Outcome of gastrocnemius recession and tendo-achilles lengthening in ambulatory children with cerebral palsy

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Preoperative and postoperative gait analysis data were retrospectively studied for 54 children with cerebral palsy who had undergone either gastrocnemius recession (GR) or tendo-achilles lengthening (TAL) as part of multi-level surgery. Decision-making between GR and TAL was based on the Silfverskiöld test. The TAL group had greater equinus preoperatively than the GR group. Both groups showed significant improvement in static and dynamic dorsiflexion and in outcome measured by a modified Physician Rating Scale (PRS) postoperatively. Calf spasticity decreased and push-off power increased after GR. Both GR and TAL are effective in appropriately selected patients. However, a potential for over- and under-correction with both GR and TAL was demonstrated. ***J Pediatr Orthop B*** **13:92–98 © 2004 Lippincott Williams & Wilkins.**

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Introduction

Equinus of the foot and ankle is one of the most prevalent deformities encountered in children with cerebral palsy (CP). Though the equinus deformity in children with CP is dynamic initially, a fixed contracture frequently develops as these children age.

The goal of treatment in a child with an equinus deformity is optimization of joint position throughout the gait cycle. In a child with a dynamic contracture, this entails controlling the ankle in a range of motion that is obtainable on static examination. In children with static contractures, lengthening of the musculotendinous unit is required to allow for an appropriate static range of motion and improved kinematics during functional activities such as gait. Treatment options for children with static contractures include serial casting, daytime or night-time splinting, vigorous stretching programs, or surgical lengthening of the involved musculotendinous units. In some cases, chemodenervation is used in combination with the non-surgical methods cited.

Two commonly performed operations for equinus deformity include tendo-achilles lengthening (TAL) and gastrocnemius recession (GR). Most studies comparing TAL and GR have reported improvements with each procedure, including improved kinematic and kinetic measures [1–4]. However, there has been concern with the potential development of calcaneal gait due to overlengthening of the triceps surae [1,5]. Segal *et al.* [5] reported a 30% incidence of calcaneal gait following TAL in diplegic children. Borton *et al.* [1] reported a 36% risk of calcaneus gait or deformity following GR and TAL, with a 60% risk in quadriplegic, a 40% risk in diplegic, and only a 4% risk in hemiplegic patients.

The goals of the current study were (1) to examine the outcome of TAL and GR in ambulatory children with cerebral palsy, (2) to compare the results of TAL and GR in these children, and (3) to identify predictors of outcome for TAL and GR to guide surgical decision-making in the treatment of ambulatory children with CP.

Methods

Subjects

A retrospective review of 54 patients with static encephalopathy who had undergone 81 surgical lengthenings of the triceps surae was undertaken. Overall, there were 23 TALs and 58 GRs. Twenty-seven patients had bilateral surgery, and 27 had unilateral surgery. Of those diplegic participants who underwent bilateral lengthening of the triceps surae, all but one had the same procedure (TAL or GR) performed bilaterally, while one child had a TAL on one side and a GR on the other. For those who underwent the same lengthening procedure bilaterally, one limb was randomly selected for statistical analysis. For those undergoing a unilateral triceps surae lengthening, the side undergoing the triceps lengthening was evaluated. Both limbs were evaluated in the child who underwent a TAL on one side and a GR on the other side. This left 55 limbs for evaluation in the 54 patients.

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Table 1 Patient demographics

	TAL ($n=17$)	GR ($n=38$)
Age at surgery (years)	11.1 ± 5.5	9.6 ± 4.1
Sex	9 males, 8 females	19 males, 19 females
Motor distribution	4 diplegia, 11 hemiplegia, 2 quadriplegia	22 diplegia, 12 hemiplegia, 4 quadriplegia
Number of simultaneous surgeries	5 ± 4	5 ± 3
Time to follow-up (months)	17 ± 8	19 ± 10

GR, gastrocnemius recession; TAL, tendo-achilles lengthening.

Of the 55 limbs evaluated, 17 had undergone TAL and 38 had undergone GR. The groups did not differ significantly with respect to age, sex, number of simultaneous surgeries, or time between surgery and follow-up (Table 1). The TAL group had more hemiplegic (61%) than diplegic (22%) patients, while the GR group had more diplegic (59%) than hemiplegic (32%) participants. Five patients (28%) in the TAL group and nine (24%) in the GR group used assistive devices (crutches or walkers) preoperatively and postoperatively. All other patients were independently ambulatory.

The surgeries were performed by seven different surgeons who are experienced with both GR and TAL. All surgeons used the data from the computerized motion analysis and static examinations as the basis for surgical decision-making. The gait data were used to determine whether or not lengthening of the triceps surae was necessary, but not to decide which type of triceps lengthening was indicated. Static examination was generally used to determine whether GR or TAL was indicated. Patients who had dorsiflexion to at least 0° with the knee flexed generally underwent GR, while those whose ankles could not be dorsiflexed to neutral with the knee flexed had TAL.

Most patients had additional soft tissue and bony procedures with an average of five additional procedures per patient at the time of the index surgery (Table 2). Only one patient (in the TAL group) had no other surgery. In the TAL group, one participant had previous bilateral TALs and another had previous bilateral GRs. In the GR group, four patients had previous bilateral TALs, one had a right TAL done twice previously, and one had previous bilateral GRs.

Procedures

An experienced gait lab physical therapist assessed range of motion, strength, selective control, and spasticity at each testing session for all patients. Joint range of motion was measured using standard goniometry. Muscle strength was assessed using the traditional 0–5 grade scale, allowing patterned motion if necessary to assess full muscle strength capacity. Muscle selectivity was rated

Table 2 Number and type of additional surgeries performed for each group

	TAL ($n=17$)	GR ($n=38$)
Psoas recession	9	24
Adductor lengthening	8	10
Hamstring lengthening	11	32
Gracilis tenotomy	3	0
Distal rectus femoris transfer	13	31
Soleus recession	0	1
Split anterior tibialis tendon transfer	1	2
Split posterior tibialis tendon transfer	2	2
Posterior tibialis tendon lengthening	4	0
Posterior tibialis tendon transfer to dorsum	1	2
Flexor digitorum longus lengthening	2	1
Femoral derotation osteotomy	5	11
Tibial derotation osteotomy	2	5
Plantar fasciotomy	3	1
Medial calcaneal slide	2	0
Calcaneal osteotomy	3	1
Cuboid osteotomy	0	1
Lateral column lengthening	0	4
Lateral column shortening	0	1
Tibial valgus osteotomy	2	0

GR, gastrocnemius recession; TAL, tendo-achilles lengthening.

none (0) if the subject could not perform the motion without using a flexor or extensor pattern, partial (1) if able to move through a partial range before recruiting patterned movement, or full (2) if able to complete the motion without using a flexor or extensor pattern. Muscle spasticity was rated from 0 to 4 using the modified Ashworth Scale [6]. A score of 5 was added to the scale for subjects whose fixed contractures were so severe that spasticity could not be elicited.

All subjects but five underwent computerized gait analysis both before and after operation. Five patients were unable to walk sufficiently to participate in computerized gait analysis before surgery, but were able to complete testing postoperatively. These patients were excluded from the analysis of kinematic and kinetic variables, but their clinical examination data were included in the analysis of static measures. Follow-up assessments took place an average of 18 ± 8 months postoperatively.

The gait analysis utilized a seven camera three-dimensional motion analysis system (Vicon Motion Systems, Oxford, UK). This system uses a set of 15 to 19 passive retro-reflective markers attached over specific bony landmarks of the pelvis and lower extremities. Subjects made several passes down a 15 m path with the markers in place. Kinetic data were obtained simultaneously with four floor-mounted strain gauge force-plates (AMTI, Watertown, Massachusetts, USA). Each patient walked barefoot at a self-selected speed and used assistive devices as necessary. Force plate data were not collected for children who used walking aids. For participants who walked independently, data collection continued until they had achieved three 'clean' force-plate strikes per side. Kinematic and kinetic data from at least three trials were averaged, and the averaged data were used for statistical analysis.

The static parameters analyzed were dorsiflexion range of motion with knee flexed and extended, calf spasticity with knee flexed and extended, dorsiflexor strength and selectivity, and plantarflexor strength and selectivity. The dynamic parameters considered were maximum and minimum dorsiflexion angles during single limb stance and midswing, mean angular velocity during single limb stance and midswing, and push-off power.

As a measure of outcome, maximum ankle dorsiflexion (DF) achieved during the single limb stance and midswing phases of gait were scored according to the type and amount of change preoperatively to postoperatively. Normal limits were defined as within 5° of the average value from able-bodied subjects in our laboratory's database (23 children with mean age 9.9 ± 2.2 years, range 7.3–14.3). Changes were considered to be clinically significant if they were at least 5°. The outcomes were scored as follows: 1 for those within normal limits postoperatively (postoperative DF within ± 5° of average from normal subjects); 2 for those undercorrected ($\geq$ 5° change and postoperative DF at least 5° below average from normal subjects); 3 for no improvement (< 5° difference between preoperative and postoperative values); 4 for worse equinus (DF decreased by $\geq$ 5°); and 5 for those overcorrected ($\geq$ 5° change and postoperative DF at least 5° above average from normal subjects).

Before and after operation foot–floor contact patterns were also rated using the Physician's Rating Scale (PRS) [7,8]. Because this was a retrospective study, the PRS was assessed using biplanar video recordings obtained at the time of both preoperative and postoperative gait analysis. Two independent observers (R.K. and S.R.) reviewed videotapes of each subject taken during gait analysis testing. In addition, in order to maximize accuracy, the videotape was slowed down as necessary to facilitate scoring. Foot–floor contact patterns were rated as 1 for toe–toe, 2 for toe–heel, 3 for flat foot, 4 for occasional heel–toe, and 5 for heel–toe contact.

Statistics

Group means and standard deviations were compared using unpaired *t*-tests to identify differences between the GR and TAL groups (pre and postoperatively). Same-subject preoperative and postoperative results were compared within each group using paired *t*-tests to determine the effects of each surgery. Same-subject preoperative to postoperative changes in static and dynamic measures were compared between groups using unpaired *t*-tests to identify differences in the surgery effects between the GR and TAL groups.

Outcome scores for the GR and TAL groups were compared using non-parametric Wilcoxon rank sum (Mann–Whitney) tests, and the frequency of under- and over-corrections was compared between unilaterally and bilaterally involved patients using logistic regression. The weighted κ statistic was used to assess agreement in PRS scores between the two observers, and Pearson's correlation coefficients were used to identify the static and dynamic variables most closely associated with the PRS scores. Linear regression was used to examine the effects of surgery type, patient demographics, and preoperative variables on the change in PRS score following surgery. Results were considered statistically significant for $P < 0.05$.

Results

Dorsiflexion range of motion improved following surgery for both the GR and TAL groups (Table 3). The patients treated with TAL had greater preoperative equinus than those treated with GR, but there was no difference in postoperative dorsiflexion range between the two groups. The change in maximum passive dorsiflexion was therefore greater with TAL than with GR (Table 4).

There was a significant decrease in calf spasticity following GR (Table 3). Calf spasticity did not change with TAL, and none of the other static measures changed with either GR or TAL. Compared with the TAL group, the GR group had greater plantarflexor spasticity with the knee flexed preoperatively and greater dorsiflexor strength postoperatively. The GR patients experienced greater reductions in calf spasticity with the knee flexed than the TAL patients (Table 4).

Preoperatively, members of both groups exhibited excessive plantarflexion during single limb stance and midswing (Table 5). Surgery reduced the excessive plantarflexion in both stance and swing. Postoperatively, patients were able to achieve dorsiflexion during stance and either dorsiflexion or a neutral position during swing. In addition, the abnormal plantarflexing angular velocity observed during stance preoperatively was corrected to a dorsiflexing angular velocity postoperatively. During swing, a dorsiflexing angular velocity was observed both preoperatively and postoperatively. This velocity was significantly reduced after surgery. Push-off power increased in both groups following surgery, but this improvement was statistically significant for the GR group only.

The only statistically significant differences in dynamic measures between the TAL and GR groups were greater preoperative peak dorsiflexion in single limb stance

Table 3 Group results for static measures

	GR			TAL			GR versus TAL *P*-value	
	Pre	Post	*P*-value Pre versus post	Pre	Post	*P*-value Pre versus post	Pre	Post
Maximum dorsiflexion (°)								
Knee flexed	7.1 ± 9.5	15.8 ± 8.6	< 0.0001	− 5.9 ± 14.0	17.6 ± 13.8	< 0.0001	0.0002	0.72
Knee extended	− 4.4 ± 9.0	8.8 ± 8.4	< 0.0001	− 15.3 ± 11.5	9.1 ± 11.3	< 0.0001	0.0005	0.94
Dorsiflexor strength	2.7 ± 0.5	2.8 ± 0.4	0.17	2.4 ± 0.8	2.4 ± 1.0	0.78	0.12	0.03
Dorsiflexor selectivity	0.7 ± 0.7	0.8 ± 0.7	0.63	0.3 ± 0.5	0.6 ± 0.8	0.17	0.052	0.47
Plantarflexor strength	1.6 ± 0.9	1.4 ± 0.8	0.23	1.4 ± 0.7	1.1 ± 0.3	0.36	0.48	0.17
Plantarflexor selectivity	0.9 ± 0.7	0.9 ± 0.7	Undefined*	0.6 ± 0.8	0.8 ± 0.8	0.34	0.31	0.61
Calf spasticity								
Knee flexed	2.9 ± 1.2	1.3 ± 1.3	< 0.0001	2.0 ± 0.9	1.9 ± 1.9	0.78	0.045	0.25
Knee extended	3.0 ± 1.1	2.3 ± 1.3	0.01	2.2 ± 1.1	1.9 ± 1.6	0.47	0.08	0.40

GR, gastrocnemius recession; TAL, tendo-achilles lengthening; pre, preoperatively; post, postoperatively. *P-value is undefined because mean difference is zero.

Table 4 Same-subject change in static measures

	GR	TAL	GR versus TAL *P*-value
Maximum dorsiflexion (°)			
Knee flexed	8.7 ± 8.6	23.6 ± 12.7	< 0.0001
Knee extended	13.8 ± 10.4	24.6 ± 11.3	0.001
Dorsiflexor strength	0.2 ± 0.7	0.1 ± 1.0	0.68
Dorsiflexor selectivity	0.1 ± 0.7	0.3 ± 0.8	0.33
Plantarflexor strength	− 0.2 ± 0.9	− 0.3 ± 0.8	0.87
Plantarflexor selectivity	0.0 ± 0.6	0.1 ± 0.3	0.64
Calf spasticity			
Knee flexed	− 1.6 ± 1.2	− 0.3 ± 2.3	0.04
Knee extended	− 0.6 ± 1.3	− 0.8 ± 2.2	0.92

GR, gastrocnemius recession; TAL, tendo-achilles lengthening.

achieved by the GR group and greater preoperative push off power for the GR group (Table 5). The TAL group experienced a greater change in peak dorsiflexion during single limb stance and midswing (Table 6). There was no statistically significant difference in any of the outcome scores between the GR and TAL groups (Table 7). There was also no significant difference in the frequency of overcorrection (outcome score 5) or undercorrection (outcome score 2) between unilaterally (hemiplegic) and bilaterally (diplegic and quadriplegic) involved patients in each of the groups.

There was good agreement in the PRS scores given by the two observers. Out of a total of 54 patients, 41 (76%) received the same preoperative score from both observers, and 33 (61%) received the same postoperative score. Weighted κ values of 0.82 preoperatively and 0.72 postoperatively indicated good interobserver agreement [9]. PRS results are therefore reported using the average of the scores given by the two observers (Table 5).

The PRS scores were best correlated with the dynamic dorsiflexion angles. Pearson's correlation coefficients above 0.4 were obtained both preoperatively and postoperatively for the maximum dorsiflexion angle in stance and the maximum and minimum dorsiflexion angles in midswing.

The PRS scores improved significantly after treatment with both GR and TAL. No significant difference was observed in PRS scores among the two groups, but the same-subject change in PRS score tended to be greater for the TAL group (Table 6). On average, the PRS scores for patients in the TAL group improved by 1.9 ± 0.8 while the scores for patients in the GR group improved by 1.4 ± 1.0. Multiple linear regression indicated that younger patients ($P = 0.004$) and patients treated with TAL ($P = 0.03$) achieved greater improvement in PRS score than older participants and those treated with GR.

Discussion

The current study demonstrates improvements in both static and dynamic measures following surgical lengthening of the triceps surae in ambulatory children with cerebral palsy. The improvements in each group are significant. The differences between the groups are often less striking but merit further discussion.

Table 5 Group results for dynamic measures

	GR			TAL			GR versus TAL *P*-value		Normal
	Pre	Post	*P*-value Pre versus post	Pre	Post	*P*-value Pre versus post	Pre	Post	
Dorsiflexion in single limb stance									
Maximum angle (°)	−0.6 ± 12.1	11.0 ± 9.2	< 0.0001	−11.7 ± 19.5	9.8 ± 11.6	0.0015	0.03	0.69	11.6
Minimum angle (°)	−10.8 ± 16.0	2.8 ± 7.0	< 0.0001	−16.3 ± 20.1	2.2 ± 6.3	0.008	0.32	0.82	0.8
Mean angular velocity (° per %GC)	−0.1 ± 0.3	0.1 ± 0.3	0.0002	−0.1 ± 0.2	0.3 ± 0.2	0.0002	0.94	0.07	0.3
Dorsiflexion in midswing									
Maximum angle (°)	−13.3 ± 12.8	−0.2 ± 9.4	< 0.0001	−21.3 ± 14.8	1.5 ± 9.5	< 0.0001	0.06	0.57	2.2
Minimum angle (°)	−20.0 ± 16.4	−4.5 ± 9.5	< 0.0001	−27.2 ± 16.0	−1.4 ± 9.1	< 0.0001	0.17	0.30	−7.2
Mean angular velocity (° per %GC)	0.4 ± 0.5	0.3 ± 0.2	0.02	0.4 ± 0.3	0.2 ± 0.3	0.01	0.50	0.27	0.7
Push-off power	1.1 ± 0.5	1.3 ± 0.5	0.047	0.4 ± 0.3	0.8 ± 0.6	0.09	0.003	0.22	2.8
PRS score	1.6 ± 0.9	3.0 ± 1.0	< 0.0001	1.2 ± 0.5	3.2 ± 0.9	< 0.0001	0.09	0.57	

GR, gastrocnemius recession; TAL, tendo-achilles lengthening; pre, preoperatively; post, postoperatively; %GC, percentage of gait cycle.

Table 6 Same-subject change in dynamic measures

	GR	TAL	GR versus TAL *P*-value
Dorsiflexion in single limb stance			
Maximum angle (°)	11.6 ± 13.4	21.5 ± 20.1	0.09
Minimum angle (°)	13.6 ± 14.7	19.3 ± 21.9	0.35
Mean angular velocity (° per %GC)	0.2 ± 0.4	0.4 ± 0.3	0.35
Dorsiflexion in midswing			
Maximum angle (°)	13.1 ± 12.8	22.8 ± 14.4	0.049
Minimum angle (°)	15.4 ± 16.4	25.7 ± 15.5	0.09
Mean angular velocity (° per %GC)	−0.2 ± 0.4	−0.2 ± 0.2	0.95
Push-off power	0.2 ± 0.4	0.5 ± 0.5	0.08
PRS score	1.4 ± 1.0	1.9 ± 0.8	0.52

GR, gastrocnemius recession; TAL, tendo-achilles lengthening; %GC, percentage of gait cycle.

Table 7 Surgical outcome reported as number of patients receiving each score

Score	Single limb stance		Midswing	
	GR (*n* = 36)	TAL (*n* = 14)	GR (*n* = 36)	TAL (*n* = 14)
1 (normal postoperative)	17	4	14	7
2 (undercorrected)	5	3	10	1
3 (no improvement)	4	1	4	3
4 (worse equinus)	2	1	1	0
5 (overcorrected)	8	5	7	3

GR, gastrocnemius recession; TAL, tendo-achilles lengthening.

The surgeons caring for the patients in this series are experienced with both TAL and GR procedures, and the decision-making between TAL and GR was generally based on the results of static examination (including the Silfverskiöld test) and computerized motion analysis. The surgeries selected using these criteria produced good results overall. The static and dynamic dorsiflexion measures for each group (GR and TAL) improved significantly postoperatively. Because the patients who underwent TAL had worse equinus preoperatively but comparable dorsiflexion postoperatively, the magnitude of improvement in the TAL group was greater than that in the GR group. These results suggest that GR and TAL are both good treatments in appropriately selected patients. The results of this study, however, do not allow a generalization to all ambulatory CP patients in whom such selection criteria are not utilized. Since both groups had good results, we could not identify specific preoperative predictors of outcome (such as age, type of CP, preoperative static or dynamic dorsiflexion, dorsiflexor strength) for the two surgeries. It is possible that this is due to small sample size in the current study or the relatively short time to follow-up evaluation (18 months).

There was a statistically significant difference between the two groups with regard to both the amount of calf spasticity with the knee flexed preoperatively and the improvement in calf spasticity with the knee flexed postoperatively. The GR group had calf spasticity with the knee flexed of 2.9 before the operation and 1.3

postoperatively (change 1.6) compared with a change from 2.0 before to 1.9 after operation in the TAL group (change 0.1). The reason for this difference is unknown. Previous authors have discussed changes in ankle reflexes and spasticity during static examination and gait in people with CP following surgical and non-surgical lengthening of the triceps surae [10,11]. The difference in calf spasticity between the TAL and GR groups in this study may also be clinically important because calf spasticity appears to be an etiologic factor in knee hyperextension in ambulatory children with CP [12].

Push-off power was lower in the TAL group than in the GR group both before and after operation. Push-off power improved in both groups postoperatively, though the improvement only reached statistical significance in the GR group. Improvement in push-off power following both TAL and GR has been reported previously [4,13].

The current study demonstrates that the PRS scores do provide useful clinical information. Weighted κ values for interobserver scores were 0.82 preoperatively and 0.72 postoperatively, thus demonstrating good reliability. It is important to remember, however, that the PRS was assigned in this study based on slow motion, biplanar video analysis and not based simply on real-time observation in a clinical setting.

The improvement in PRS scores in both groups postoperatively was statistically significant. Though there was no significant difference in the PRS scores between groups, the mean improvement in PRS scores postoperatively was 1.9 ± 0.8 in the TAL group and 1.4 ± 1.0 in the GR group. Multiple linear regression revealed statistically greater improvement in young patients and in those who had undergone TAL. The improved results in the younger patients differs from the results reported by Borton *et al.* [1] which showed less predictable long-term results following lengthening of the triceps surae in children less than 8 years old at the time of surgery.

Postoperatively, there was equinus in single-limb stance phase in seven out of 36 GR patients (19%) and in four of 14 TAL patients (29%). In contrast, equinus was present in midswing in 31% of children (11 of 36) in the GR group and 7% of children (one of 14) in the TAL group. These rates are close to the commonly reported frequency of equinus (5–23%) in children with cerebral palsy following lengthening of the triceps surae [1–3,14,15]. Three children were found to have worse equinus in stance postoperatively. While the reason for this outcome remains unknown, we suspect that calf and quadriceps weakness may contribute because two of the three children developed knee hyperextension postoperatively despite adequate passive dorsiflexion range of motion. We found no statistically significant difference between the TAL and GR groups for postoperative equinus, possibly due to sample size. In the current study, there were often considerable differences between static and dynamic measurements, which is consistent with previous studies [16].

Calcaneal gait or deformity has been reported in 0–36% of children with cerebral palsy following surgical lengthening of the triceps surae [1–3,5,13–15]. The rates of calcaneus or overlengthening in the current study are consistent with previous reports. Calcaneus gait (outcome score 5) was noted in 36% of TAL patients (five of 14) and 22% of GR patients (eight of 36) during single limb stance, an overall rate of 26% (13 of 50 limbs). Excessive dorsiflexion in swing phase was present in approximately 20% of each group (10 of 50 limbs total). There were no statistically significant differences between the two groups with regard to overlengthening, possibly due to sample size limitations, insufficient length of time from surgery to follow-up, or appropriate surgical decision-making. Unlike Borton *et al.* [1], we did not find a significant difference between hemiplegic and bilaterally-involved children. However, it is possible that the incidence of calcaneus gait will increase with time as the children become taller and heavier, especially if they are diplegic or quadriplegic.

The current study reports good short-term results following both TAL and GR in appropriately selected ambulatory children with cerebral palsy. We could not identify specific preoperative predictors of outcome and suggest that the physician decide between TAL and GR based on static and dynamic evaluation. Application of the PRS using slow motion biplanar video recording appears to be a useful adjunct in the assessment of these children.

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References

1 Borton DC, Walker K, Pirpiris M, Nattrass GR, Graham HK. Isolated calf lengthening in cerebral palsy. Outcome analysis of risk factors. *J Bone Joint Surg Br* 2001; **83B**:364–370.
2 Etnyre B, Chambers CS, Scarborough NH, Cain TE. Preoperative and postoperative assessment of surgical intervention for equinus gait in children with cerebral palsy. *J Pediatr Orthop* 1993; **13**:24–31.
3 Sharrard WJ, Bernstein S. Equinus deformity in cerebral palsy. A comparison between elongation of the tendo calcaneus and gastrocnemius recession. *J Bone Joint Surg Br* 1972; **54B**:272–276.
4 Yngve DA, Chambers C. Vulpius and Z-lengthening. *J Pediatr Orthop* 1996; **16**:759–764.
5 Segal LS, Thomas SE, Mazur JM, Mauterer M. Calcaneal gait in spastic diplegia after heel cord lengthening: a study with gait analysis. *J Pediatr Orthop* 1989; **9**:697–701.
6 Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther* 1987; **67**:206–207.

7 Corry IS, Cosgrove AP, Duffy CM, McNeill S, Taylor TC, Graham HK. Botulinum toxin A compared with stretching casts in the treatment of spastic equinus: a randomised prospective trial. *J Pediatr Orthop* 1998; **18**:304–311.
8 Koman LA, Mooney JF 3rd, Smith B, Goodman A, Mulvaney T. Management of cerebral palsy with botulinum-A toxin: preliminary investigation. *J Pediatr Orthop* 1993; **13**:489–495.
9 Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977; **33**:159–174.
10 Lin JP, Brown JK, Brotherstone R. Assessment of spasticity in hemiplegic cerebral palsy. II: Distal lower-limb reflex excitability and function. *Dev Med Child Neurol* 1994; **36**:290–303.
11 Perry J, Hoffer MM, Giovan P, Antonelli D, Greenberg R. Gait analysis of the triceps surae in cerebral palsy. A preoperative and postoperative clinical and electromyographic study. *J Bone Joint Surg Am* 1974; **56A**:511–520.
12 Kay RM, Rethlefsen SA, Skaggs D, Leet A. Outcome of medial versus combined medial and lateral hamstring lengthening surgery in cerebral palsy. *J Pediatr Orthop* 2002; **22**:169–172.
13 Rose SA, DeLuca PA, Davis RB 3rd, Ounpuu S, Gage JR. Kinematic and kinetic evaluation of the ankle after lengthening of the gastrocnemius fascia in children with cerebral palsy. *J Pediatr Orthop* 1993; **13**: 727–732.
14 Gaines RW, Ford TB. A systematic approach to the amount of Achilles tendon lengthening in cerebral palsy. *J Pediatr Orthop* 1984; **4**:448–451.
15 Moreau MJ, Lake DM. Outpatient percutaneous heel cord lengthening in children. *J Pediatr Orthop* 1987; **7**:253–255.
16 McMulkin ML, Gulliford JJ, Williamson RV, Ferguson RL. Correlation of static to dynamic measures of lower extremity range of motion in cerebral palsy and control populations. *J Pediatr Orthop* 2000; **20**:366–369.