical plan for 70 (86%) of these patients, and at least one recommended change was implemented in 68/70 (97%) patients. Thus, surgery was changed for 84% (68/81) of patients overall in accordance with gait analysis recommendations.

The procedures most commonly recommended for addition to the surgical plan (>10% of the time) included hip adductor lengthening, hamstring lengthening, femoral osteotomy, tibial osteotomy, and valgus foot correction (Fig. 1A). The recommendations to add procedures were followed in 98% (48/49) of cases in the gait laboratory group, 87% (78/90) of cases in the institutional group, and 77% (17/22) of cases in the non-affiliated group (Table...
2). The procedures most frequently not added in the institutional and non-affiliated groups were rectus femoris transfer (56%, 5/9 added), femoral osteotomy (72%, 13/18 added), tibial osteotomy (80%, 12/15 added), and valgus foot correction (83%, 10/12 added).

The procedures the gait laboratory most frequently recommended dropping (>10% of the time) were triceps surae lengthening, rectus femoris transfer, and femoral osteotomy (Fig. 1B). The recommendations to drop procedures were followed in all cases except for valgus foot correction (2/5 dropped) and femoral osteotomy (8/9 dropped) in the institutional group and triceps surae lengthening (3/5 dropped) in the non-affiliated group.

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4. Discussion

This study demonstrates that gait analysis influences the treatment decision-making of surgeons regardless of affiliation with the examining gait laboratory, although the influence is stronger for surgeons practicing within the same institution as the gait laboratory. Even among surgeons from outside the institution, adherence to the gait analysis recommendations was high with gait analysis recommendations being followed over 75% of the time. Operative notes indicated that the main reasons for not implementing gait laboratory recommendations among non-affiliated surgeons were usually patient/parent preference or the referring surgeon’s judgment that a given problem was not of primary importance for intervention. In addition, previous research has shown that decisions not to follow gait analysis recommendations are sometimes based on radiographic or intra-operative findings or changes in the patients’ presentation between gait analysis and surgery [2].

Greater adoption of gait analysis recommendations among surgeons more closely associated with the gait laboratory is not surprising. Surgeons within the gait laboratory’s institution are more likely to have had exposure to gait analysis data and interpretation. They may also be influenced by a direct professional relationship with a gait laboratory-trained physician, as well as institutional practice patterns related to the use of gait analysis in treatment planning. There are several reasons why surgeons from outside the gait laboratory’s institution may not follow the gait laboratory recommendations as closely as surgeons within the institution. The outside surgeons may not be trained and/or facile in performing some of the procedures recommended after gait analysis, such as distal rectus femoris transfers, which were developed based on findings from gait analysis [5–7]. Surgeons may also not be comfortable performing the extensive multilevel surgeries often recommended by gait laboratory physicians [8]. In addition, there are institutional and regional differences in surgical practice patterns [9,10] which may affect individual surgeons’ thresholds for performing specific procedures such as muscle–tendon lengthenings or long bone rotational osteotomies [11].

Surgeons, particularly those from outside the institution, were more inclined to drop than to add procedures based on gait analysis recommendations. When the gait laboratory recommended dropping a planned procedure, it was almost always dropped, except for valgus foot correction which is primarily evaluated based on clinical and radiographic findings rather than gait analysis data. When the gait laboratory recommended adding a procedure, it was usually added. The procedures most commonly not added were distal rectus femoris transfer, which some surgeons may not be familiar with, and derotational osteotomies, where the threshold for surgery differs significantly among different institutions [11].

Gait analysis appears to be particularly helpful in informing decision-making for hip adductor lengthening, hamstring lengthening, distal rectus femoris transfer, triceps surae lengthening, valgus foot correction, and long bone osteotomies. Additional adductor and hamstring lengthenings were often recommended by gait analysis and were almost always performed, possibly because most surgeons feel comfortable performing these procedures and are able to add them without greatly increasing surgical time and complexity. In contrast, triceps surae lengthening was often recommended for elimination, but this recommendation was only followed 60% of the time by outside surgeons, perhaps reflecting less awareness of apparent equinus outside the gait laboratory [12]. Rectus femoris transfers and derotational osteotomies were sometimes recommended for addition and sometimes recommended for elimination. This may indicate greater difficulty in assessing the need for these procedures without gait analysis even among experienced gait laboratory physicians. Dynamic rectus femoris and posterior tibialis activity cannot be assessed without electromyography, and multi-level rotational deformities are difficult to quantify and isolate based on clinical and visual assessment alone. Previous studies have reported similar differences between clinical assessment and gait analysis for derotational osteotomies [13,14] and rectus femoris transfer [14,15].

Our results demonstrate that clinical gait analysis greatly influences the treatment decisions of surgeons who refer patients to the gait laboratory. Even surgeons from outside the gait laboratory institution followed over 75% of the gait analysis recommendations. While there may be a limit to the extent to which gait analysis recommendations are followed due to institutional differences or differences in individual surgeons’ practice patterns, it is clear that gait analysis results are seriously considered in the treatment decision-making process. Additional research, education, and outreach may expand utilization of gait analysis to surgeons with less exposure to this technology.

Conflict of interest statement

None of the authors have any financial or personal relationships with other people or organizations that could inappropriately influence this work.

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