Multilevel Surgery for Equinus Gait in Children with Spastic Diplegic Cerebral Palsy

Medium-Term Follow-up with Gait Analysis

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Background: In children with spastic diplegia, surgery for ankle equinus contracture is associated with a high prevalence of both overcorrection, which may result in a calcaneal deformity and crouch gait, and recurrent equinus contracture, which may require revision surgery. We sought to determine if conservative surgery for equinus gait, in the context of multilevel surgery, could result in the avoidance of overcorrection and crouch gait as well as an acceptable rate of recurrent equinus contracture at the time of medium-term follow-up.

Methods: This was a retrospective, consecutive cohort study of children with spastic diplegia who had had surgery for equinus gait between 1996 and 2006. All children had distal gastrocnemius recession or differential gastrocnemius-soleus complex lengthening, on one or both sides, as part of single-event multilevel surgery. The primary outcome measures were the Gait Variable Scores (GVS) and Gait Profile Score (GPS) at two time points after surgery.

Results: Forty children with spastic diplegia, Gross Motor Function Classification System (GMFCS) level II or III, were included in this study. There were twenty-five boys and fifteen girls. The mean age was ten years at the time of surgery and seventeen years at the time of final follow-up. The mean postoperative follow-up period was 7.5 years. The mean ankle GVS improved from 18.5 before surgery to 8.7 at the time of short-term follow-up (p < 0.005) and 7.8 at the time of medium-term follow-up. The equinus gait was successfully corrected in the majority of children, with a low rate of overcorrection (2.5%) and a high rate of recurrent equinus (35%), as determined by sagittal ankle kinematics. Mild recurrent equinus was usually well tolerated and conferred some advantages, including contributing to strong coupling at the knee and independence from using an ankle-foot orthosis.

Conclusions: Surgical treatment for equinus gait in children with spastic diplegia was successful, at a mean of seven years, in the majority of cases when combined with multilevel surgery, orthoses, and rehabilitation. No patient developed crouch gait, and the rate of revision surgery for recurrent equinus was 12.5%.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

When children with spastic diplegia begin walking, they usually walk on tiptoe with an equinus gait. Older children and adolescents more often have flexed-knee patterns and crouch gait. Crouch gait may be part of the natural history of gait evolution in children with spastic diplegia but may be precipitated by isolated lengthening of the gastrocnemius-soleus complex, especially percutaneous lengthening of the Achilles tendon. The standard of care for the management of gait dysfunction in children with spastic diplegia is single-event multilevel surgery in which all contractures and osseous deformities are dealt with during a single operative session, commonly on the basis of three-dimensional

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gait analysis. In this context, the correction of equinus deformity is important to the overall outcome because of its contribution to sagittal plane balance.

Many procedures for the correction of equinus deformity in children with spastic cerebral palsy have been reported. The outcomes of ten different procedures were summarized and grouped by anatomic zone in a recent systematic review. Zone 1 extends from the origin of the gastrocnemius to the most distal fibers of the medial gastrocnemius muscle belly. Zone-1 procedures include proximal gastrocnemius recession as described by Silfverskiöld, intramuscular lengthening of the gastrocnemius and soleus as described by Baumann and Koch, and distal gastrocnemius recession as described by Strayer. Zone 2 extends from the termination of the medial gastrocnemius muscle belly to the most distal extent of the soleus fibers. Zone-2 procedures include recession of the gastrocnemius-soleus complex as described by Vulpius and Stoffel and by Baker. Zone 3 is the Achilles tendon, and procedures within this zone include Achilles tendon lengthening and translocation.

The gastrocnemius muscle spans two joints and has been implicated as a more important contributor to equinus gait in spastic diplegia than the soleus, which spans just one joint. Given the importance of the soleus muscle in maintaining plantar flexion-knee extension coupling with gait, intramuscular gastrocnemius lengthening or gastrocnemius recession might be preferable to more commonly used procedures in which both the gastrocnemius and the soleus are lengthened. Some studies suggest that calcaneal gait leading to crouch gait in spastic diplegia is more common after Achilles tendon lengthening than after gastrocnemius recession. Some studies suggest that calcaneal tendon leading to crouch gait in spastic diplegia is more common after Achilles tendon lengthening than after gastrocnemius recession. However, some short-term studies demonstrated no difference based on the surgical procedure or the zone of the procedure. Biomechanical studies of human cadavers have provided evidence to suggest that procedures performed proximally in a muscle-tendon unit, where the cross-sectional area is greater, may provide more biomechanically stable results than distal procedures. Given that both calcaneal/crouch gait and recurrent equinus may not be apparent for many years after surgery, studies with long-term follow-up and objective outcome measures may be superior to randomized trials to investigate these important outcomes. The purpose of this study was to report the medium-term outcomes of conservative (mainly Zone-1) surgery for the management of equinus gait in the context of single-event multilevel surgery in children with spastic diplegia. Specifically, we wanted to determine if conservative surgery resulted in the avoidance of crouch gait at the expense of recurrent equinus and the need for revision surgery.

**Materials and Methods**

This was a retrospective, consecutive cohort study of data that were prospectively gathered according to standardized gait laboratory protocols, which have good reliability. The study was approved under the audit provisions of our institution's Ethics in Human Research Committee. Parents provided written informed consent for the children to undergo the surgery.

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**Surgery for Equinus**

The indications for surgery included tripping, falling, forefoot pain, and poor balance combined with functional impairment. Objective criteria included an equinus position in late stance more than two standard deviations below the laboratory mean and the presence of a fixed equinus contracture at the ankle, with dorsiflexion to less than neutral, on examination with the patient under anesthesia immediately prior to surgery. The principle governing the surgery was to use the most conservative gastrocnemius lengthening procedure possible to achieve 5° of dorsiflexion with the knee extended. Three different "surgical doses" for equinus were utilized according to the severity of the equinus contracture as described in the following sections.

**Distal Gastrocnemius Recession: Strayer Procedure**

The distal limit of the gastrocnemius was identified by inspection and palpation. The junction of the gastrocnemius aponeurosis with the soleus fascia was explored from a 2 to 3-cm vertically oriented posteromedial skin incision. The interval between the gastrocnemius and soleus fascia was identified and was opened by blunt dissection on the medial side. The sural nerve was protected. The gastrocnemius aponeurosis was divided transversely from medial to lateral and

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**A. Strayer**

Gastrocnemius recession with the Strayer procedure (Fig. 1-A) and the modified Strayer procedure, which combines distal gastrocnemius resection with soleal fascial lengthening (S.F.L.) (Fig. 1-B). Both are Zone-1 procedures. Recurrent equinus was managed with lengthening of the gastrocnemius-soleus complex fascia, according to the method described by Vulpius and Stoffel (Zone-2 procedure) (Fig. 1-C).
allowed to retract proximally. The Silfverskiöld test was performed and if 5° of ankle dorsiflexion with the knee extended was achieved no additional surgery was performed. The gastrocnemius aponeurosis was sutured distally to the soleus fascia at the level at which it rested when the knee was in full extension and the foot was at 90° to the leg.

**Distal Gastrocnemius Recession Plus Soleal Fascial Lengthening: Modified Strayer Procedure (Fig. 1)**: When the Silfverskiöld test revealed residual soleus contracture after the Strayer procedure, a single transverse stripe/division of the soleus fascia was performed. The Silfverskiöld test was repeated to confirm 5° of dorsiflexion with the knee extended. The combination of distal gastrocnemius recession and soleal fascial lengthening is called a modified Strayer procedure.

White Slide Lengthening of the Achilles Tendon: Lengthening of the Achilles tendon was used only when there was a contracture of both the gastrocnemius and the soleus of >30° and no improvement with knee flexion.

In children with symmetric equinus deformities, both sides were treated with either a Strayer procedure or a modified Strayer procedure. Asymmetric equinus contractures were managed with various combinations, including the Strayer procedure on one side plus Botox injection on the contralateral side, the Strayer procedure plus the modified Strayer procedure, or slide lengthening of the Achilles tendon by double hemisection (White slide procedure) accompanied by a contralateral Strayer or modified Strayer procedure. The final choice was always based on an intraoperative Silfverskiöld test.

Recurrent equinus was corrected with a Vulpian gastrocnemius–soleus complex recession with use of a single transverse division of both the gastrocnemius aponeurosis and the soleus fascia, in Zone 2 (Fig. 1). Indications for revision surgery were identical to those for the index surgery.

Postoperative management was uniform for all of the equinus surgical procedures. A below-the-knee plaster cast was applied with the foot in a neutral position of dorsiflexion. Concomitant hamstring surgery was protected by knee immobilizers. The children were discharged from the hospital four to seven days after surgery, at which time they used knee immobilizers with elevating footrests on their wheelchair. Unrestricted weight-bearing beginning the first postoperative day was prescribed for children who had had soft-tissue surgery only. Children treated with osteotomies were encouraged to begin full weight-bearing at one to three weeks after surgery, according to the surgeon’s assessment of the stability of fixation and osteotomy site healing.

Casts were removed after three weeks to check healing and to cast molds for ankle-foot orthoses. The standard postoperative ankle-foot orthosis was solid with hinges inserted but not activated. Fiberglass casts were applied and worn for an additional three weeks. These were removed at six weeks after surgery and replaced by ankle-foot orthoses. Gait and function were checked in the gait laboratory with use of a standardized protocol for two-dimensional video-based gait analysis at three, six, and nine months after surgery. The decision to activate the ankle-foot-orthosis hinges was contingent on stable plantar flexion–knee extension coupling, full knee extension in stance phase, and a clinical assessment showing sufficient gastrocnemius-soleus complex length and strength. Repeat three-dimensional gait analysis was performed at twelve to eighteen months after surgery (prior to removal of implants) and again at four to fourteen years after surgery (Time 3).

GMFCS level, Functional Mobility Scale (FMS) score, height, weight, and body mass index (BMI) were all available at Time 1 (in the six months before surgery), Time 2, and Time 3 (Table I). Physical examination was performed by an experienced physical therapist using standardized protocols, which have good reliability. Quantitative three-dimensional gait-analysis data were collected with a state-of-the-art Vicon system (Oxford Metrics Group, Oxford, United Kingdom) and two AMTI force plates (Watertown, Massachusetts). Reflective markers were applied to the osseous landmarks with use of a standardized procedure. Kinematic data were calculated with use of Plug In Gait (Oxford Metrics Group) and uploaded to GaitBase, a web-interfaced repository for gait data.

The Gait Profile Score (GPS) as well as the Gait Variable Scores (GVS) for nine kinematic parameters (pelvic tilt, pelvic obliquity, pelvic rotation, hip flexion, hip abduction, hip rotation, knee flexion, ankle dorsiflexion, and foot progression) were calculated for each child. The nine GVS values and the GPS value formed the Movement Analysis Profile (MAP), which is a graphical representation of these data (Fig. 2). The GVS was also calculated for two kinetic parameters: sagittal ankle moment and ankle power. Each GVS is a measure of the distance of the patient’s curve from the corresponding

### Table I: Study Population Characteristics at Time 1, Time 2, and Time 3

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>9.3 (4.8-15.1)</td>
<td>11.1 (7.6-17.7)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>129.4 (101.4-160.8)</td>
<td>138.2 (119.8-169.6)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>29.9 (16.5-40.0)</td>
<td>37.3 (24.0-60.3)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>17.6 (13.7-24.3)</td>
<td>19.3 (13.9-26.8)</td>
</tr>
<tr>
<td>GMFCS level (no.)</td>
<td>I = 0, II = 27, III = 13</td>
<td>I = 0, II = 30, III = 10</td>
</tr>
<tr>
<td>Ankle-foot orthoses (no. [%])</td>
<td>23 (58%)</td>
<td>39 (98%)</td>
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*There were forty patients (twenty-five boys and fifteen girls). The mean interval between Time 1 and Time 3 was 7.5 years (range, 4.4 to 14.6 years). The values are given as the mean with the range in parentheses.
normative curve. The GPS is a composite measure of gait quality or summary statistic of GVS. The GPS and kinematic GVS units are degrees, and the larger the value the more abnormal is the subject’s gait.

The MAP provides a graphical display of the subject’s specific gait deviations giving rise to the overall GPS. The GVS and GPS were calculated for both lower limbs during four individual gait cycles. The median GPS was calculated for each child by an independent assessor using GaitBase. The minimum clinically important difference for the GPS has recently been reported to be 1.6°.

Kinematic and kinetic data were captured during barefoot walking, without external support whenever possible. The need for assistive devices was recorded for every subject at each assessment. All forty patients had kinematic data at Time 1 and Time 3, and thirty-nine patients had kinematic data at Time 2. Twenty-seven patients had kinetic data at Time 1 and Time 3, and twenty-five patients had kinetic data at Time 2.

Recurrent equinus was defined as maximum dorsiflexion more than two standard deviations below the normal range in late stance on gait analysis. Overlengthening was defined as maximum dorsiflexion more than two standard deviations above the normal range in late stance on gait analysis. The need for revision surgery for recurrent equinus deformity was also recorded.

Ankle First Rocker
A qualitative assessment of initial contact was made from ankle kinematic traces at each of the three assessments. If initial contact was made by the heel and the first ankle movement was into plantar flexion, first ankle rocker was deemed to be present (see Appendix).

Statistical Methods
Paired t-tests were used to assess change in GPS over time (Time 1 versus Time 2, Time 1 versus Time 3, and Time 2 versus Time 3). The GVS were assessed separately for the right and left lower limb for each child, so each child contributed two measurements to each GVS at each time point. Since these two measurements could not be assumed to be independent of each other, linear regression estimation with robust standard errors to allow for clustering of measurements within patients was used to assess the change in GVS over time.

Source of Funding
Funding in the form of salary support for two of the authors was provided by a philanthropic organization (The Hugh Williamson Foundation), which had no direct role in the conduct of the research.

Results
Forty children, twenty-five boys and fifteen girls with a mean age at surgery of ten years (range, 5.5 to 16.7 years), were included in the study. No patient had had a prior selective dorsal rhizotomy or gastrocnemius-soleus complex lengthening, but twenty-two patients had had one or more injections of Botox at a minimum of twelve months prior to the multilevel surgery. The mean duration of follow-up between Time 1 and Time 3 was 7.5 years (range, 4.4 to 14.6 years). Changes in height, weight, BMI, GMFCS level, and use of ankle-foot orthoses are summarized in Table I. The ankle physical examination measures (Silfverskiöld test) are summarized in Table II.

The single-event multilevel surgery included 271 soft-tissue procedures and ninety-four osseous procedures, for a mean of 9.1 procedures (range, five to eighteen) per child. The sites of muscle-tendon lengthening included the psosas at the brim of the pelvis in twenty-three cases, hip adductors in thirty-four, medial hamstrings in sixty-six, tibialis posterior in six, peroneus brevis in three, and gastrocnemius-soleus complex in seventy-four (fifty-six Strayer procedures, fifteen modified Strayer procedures, and three White slide procedures). Botox injections were performed in the gastrocnemius-soleus complex unilaterally in six cases. Thirty-four patients had a bilateral calf-lengthening procedure, and six patients had a calf-lengthening procedure with a Botox injection on the contralateral side. Tendon transfers included semitendinosus to the adductor tubercle (seven), split tibialis anterior (three), and rectus femoris (forty-two). The osseous surgical procedures included femoral derotation osteotomy (seventy-four), tibial derotation osteotomy (four), calcaneus lengthening (eleven), and subtalar fusion (five).

The changes in gait parameters among Time 1, Time 2, and Time 3 are summarized in Figure 2 and the Appendix. Ankle kinematics, moments, and powers all demonstrated clinically relevant and statistically significant improvements at Time 2 compared with Time 1 and at Time 3 compared with Time 1. The mean ankle dorsiflexion kinematic in late stance was 4.9° at Time 1. This increased to 10.7° at Time 2 and stabilized at 8.6° at Time 3. The GPS also demonstrated clinically relevant and statistically significant improvement at both Time 2 and Time 3 compared with Time 1. The mean decrease in GPS was 5.9° between Time 1 and Time 2 and 6.6° between Time 1 and Time 3.

Maximum Ankle Dorsiflexion in Late Stance (Fig. 3)
Figure 3 summarizes the data for maximum ankle dorsiflexion at Time 1, Time 2, and Time 3 with the use of a box-and-whisker plot showing the median and interquartile ranges. At Time 3, the rate of overcorrection was 2.5% and the rate of recurrent equinus was 35%, according to sagittal ankle kinematic criteria described above. Revision calf surgery was performed in five patients (13%), bilaterally in two and unilaterally in...
TABLE II Physical Examination Results of Silfverskiöld Test at Time 1, Time 2, and Time 3

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<th></th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
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<tbody>
<tr>
<td>Dorsiflexion of right ankle (deg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With knee extended</td>
<td>−7 (−40 to +12)</td>
<td>2 (−15 to +20)</td>
<td>3 (−12 to +28)</td>
</tr>
<tr>
<td>With knee flexed</td>
<td>6 (−22 to +35)</td>
<td>17 (−5 to +45)</td>
<td>17 (−4 to +45)</td>
</tr>
<tr>
<td>Dorsiflexion of left ankle (deg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With knee extended</td>
<td>−6 (−32 to +15)</td>
<td>3 (−20 to +20)</td>
<td>2 (−12 to +26)</td>
</tr>
<tr>
<td>With knee flexed</td>
<td>7 (−12 to +35)</td>
<td>18 (−5 to +45)</td>
<td>16 (−6 to +40)</td>
</tr>
</tbody>
</table>

Discussion

In patients with cerebral palsy, “a little equinus is better than calcaneus” because overcorrection may set in motion a cascade of events that result in a severe crouch gait and loss of walking ability. If it is not feasible to achieve and maintain perfect length and strength of the gastrocnemius-soleus complex in every case, it is better to err on the side of undercorrection. The correct surgical “dose” for equinus deformity must not only achieve adequate length of the gastrocnemius-soleus complex for dorsiflexion in stance phase, but also preserve adequate strength and moment generation to control advancement of the tibia over the foot during the stance phase of gait (second rocker). The ankle moment must be adequate not only in the short term but also in the long term, when the child with spastic diplegia becomes mature. In this study, the mean height increased from 129 to 162 cm, the mean weight increased from 30 to 59 kg, and the mean BMI increased from 17.6 to 22.7 kg/m² between Time 1 and Time 3 (Table I). By Time 3, the majority of adolescents had reached skeletal maturity.

The results of equinus contracture surgery may deteriorate with time, and long-term follow-up with objective measures offers the best opportunity to report meaningful outcomes. To the best of our knowledge, the present study has the second longest follow-up among studies in which gait analysis has been utilized. It is relatively easy to determine the rate of recurrent equinus requiring revision surgery from a chart review. However, only three-dimensional gait analysis permits precise documentation of more minor degrees of both overcorrection and undercorrection and recurrent equinus deformity.

In this study, we report the outcomes of a conservative approach to equinus contracture surgery in the context of single-event multilevel surgery, with the aim being to preserve strong coupling between the ankle and knee and to prevent the cascade of events that can lead to progressive crouch gait. The potential danger of this approach is undercorrection, recurrent deformity, and the need for repeat surgery. This study demonstrated satisfactory correction at the ankle level in most children as well as a clinically relevant and statistically significant correction of the overall gait pattern. The improvement in GPS was clinically relevant and statistically significant, equating to a 38% improvement in gait function between Time 1 and Time 3—more than four times the minimum clinically important difference. The ankle also showed major improvements in terms of both the kinematic GVS and the kinetic GVS (ankle moments and powers; see Appendix).

A previous study of gastrocnemius-soleus complex lengthening for equinus contracture, in which the investigators used the same criteria as we used in this study, showed that 40% of children with spastic diplegia developed calcaneal deformity, crouch gait, and increased dependence on aids and ankle-foot orthoses after a mean duration of follow-up of seven years. The rate of recurrent equinus was 16%. In comparison, the current series showed a major decrease in calcaneal gait, to 2.5%, but an increase in the prevalence of equinus, to 35%. Dietz and colleagues reported the outcomes of Zone-3 surgery, as part of multilevel surgery, for equinus deformity in children with spastic diplegia and quadriplegia. Forty-one percent of patients...
with spastic diplegia and 50% of patients with quadriplegia developed crouch gait and required bracing. Dietz et al. also noted that ground-reaction ankle-foot orthoses were difficult to don and doff, were poorly tolerated, and were relatively ineffective.

In contrast, Dreher and colleagues recently reported excellent long-term results after gastrocnemius-soleus intramuscular aponeurotic recession as part of multilevel surgery in patients with spastic diplegic cerebral palsy. The patients in their study had less severe cerebral palsy than the patients in our study, according to the GMFCS levels, and the equinus contracture was less severe. The mean ages of the patients (9.8 years versus ten years), the concomitant procedures in the multilevel surgery (both osseous and soft-tissue), and the changes in the height, weight, and BMI of the patients during the follow-up period were similar. Dreher et al. used the same kinematic criteria for overcorrection and undercorrection as were utilized in our study, permitting a direct comparison between the studies. In their study, fixed equinus was corrected by intramuscular aponeurotic recession of the gastrocnemius or intramuscular aponeurotic recession of the gastrocnemius and soleus, with three legs (in the group of forty-four patients) not requiring a lengthening procedure. The Baumann procedure consists of intramuscular aponeurotic lengthening of the gastrocnemius (and soleus when indicated) and is performed in Zone 1. In the current study, distal gastrocnemius recession (the Strayer procedure) or distal gastrocnemius recession with soleal fascial lengthening (the modified Strayer procedure) were the principal procedures utilized, and they are Zone-1 surgical procedures that yield stable results. An important difference between the two studies was the intraoperative goal. Dreher et al. aimed for 15° to 20° of dorsiflexion with knee extension and knee flexion whereas our goal was 5° of dorsiflexion with the knee extended. Overcorrection with calcaneal gait and severe crouch gait was more common in their study. It would seem that both Zone-1 procedures are associated with a significant rate of recurrent equinus, as determined by kinematics, and a relatively low rate of overcorrection. However, aiming for 15° to 20° of dorsiflexion intraoperatively may be overly aggressive, and our data suggest that a more conservative goal of 5° may be better.

The categorical classification of dynamic gastrocnemius-soleus complex length is a useful method for summarizing outcomes and comparing results between series. However, dichotomous outcomes that are quantitatively similar are not of equal clinical relevance. A gastrocnemius-soleus complex length that is two standard deviations above the mean may, in the long term, result in severe crouch gait with severe disability. There are currently no reliable methods with which to shorten an overlengthened gastrocnemius-soleus complex. Surgery for severe crouch gait is invasive and requires prolonged rehabilitation. In contrast, recurrent equinus can be easily managed with revision surgery. Most cases of equinus gait at Time 3 in our study were the result of recurrent equinus deformity and not undercorrection at the index surgery.

We believe that we are the first to report on the presence of first rocker at the time of medium-term follow-up after surgery for equinus gait. First rocker is a hallmark of normal gait and is rarely present in children with cerebral palsy. The presence of first rocker is associated with a gait pattern that appears more “normal.” Conversely, the absence of first rocker, even when equinus has been corrected, is associated with an abnormal appearance of gait, or “limping.” In this study, no patient had first rocker before surgery and 25% had first rocker at Time 3. Equinus deformity precludes first rocker in children with cerebral palsy. Effective surgery for equinus gait may restore first rocker but only when the correction is precise and underlying strength and selective motor control are adequate (see Appendix).

Five children had surgery for recurrent equinus contracture between Time 2 and Time 3. No overcorrection or recurrent equinus had been recorded in these children at Time 3, at a mean of 4.8 years (range, 1.1 to 10.0 years). Two children were offered additional surgery and declined. The equinus in the remaining nineteen adolescents was asymptomatic and well tolerated at the time of writing. The equinus could be considered to be an advantage for some in that it preserved extension at the knee and allowed them to walk without the need for ankle-foot orthoses (see Appendix). The results of the medium-term gait analysis (Time 3) were used to determine which children and adolescents could safely discontinue the use of ankle-foot orthoses; it was possible for 65% to do so.

The strengths of this study were a standardized approach to surgery, rehabilitation and orthotic prescription, and long-term follow-up with objective outcome measures. A rigorous kinematic definition of both overcorrection (calcaneus gait) and undercorrection/recurrence (recurrent equinus) was utilized, allowing for direct comparison with previous studies in which the same outcome criteria had been used. The weaknesses of the study were variability in the single-event multilevel surgery prescription and in the duration of follow-up. In addition, the variable surgical prescription, including both soft-tissue and osseous procedures at multiple levels, has both known and unknown impacts on the ankle level and dynamic ankle function. However, given the documented poor results of single-level surgery for equinus, it is likely that a multilevel surgical approach will remain the treatment paradigm for the foreseeable future. Clinical researchers and surgeons will continue to have to grapple with the complexity of the local and distant effects of multilevel surgical procedures when they evaluate outcomes. In addition, given that patients cannot ethically remain in randomized trials for long periods of time, prospective studies with long-term objective outcome measures are likely to offer the best opportunity for meaningful clinical research in this complex area.

Appendix

A table showing comparisons of GPS and GVS among the evaluation times and figures demonstrating sagittal
kinematic traces of the knee and ankle of specific patients are available with the online version of this article as a data supplement at jbjs.org.

References