The Recurrent Clubfoot

Can Gait Analysis Help Us Make Better Preoperative Decisions?

Wuddhav N. Sankar MD, Susan A. Rethlefsen PT,
Jennifer Weiss MD, Robert M. Kay MD

Published online: 18 December 2008
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Abstract Gait patterns in children with recurrent clubfoot are often associated with more or less subtle factors contributing to the patterns, such as tibial torsion that might not be detected by visual observation and therefore not considered in a treatment plan. We therefore used gait analysis to elucidate the contributions to recurrent clubfoot deformity and to determine whether gait analysis could be important in preoperative decision-making for these patients. We reviewed all 35 patients (56 feet) referred to our gait laboratory for recurrent deformity following treatment of idiopathic clubfoot. The average age of the children in our series was 6.7 years (range, 3.6–15.4 years). Data were acquired from computerized motion analysis, dynamic electromyography, and static measurements by a physical therapist. We found a high incidence of transverse plane deformities including intoeing in 45 of 56 feet (80%), internal tibial torsion in 40 of 56 feet (71%), and forefoot adductus in 40 of 56 feet (71%). Forty feet were supinated in stance; of these patients, 28 (70%) had

overactive tibialis anterior muscle activity based on dynamic EMG. Dynamic compensatory hip external rotation was present in 28 of 56 (50%) of limbs. Thirty of the 35 patients underwent surgery following gait analysis; the most common procedures included split anterior tibial tendon transfers (34), tibial derotational osteotomies (34), and midfoot osteotomies (20). Quantitative gait analysis resulted in 28 changed procedures in 19 of 30 patients (63%) compared to prestudy surgical plans.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Previous studies have used gait analysis to compare outcomes following serial casting and surgical release of idiopathic clubfeet [1, 3, 4, 7, 9]. Many of these data provided valuable insight into the treatment of clubfoot by demonstrating that feet treated with serial manipulation and casting often have superior strength, flexibility, and kinematic function compared to feet treated with posteromedial/lateral release [7]. With the goal of treatment being a supple and functional foot, the current standard of care has moved toward serial manipulation and casting with or without percutaneous Achilles tenotomy.

Regardless of improved treatment methods, recurrent deformity can and does occur. The incidence of recurrence following Ponseti treatment has been reported between 11% and 41% [6, 8]. One series with long-term followup after extensive soft tissue release for clubfeet reported that 39 of 45 patients needed additional surgery [5]. Current decision-making for these children with recurrent clubfeet seems based on clinical evaluation and experience, since

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Electronic supplementary material The online version of this article (doi:10.1007/s11999-008-0665-x) contains supplementary material, which is available to authorized users.

W. N. Sankar, S. A. Rethlefsen, J. Weiss, R. M. Kay (✉)
Division of Orthopedic Surgery, Childrens Hospital Los
Angeles, 4650 Sunset Blvd, Los Angeles, CA 90027, USA
e-mail: rkay@chla.usc.edu

little data exist to systematically characterize the deformity in cases of clubfoot recurrence. Objective data describing typical deformity patterns could improve awareness of more subtle factors contributing to the patterns such as tibial torsion, thereby minimizing the possibility of inadequate treatment. We are aware of only one small study that used gait analysis to describe the recurrent clubfoot [2]. Although the authors described a 72% prevalence of intoeing, specific information including the prevalence of internal tibial torsion, knee hyperextension, and dropfoot during gait were not reported.

The purpose of our study was twofold: (1) to elucidate the various contributions to deformity in cases of recurrent clubfoot, and (2) to determine the utility of gait analysis in preoperative decision making for these patients.

Materials and Methods

We retrospectively reviewed our gait laboratory records and identified 35 patients (56 feet) referred for evaluation of recurrent deformity following treatment of idiopathic clubfoot; we excluded all children with an identified cause for the clubfoot. Forty-one of the 56 (73%) feet had previously undergone posteromedial/lateral release. Thirteen feet had been treated with serial manipulation and casting; two had initially been treated nonoperatively, but later underwent either an anterior tibialis tendon transfer (1) or an external tibial derotational osteotomy [1]. In all cases,

the child was brought back to clinic for reevaluation because of gait disturbances observed by the families. Based on the clinical evaluation of the physician, the patient was then referred to the gait laboratory. The average age of the children in our series was 6.7 years (range, 3.6–15.4 years). There were 24 boys and 11 girls. In patients with unilateral clubfoot five were on the right and nine on the left; in 21 patients, both feet were affected. We obtained prior institutional review board approval for the study.

In all cases, patients underwent a gait analysis evaluation which included static measurements by a physical therapist (including SAR), computerized motion analysis, and dynamic electromyography.

Examination included measurement of range of motion of the hips, knees, and ankles. Measures of lower extremity rotational deformity included transmalleolar angle, hindfoot-thigh angle, and the thigh-foot angle. Transmalleolar angle was measured prone with the knee flexed to 90°, and was represented by the angle between a line connecting the medial and lateral malleoli and a line perpendicular to the long axis of the thigh (Fig. 1A). For this and all the measures of lower extremity rotational deformity, a negative value denoted internal and a positive value external rotation. A transmalleolar angle of 10° or less was considered abnormal. The hindfoot-thigh angle measurement was taken and compared to the transmalleolar angle to detect any additional rotation of the lower limb occurring below the level of the malleoli, such as in the talus.

Fig. 1A–C (A) The transmalleolar angle is measured between the line connecting the medial and lateral malleoli and a line perpendicular to the long axis of the thigh. (B) The hindfoot-thigh measurement is the angle created between the long axis of the calcaneus and the thigh. (C) The thigh-foot angle represents the angle created between the long axes of the thigh and the foot.

The hindfoot-thigh measurement is the angle created between the long axis of the hindfoot and that of the thigh in the prone position (Fig. 1B). The thigh-foot angle was also measured prone, and represents the angle created between the long axes of the thigh and the foot (goniometer aligned to the space between the second and third metatarsal heads). This measure includes lower leg torsion originating from the tibia, hindfoot, and forefoot, including metatarsus adductus (Fig. 1C).

The computerized motion analysis tests were performed with an eight-camera VICON 3-D motion system (Lake Forest, CA), which uses 15 to 20 passive retroreflective markers attached to specific bony landmarks of the lower extremities and pelvis. EMG data were recorded at 2500 Hz. Footswitches (B&L Engineering, Tustin, CA) with pressure sensors under the heel, first and fifth metatarsal heads, and great toe were used to determine the phasing of muscle activity, as well as to detect the presence of forefoot pronation or supination in stance phase. Surface electrodes were placed over the greatest bulk of each muscle, palpated during active contraction. The muscles sampled included the anterior tibialis, peroneus longus, and medial gastrocnemius in all cases. Surface electrodes were secured in place with tape and Coban self-adherent wrap (3 M, St. Paul, MN) to prevent movement on the skin. The data were then processed using the EMG Analyzer software (B&L Engineering, Tustin, CA). This software program performs signal rectification, as well as both time normalization (to percent of the gait cycle) and amplitude normalization (to percent of maximum amplitude EMG signal during the gait cycle) for each stride of data collected. After examination for stride-to-stride consistency, the data from all strides were averaged into a mean muscle profile for each muscle or muscle group sampled.

The subjects walked at a self-selected pace along a 15-m walkway with the EMG electrodes, footswitches, and retroreflective markers in place. The subject's gait was also videotaped during gait analysis testing. Data were collected for every 2% of the gait cycle for multiple strides, averaged, and plotted for interpretation. Three-dimensional joint rotations (kinematic) data were obtained for the hips, knees, and ankles bilaterally, in the sagittal, coronal, and transverse planes. The kinematic data were plotted against data from 31 able-bodied children for visual comparison during interpretation. Kinematics data included pelvic, hip, knee, and ankle rotations in the sagittal, coronal, and transverse planes from bilateral lower extremities. EMG data were collected from bilateral lower extremities, and included the anterior tibialis, medial gastrocnemius, and peroneus longus in all cases.

Forefoot supination during gait was determined based on footswitch data (decreased or absent first metatarsal

head and great toe contact) and the video record. The presence of forefoot adductus was determined based on static examination and the video record of foot position. For the purposes of this study, we determined that adductus was present if the thigh-foot angle was at least 10° more internal than the hindfoot-thigh angle.

After data collection, data were analyzed and a detailed report written by a physical therapist (including SAR) experienced in gait analysis (Appendix 1; supplemental materials are available with the online version of CORR). The motion laboratory physician (RMK) then reviewed the video and gait analysis data with the physical therapist (SAR) and motion laboratory team to determine treatment recommendations. Clinical examination measures were reviewed for the presence of deformities such as internal tibial torsion, forefoot adductus, equinus contractures, dorsal bunions, etc. Then the kinematic data were examined, with specific attention to the transverse plane (foot progression angle as compared to pelvic and hip rotations) and the sagittal plane (dorsi/plantarflexion, knee flexion/extension), and any other apparent gait deviations. The footswitch data were then evaluated and the EMG data were assessed, with particular attention to anterior tibialis timing in stance phase in cases where footswitch data indicated forefoot supination in stance.

All information was then integrated, and a list of problems and recommended treatments were made by the physician (RMK). A split anterior tibialis tendon transfer (SPLATT) was generally recommended if there was a varus foot (based on footswitch and slow-motion video analysis) at the time of inappropriate tibialis anterior EMG activity. A tibial derotational osteotomy was usually recommended for a child with a foot progression angle more than 10° more internal than the sum of the ipsilateral pelvic rotation and hip rotation during stance phase. This recommendation was confirmed by a relatively internal transmalleolar angle and thigh-foot angle. Indications for a midfoot osteotomy were a thigh-foot angle at least 10° more internal than the hindfoot-thigh angle with concomitant intoeing not due to the tibia that had functional effects. Fixed supination in both gait (confirmed by footswitch data and video analysis) and clinical exam was also an indication for a midfoot osteotomy.

We reviewed outpatient charts to record demographic data (age, gender), underlying diagnoses, and treatment history. Pregait study surgical plans were determined from the gait lab referral form. Operative records were reviewed to determine what procedures were performed at the time of surgery. Gait lab recommendations were compared to pre-gait study surgical plans as well as to the actual surgical procedures performed to determine the number of changed procedures (either added or subtracted).

Results

Based on quantitative gait analysis, the gait disturbances in a recurrent clubfoot proved to be multifactorial (Table 1). Forty-five of 56 feet (80%) had internal foot progression angles, indicating a substantial prevalence of intoeing (Table 2). Twenty-eight extremities (50%) had compensatory

Table 1. Static gait analysis data

Variable	Mean (range)
Hip IR	61° (35° to 90°)
Hip ER	48° (25° to 70°)
Ankle DF (knee extended)	4° (−5° to 30°)
Ankle DF (knee flexed)	8° (−10° to 40°)
Hindfoot-thigh axis	0° (−35° to 30°)
Thigh-foot axis	−11° (−45° to 20°)
Transmalleolar angle	5° (−30° to 30°)

Table 2. Dynamic gait analysis data

Variable	Number of feet (%)
Internal FPA	45 (80%)
Dynamic hip ER	28 (50%)
Dynamic knee hyperextension	16 (29%)
Dropfoot in swing	10 (18%)
Forefoot supination	40 (71%)
Equinus in stance	15 (27%)
Forefoot adductus	40 (71%)

hip external rotation during gait, including 20 of 35 (57%) limbs with internal and eight of 11 with external foot progression angles. Adductus and supination of the forefoot were seen in 40 feet each (71.4%). Dynamic EMG showed inappropriate stance phase activity in 28 of the 40 feet (70%) that were supinated during stance (Fig. 2A–B). The typical child with bilateral recurrent clubfeet displayed multiple kinematic anomalies in the transverse plane (Fig. 3).

Thirty of 35 patients (86%) had surgery following gait analysis. The most common procedures performed included split anterior tibial tendon transfers (34), tibial derotational osteotomies (34), and midfoot osteotomies (20). Quantitative gait analysis resulted in 28 changed procedures in 19 of 30 patients (63%) compared to prestudy surgical plans (Table 3). The most common additional procedures recommended were tibial derotational osteotomy (13), gastrocnemius recession (four), and split anterior tibialis tendon transfer (two). For 15 patients (21 feet), the referring surgeon recommended a tendon transfer prior to gait analysis but had requested advice as to whether an anterior tibial tendon transfer or a posterior tibial tendon transfer would be necessary. In all cases, gait analysis was able to recommend that the anterior tibial tendon be transferred.

Discussion

Current surgical decision making for children with recurrent clubfeet seems based on clinical evaluation and experience since a systematic analysis of the deformity has

Fig. 2A–B (A) Sample foot-switch data (left side) showing curtailed contact with the first metatarsal head, an indication of forefoot supination in stance phase. (B) Sample EMG data from the anterior tibialis showing inappropriate activity in stance phase. Solid bar indicates normal timing. TO = toe off.

Fig. 3 Sample transverse and sagittal plane kinematic data from a patient with bilateral recurrent clubfoot deformity. Note the external rotation of the hip and the internal foot progression angle. Darkest grey = left; medium gray = right; lightest grey = normal.

not been presented in the literature. Objective data describing typical deformity patterns could alert physicians of more subtle factors related to the deformity, thereby minimizing the possibility of inadequate treatment. Gait analysis has previously been used with success to characterize idiopathic clubfeet, but with the exception of one limited study has not been applied to cases of clubfoot recurrence [2]. The purposes of our study were to describe the various contributions to deformity in cases of recurrent clubfoot and to determine the utility of gait analysis in preoperative decision-making for these patients.

A limitation of our study is the lack of postoperative gait data that validates the recommended changes based on the preoperative gait analysis. We therefore cannot definitively

state that the alterations to the surgical plan based on gait analysis resulted in improved outcomes for our patients. We are currently securing funding to perform followup gait studies on our patients. Another potential point of contention is our definition of recurrent clubfeet. One could argue that some of our patients did not have clubfoot recurrence but rather residual deformity that had persisted since the original treatment. One might then conclude that our study population could consist of two separate patient groups, thereby weakening its importance. In all cases, families who were presumably initially satisfied after treatment came back for reevaluation with complaints of worsened gait and/or foot deformity. According to Ponseti, it is incorrect to assume that relapses occur because the

Table 3. Results of quantitative gait analysis

Patient	Pregait study surgical plan	Gait study recommendation	Changed procedure	Basis for change in recommendation	Actual surgical procedures performed
1	B TDRO, B SPLATT	B TDRO, B SPLATT	None	N.A.	B TDRO, B SPLATT
2	B TDRO, B MFO, B SPLATT	B TDRO, B MFO, B SPLATT	None	N.A.	B TDRO, B MFO, B SPLATT
3	L SPLATT vs. SPOTT, L MFO	L SPLATT, L MFO	None	N.A.	L SPLATT, L MFO
6	L SPLATT, L HFO, L FHL tx, R MM screw	L Ant tib lx, L MFO, L FHL tx	+ L Ant tib lx, L MFO, - R MM screw	Dorsal bunion with tib ant overactivity; TFA 10° more internal than HTA with functional effect; insufficient ankle valgus on xray	L SPLATT, L Ant tib lx, L MFO, L FHL tx
7	R SPLATT, R TDRO, R MFO	R SPLATT, R TDRO, R MFO, R GR	+ L TDRO, R GR	FPA 10° more internal than sum of pelvic and hip rotation; relative equinus in stance based on sagittal kinematic plots	R SPLATT, B TDRO, R MFO, R GR
8	L SPLATT, L TDRO, L GR	L SPLATT, L TDRO, L GR	None	N.A.	L SPLATT, L TDRO, L TAL
9	R TDRO, R SPLATT, L HFO, L Ant tib lx	R TDRO, R SPLATT, L HFO, L Ant tib lx	None	N.A.	R TDRO, R SPLATT, L HFO, L Ant tib lx
10	R SPLATT, B TDRO	B SPLATT, B TDRO	+ L SPLATT	Varus foot at the time of ant tib overactivity	B SPLATT, B TDRO
11	R SPLATT, R TDRO, R GR	R SPLATT, R GR	- R TDRO	FPA was not 10° more internal than sum of pelvic and hip rotation	R SPLATT, R GR
13	L SPLATT vs. SPOTT, L TDRO	L SPLATT, L TDRO	None	N.A.	L SPLATT, L TDRO
14	R SPLATT vs. SPOTT, R MFO, R HFO	R SPLATT, R FHL tx, R MFO, R HFO	+ FHL tx	Dorsal bunion more evident during gait than static exam. Confirmed by decreased 1 st metatarsal contact on footswitch	R SPLATT, R MFO, R FHL tx
15	L SPLATT, L MFO	L SPLATT, L MFO, B TDRO	+ B TDRO	FPA 10° more internal than sum of pelvic and hip rotation	L SPLATT, L MFO, B TDRO
16	L MFO, L HFO, L SPLATT	L MFO, L SPLATT, L TDRO	+ L TDRO, - L HFO	FPA 10° more internal than sum of pelvic and hip rotation; flexible hindfoot varus	L MFO, L SPLATT, L TDRO
17	L TDRO, L SPLATT vs. SPOTT, L MFO, L GR, L PR	L SPLATT, L MFO, L GR, L PR	- L TDRO	FPA was not 10° more internal than sum of pelvic and hip rotation	L SPLATT, L MFO, L PR
18	R MFO, R SPLATT, B HFO	R SPLATT, B HFO	- R MFO	TFA was not 10° more internal than HTA with functional effect	R SPLATT, B HFO
19	B SPLATT vs. SPOTT, B PR, B MFO	B SPLATT, B PR, B MFO, B TDRO	+ B TDRO	FPA 10° more internal than sum of pelvic and hip rotation	B SPLATT, B PR, B MFO, B TDRO
20	L SPLATT vs. SPOTT, L MFO	L SPLATT, L MFO, L TDRO	+ L TDRO	FPA 10° more internal than sum of pelvic and hip rotation	L SPLATT, L MFO, L TDRO

Table 3. continued

Patient	Pregait study surgical plan	Gait study recommendation	Changed procedure	Basis for change in recommendation	Actual surgical procedures performed
21	R SPLATT vs. SPOTT, R MFO	R SPLATT, R MFO, B TDRO	+ B TDRO	FPA 10° more internal than sum of pelvic and hip rotation	R SPLATT, R MFO, B TDRO
22	R SPLATT, R GR	R SPLATT, R GR, R TDRO	+ R TDRO	FPA 10° more internal than sum of pelvic and hip rotation	R SPLATT, R GR, R TDRO
23	B TDRO, L SPLATT	B TDRO, L SPLATT	None	N.A.	B TDRO, L SPLATT
25	R SPLATT vs. SPOTT	R SPLATT, B TDRO	+ B TDRO	FPA 10° more internal than sum of pelvic and hip rotation	R SPLATT, B TDRO
26	L TDRO	L SPLATT, L TDRO	+ L SPLATT	Varus foot at the time of ant tib overactivity	L SPLATT, L TDRO
27	L SPLATT vs. SPOTT, L TDRO, L MFO	L SPLATT, L TDRO, L MFO	None	N.A.	L SPLATT, L TDRO, L MFO
28	R SPLATT vs. SPOTT, R MFO	R SPLATT, R MFO, R TDRO	+ R TDRO	FPA 10° more internal than sum of pelvic and hip rotation	R SPLATT, R MFO, R TDRO
29	L TDRO, L SPLATT	L TDRO, L SPLATT	None	N.A.	L TDRO, L SPLATT
31	B SPLATT, B MFO, B TDRO	B SPLATT, B MFO, B TDRO, R GR	+ R GR	Relative equinus in stance based on sagittal kinematic plots	B SPLATT, B MFO, B TDRO, R GR
32	R TDRO, R MFO	R TDRO, R MFO, R GR	+ R GR	Relative equinus in stance based on sagittal kinematic plots	R TDRO, R MFO, R GR
33	L SPLATT, L MFO, L GR	L TAL, L TDRO, L SPLATT, L MFO	+ L TAL, L TDRO	Equinus in stance based on sagittal kinematic plots with inability to bring ankle to at least neutral with knee flexed; FPA 10° more internal than sum of pelvic and hip rotation	L TAL, L TDRO, L SPLATT, L MFO
34	L SPLATT, L GR	L SPLATT, L GR	None	N.A.	L SPLATT, L GR
35	L SPLATT, L TDRO, L GR	L SPLATT, L TDRO, L GR	None	N.A.	L SPLATT, L TDRO, L GR

SPLATT = split anterior tibialis tendon transfer; SPOTT = split posterior tibialis tendon transfer; PR = plantar release; HFO = hindfoot osteotomy; TAL = tendoachilles lengthening. GR = gastrocsoleus recession; TDRO = tibial derotational osteotomy; MFO = midfoot osteotomy; Ant Tib = anterior tibialis muscle; FPA = foot progression angle; TFA = thigh-foot angle; HTA = hindfoot-thigh angle; N.A. = not applicable.

deformity had not been completely corrected [10]. Instead, he supports the concept of a true relapse, arguing that the same pathology of retracting fibrosis that caused the original deformity can contribute to its recurrence as a child grows. Regardless of whether the deformity is truly recurrent or just residual, we believe that it constitutes a distinct clinical entity compared to the standard posttreatment clubfoot. Unlike most gait studies, which have included all patients after treatment, ours specifically targeted those children whose parents sought further treatment for their children's lower extremity deformities (regardless of whether this was residual or due to recurrence) [1, 3, 4, 7, 9]. The patients in our study had a much higher incidence of intoeing and transverse plane deformities compared to other series. Another potential limitation of the study is interexaminer variability of surface electrode and kinematic marker placement. This is a limitation inherent in studies utilizing surface EMG. However, given the consistent techniques for placement used among the few clinicians performing the gait analyses, we did not believe this problematic.

Despite its limitations, our data demonstrate the deformity and gait patterns in recurrent clubfoot is multifactorial. Supination of the forefoot is common and in almost all cases is due to inappropriate stance activity of the tibialis anterior muscle. This finding supports the general practice of performing anterior tibialis tendon transfers on children with recurrent supination. Our data suggest a high incidence of transverse plane deformities in children with recurrent clubfoot. Internal tibial torsion and forefoot adductus were each seen in over 70% of our patients. Overall, 80% of our children walked with an intoeing gait and many children (50%) had compensatory external hip rotation as a result. This compensatory external rotation was even more frequent in those children with external foot progression angles, implying that even these children had underlying transverse plane deformities in spite of their "normal" foot progression angles. These deformities may have been missed without the aid of computerized gait analysis.

Previous studies have reported the prevalence of intoeing in all patients following initial treatment (surgical and nonoperative) of idiopathic clubfoot to be between 45% and 55% [7, 11, 12]. The prevalence of intoeing in our series of symptomatic recurrent clubfoot was much higher at 80%. As previously mentioned, our study population consisted of children who needed further treatment for their gait disturbance (usually intoeing) and therefore differed from these other studies which were more of a cross-section of treated clubfeet. It is therefore not surprising that we found a higher incidence of intoeing in our series. In 1990, Yngve used carbon paper measurements to analyze the foot progression angle in a cohort of patients

after surgical treatment for idiopathic clubfeet and in a group of age-matched controls [12]. To our knowledge, this was one of the few studies which systematically attempted to break down the individual contributions to the intoeing gait. Transmalleolar angle measurements were available for 31 extremities. Fifteen of these patients had substantial intoeing; these children had a mean transmalleolar angle of 14°. The remaining 16 patients without much intoeing had a mean transmalleolar angle of 20° [12]. Only three patients overall (9.7%) had a transmalleolar angle of 10° or less, indicating internal tibial torsion. In comparison, our children with recurrent clubfoot deformity had a lower mean transmalleolar angle (5.2°) and a much higher prevalence of internal tibial torsion (71.4%). We are aware of one previous study that specifically addresses the recurrent clubfoot [2]. Of the 18 recurrent deformities in that series, the predominant reason for referral (72%) was an intoeing gait. All but one of these patients had increased tibialis anterior activity during stance phase. Specific information including hip and ankle range of motion as well as the incidence of internal tibial torsion, knee hyperextension, and dropfoot during gait were not reported [2].

Our results also demonstrate that gait analysis is useful for preoperative decision making in children with recurrent clubfeet. In 63% of patients, surgical plans were changed based on data abstracted from the gait laboratory. The most common additional procedure recommended was a tibial derotational osteotomy which further highlights how gait analysis has improved our understanding of the transverse plane deformity in children with recurrent clubfeet. These results are similar to those of Asperheim et al. [2] who stated that the procedures most often performed after gait analysis in their series of 18 recurrent clubfeet were SPLATTs (seven) and distal tibial derotational osteotomies (three). Our findings that the most common deformities causing families to seek treatment for recurrent clubfoot are internal tibial torsion, forefoot supination, and adduction should benefit surgeons without access to a gait analysis laboratory by reminding them to look for these deformities during normal clinical examinations. While it is common to treat recurrent clubfoot deformity with an isolated SPLATT, our data suggest that such practice could result in inadequate treatment of the overall deformity.

Our experience with gait analysis for children with recurrent clubfeet has demonstrated that the deformity and gait patterns are multifactorial. Although forefoot supination is common, additional deformities usually exist (particularly in the transverse plane) including a high incidence of forefoot adductus and internal tibial torsion. In addition, compensatory external hip rotation was present in 50% with recurrent or residual clubfoot deformity and not

identified prior to gait analysis. We believe gait analysis is useful to characterize the deformity and plan for corrective surgery, especially given the high incidence of compensatory external hip rotation during gait, which may mask the extent of torsional or foot deformities contributing to intoeing in these patients.

Acknowledgments We thank Bitte S. Healy, MS PT, and Sandra W. Dennis, MS PT, for their valuable assistance with data collection and interpretation of gait analysis data for the subjects in this study.

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