Functional Gains in Children With Spastic Hemiplegia Following a Tendon Achilles Lengthening Using Computerized Adaptive Testing—A Pilot Study

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Abstract

Purpose: This pilot study evaluated the outcomes of tendon Achilles lengthening in 12 children (mean age: 11.2 years) with spastic hemiplegia. **Methods:** Cerebral Palsy Computer Adaptive Tests, the timed up-and-go, the Gross Motor Function Measure, the Gillette Functional Assessment Questionnaire, and the Pediatric Outcomes Data Collection Instrument were administered at baseline and at 6, 12, and 24 months postsurgery. **Results:** Significant improvement at the latest follow-up (12-24 months following surgery) was seen in all domains of the Cerebral Palsy Computer Adaptive Test: activity ($P = .017$), lower extremity ($P = .005$), global ($P = .005$), pain ($P = .005$), and fatigue ($P = .028$), as well as in the Gross Motor Function Measure-standing domain ($P = .02$) and the mobility domain of the Pediatric Outcomes Data Collection Instrument ($P = .04$). **Conclusion:** These findings indicate that the tendon Achilles lengthening improved functional outcome in these children as measured by tests of physical function, walking speed, and activity performance.

Cerebral palsy affects 3.1 per 1000 live births in the United States,[1] 33% of whom have hemiplegia. Impairment in patients with cerebral palsy is variable with a wide range of physical impairments leading to activity limitations and participation restrictions.[2] Cerebral palsy encompasses several nonprogressive motor impairments that include physical signs such as spasticity, muscle hypertonia, hyperreflexia, and muscle weakness leading to a loss of selective motor control that can affect all activities of daily living.[3] Spastic hemiplegia affects only one side of the body.[3] It is the most common type of cerebral palsy in children born at term.[4]

The most common orthopedic problem affecting children with cerebral palsy is an equinus deformity.[5] A recent study on the prevalence of certain gait patterns in children with cerebral palsy indicates that 64% of children with spastic hemiplegia have an equinus deformity.[6] Equinus disrupts the gait cycle by decreasing stability in the stance phase and causing inadequate clearance during the swing phase.[7] It is a common clinical finding in children with cerebral palsy caused initially by spasticity eventually leading to contractures of the triceps surae.[8] An equinus deformity causes ambulatory individuals to toe strike first rather than heel strike in the gait cycle.[8] There

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are a variety of treatment procedures to improve dorsiflexion. They range from simple stretching to surgery. Stretching exercises, bracing, casting, and botulinum toxin injections are the nonsurgical options.[7] Operative treatment can include a gastrocnemius lengthening[7] or a tendon Achilles lengthening which is one of the most commonly used orthopedic procedure to improve gait patterns in children with spastic hemiplegia. A recent study found that among 127 children with cerebral palsy having undergone an orthopedic surgical intervention of the lower extremities, 48% had a tendon Achilles lengthening.[1] The goal of a tendon Achilles lengthening is to correct the equinus deformity and obtain a plantigrade foot. The tendon Achilles lengthening also attempts to correct the gait cycle by restoring the initial contact to be heel first rather than toe first. While the immediate effects of a tendon Achilles lengthening are focused on correcting the biomechanics of gait, the intent of surgery is to improve the physical function and global health of children with cerebral palsy.

One of the major challenges in evaluating the outcomes of interventions in children with cerebral palsy is the lack of relevant and responsive outcome instruments.[9] As a direct result, the Shriners Hospitals for Children and Boston University have developed and validated Cerebral Palsy Computer Adaptive Tests. The Cerebral Palsy Computer Adaptive Tests are patient-reported outcome instruments (parent-proxy) of physical functioning[10-12] and global physical health.[13] The Cerebral Palsy Computer Adaptive Tests were developed using item banking[14,15] and item response theory[16,17] methodology. Cerebral palsy Computer Adaptive Test administration uses a computer algorithm to select items based on responses to previously administered items. As such, item selection is dynamic and tailored specifically for each child. Parents never answer a question that is irrelevant to their child or ones that are too easy or too hard. With this approach, a relatively small number of carefully selected items generate a precise estimate of the individual's "ability level" on the underlying trait (eg, mobility).[18,19] There are four separate Cerebral Palsy Computer Adaptive Tests, one for upper extremity physical function,[11] one for lower extremity mobility,[10] one for activity performance,[20] and one for global physical health.[13] The psychometric properties of the Cerebral Palsy Computer Adaptive Tests have been previously reported.[17] Recent studies have shown that the lower extremity mobility Cerebral Palsy Computer Adaptive Test is better able to discriminate among severity levels of cerebral palsy when compared to a generic computer adaptive test.[21]

Many studies have focused on the orthopedic and surgical outcomes in children with cerebral palsy who have undergone a tendon Achilles lengthening.[7,8,22] However, there is a lack of evidence as to the functional outcomes of this procedure in children with spastic hemiplegia. The Shriners Hospitals for Children has also, with the development of the Cerebral Palsy Computer Adaptive Tests, shifted its focus from technical outcome measures such as radiographs and gait analysis to more global functional domains.[23] Evaluating the child's improvement using the Cerebral Palsy Computer Adaptive Tests allows

us to determine whether a tendon Achilles lengthening does significantly improve the patients' everyday life.

The purpose of this pilot study is therefore to evaluate the functional outcome using the Cerebral Palsy Computer Adaptive Tests in conjunction with the legacy measures among children with spastic hemiplegia after having undergone a tendon Achilles lengthening. We hypothesize that the tendon Achilles lengthening does improve the child's function in everyday life.

Methods

Participants

This study was part of a larger multicenter study (M.J.M., principal investigator) on the responsiveness of Computer Adaptive Test platforms to detect functional change following orthopedic surgery in children with cerebral palsy. For this current study, children between the ages of 4 and 21 years, with a diagnosis of spastic hemiplegia who underwent a tendon Achilles lengthening between September 2009 and August 2012, were recruited. All patients were treated for lower extremity issues at a Shriners Hospital for Children in Canada (Montreal) or in the United States (Philadelphia, Northern California, Chicago, Portland).

Procedures

Eligible participants were invited to participate by a research coordinator at each recruiting site. Those who agreed to partake in the study had a baseline evaluation prior to the tendon Achilles lengthening, involving five outcome measures. Follow-up was completed at 6, 12, and 24 months postoperatively. This time interval for follow-up was selected because it coincided with the typical clinical pathway for follow-up after orthopedic surgery. A patient was indicated for surgical intervention when bracing had failed to correct the equinus deformity. By study design, there were no attempts to standardize the surgeon, surgical procedures, postoperative therapy, or postsurgical orthotic prescription. The tendon Achilles lengthening procedure was done at each site by an experienced pediatric orthopedic surgeon using the technique of his/her choice followed by below or above knee casting for 3 to 6 weeks. Full weight bearing was encouraged.[7]

Cerebral Palsy Severity Measure—Gross Motor Function Classification System

The Gross Motor Function Classification System rates ambulatory ability on a 5-level scale: level I is independent ambulation without limitations, level II is independent ambulation with some limitations on uneven surfaces, running or jumping, level III describes walking with ambulation aid (walker or cane), level IV is severe limitation in ambulation and includes the use of a manual or powered wheelchair, and level V describes impairments in all areas of motor function, and includes the use of wheeled or powered mobility. This tool was used to classify the severity of participants' lower extremity mobility impairment. Examiners were trained to use the Gross Motor Function Classification System–Expanded and Revised instruction manual[24] and assigned Gross Motor Function Classification System[25,26] levels at baseline.

Main Outcome Measure—Cerebral Palsy Computer Adaptive Tests

The Cerebral Palsy Computer Adaptive Tests are measures of physical functioning[10–12] and global physical health.[13] They include upper extremity physical function, lower extremity mobility, activity performance, and global physical health. The lower extremity mobility Cerebral Palsy Computer Adaptive Test provides parent-reported outcomes and contains items specific to gross mobility such as "When placed on belly, my child can lift head," "my child can walk across the floor," "my child can step up one step," "my child can stand on one foot," as examples. The activity Cerebral Palsy Computer Adaptive Test contains items that include both lower extremity mobility and upper extremity physical function skills, require multiple steps to complete, and provide an indication of a child's ability to engage in roles within the home and school environments. Examples of items in the activity Cerebral Palsy Computer Adaptive Test are "My child climbs and moves on high playground equipment" and "My child hops and skips while playing games with other children of similar age such as during hopscotch or a relay race." The activity items are rated by the parent or primary caregiver on a 5-point scale: "unable to do," "with much difficulty," "with some difficulty," "with little difficulty," and "without difficulty." The Global Physical Health scale includes a broad spectrum of items that capture pain during activity and rest, capture fatigue during various activities, and assess whether a child can sustain activity in expected home and school roles as evaluated by parents or caregivers. Example of items in the Global Physical Health Cerebral Palsy Computer Adaptive Test are: "How often does your child trip and fall because he/she is physically tired" and "How often does your child have physical pain when standing?"

The child's primary caregiver completed the Cerebral Palsy Computer Adaptive Test on a PC-tablet. For this study, a stop rule of 15 items was used; thus, each respondent answered 15 items from the Lower Extremity Mobility Cerebral Palsy Computer Adaptive Tests, 15 items from the Activity Cerebral Palsy Computer Adaptive Test, and 15 items from the Global Physical Health Cerebral Palsy Computer Adaptive Test. The computer adaptive tests were administered before surgery and at the point of care during routine follow-up appointments at 6, 12, and 24 months.

Performance-Based Measures

Physiotherapists with vast experience working with children with cerebral palsy administered two performance-based physical activity tests. The timed up-and-go[27] and the Gross Motor Function Measure.[28]

For the timed up-and-go, the examiner recorded the time it took for a child to rise from a chair, walk straight for 3 m at a normal pace, and return to a sitting position on the chair. Timed up-and-go scores were recorded as the average time (in seconds) across 3 trials. The timed up-and-go has demonstrated excellent reliability (ICC = 0.99), discriminant and convergent validity, and responsiveness to change in children with and without physical limitations.[29]

The Gross Motor Function Measure developed specifically for children with cerebral palsy is comprised of 5 domains (Gross Motor Function Measure-66); domains D (standing) and E (walking, running, and jumping) were administered in this study by trained clinical examiners who determined Gross Motor Function Measure scores through direct interactions with participants. The Gross Motor Function Measure—D and E domains have demonstrated excellent content, convergent, and predictive validity and interrater and test–retest reliability.[30–32] Items

are scored by percent completion using a 4-point scale: 0 = "does not initiate," 1 = "initiates," 2 = "partially initiates," and 3 = "completes." The total score for each domain is calculated into a percent range from 0 to 100, where a score of "100" reflects no impairment.

Parent-Reported Measures

The Gillette Functional Assessment Questionnaire was used to describe ambulation. The Gillette Functional Assessment Questionnaire, completed by the primary caregiver, uses a 10-point scale to describe the patients' range of walking abilities from nonambulatory to ambulatory, considering various community settings and terrains and the use of assistive devices. It has been shown to be a reliable and valid scale for walking and can detect functional change in children with chronic neuromuscular conditions.[33]

The Pediatric Outcomes Data Collection Instrument is a questionnaire used to measure functional outcomes in pediatric orthopedics. The Pediatric Outcomes Data Collection Instrument is a 114-item instrument with 5 subscales: upper extremity functioning, transfers and basic mobility, sports and physical function, comfort/pain, and global function and happiness with physical condition.[34] The Pediatric Outcomes Data Collection Instrument total score is calculated based on the scores of 4 subscales; the happiness subscale is not included in the total Pediatric Outcomes Data Collection Instrument score. The Pediatric Outcomes Data Collection Instrument questionnaire was completed by the primary caregiver and has proven to be a valid and reliable instrument in assessing function in pediatric orthopedic populations.[34] For this study, we report on Pediatric Outcomes Data Collection Instrument transfer/basic mobility, sports/physical function, pain/comfort, and global subscales as they are most aligned with the Cerebral Palsy Computer Adaptive Test scales.

Data Analysis

Descriptive statistics were used to describe the sample's demographic characteristics and performance on the various measures. Because of a small sample size and data that were not normally distributed, nonparametric tests were used (Wilcoxon signed rank test) to evaluate change from baseline to the latest follow-up postoperatively on all the outcome measures. Statistical significance was set at $P < .05$, and analyses were completed with SPSS statistical software version 22.0.

Results

The population studied included 21 patients with spastic hemiplegia who underwent a tendon Achilles lengthening. All patients underwent their surgeries between 2009 and 2012. However, 9 of the 21 patients were lost to follow-up and therefore were excluded from the analysis. A per-protocol analysis was applied. Of the 9 patients lost to follow-up, the age at surgery for only 5 patients was available (mean: 12.6 ± 4.4 years). Five of the patients lost to follow-up had assessments done at the 6-month time point, but were unreachable at 12 or 24 months, which were the minimum follow-up time points used for this study. The charts of the remaining 12 participants were reviewed retrospectively to identify the following: age at surgery, Gross Motor Function Classification System and Manual Ability Classification System levels, gender, race, ethnicity, and any concomitant procedures at the time of the

Table 1. Demographic Data (n = 12).

Age: mean (SD) years	11.2 (4.1)
Sex	
Male	6
Female	6
GMFCS level	
I	9
II	3
Side of TAL	
Right	10
Left	2
Type of TAL	
Open TAL	8
Percutaneous TAL	2
TAL + lateral column lengthening	1
Ankle modified open Achilles tendon release	1
Race	
Caucasian	10
Asian	2
Ethnicity	
Hispanic	1
Non-Hispanic	11
Responder level of education	
≤High school diploma	3
College/university diploma	9

Abbreviations: GMFCS, Gross Motor Function Classification System; TAL, tendon Achilles lengthening; SD, standard deviation.

tendon Achilles lengthening. The 12 patients (6 females, mean age: 11.2 years, range: 5-18 years) being reviewed were only treated on their lower extremities and underwent a single event surgery where only one joint was operated on. The majority of patients (n = 10) underwent a right tendon Achilles lengthening. Two of the 12 patients underwent a percutaneous tendon Achilles lengthening, while the 10 others were treated by an open tendon Achilles lengthening. See Table 1 for the participants' demographic data.

At baseline, the mean time for the timed up-and-go was 7.7 seconds (range: 6.1-12.2 seconds) as compared to the mean of 5.9 seconds for the timed up-and-go in children without physical disabilities.[29] Most were community ambulators at baseline, with 10 patients scoring a 9 or a 10 on the Gillette Functional Assessment Questionnaire. The mean at baseline for Gross Motor Function Measure-D was 41.4, and for Gross Motor Function Measure-E, it was 68.33. Out of the 4 Pediatric Outcomes Data Collection Instrument domains, parents rated their child's functioning highest in the mobility domain (mean: 91.5, range: 64-100) and lowest in the sports domain (mean: 69.1, range: 36-97). See Table 2 for performance on the various outcome measures at the different time points. Significant improvement was made in the Gross Motor Function Measure-D domain ($P = .02$) and the mobility domain of the Pediatric Outcomes Data Collection Instrument ($P = .04$) at the latest follow-up. No significant change was found for the timed up-and-go ($P = .919$), Gillette Functional Assessment Questionnaire ($P = .655$), Gross Motor Function Measure-E ($P = .888$) and Pediatric Outcomes Data Collection

Instrument sports ($P = .059$), pain ($P = .343$), and global domains ($P = .113$).

The baseline scores for the Cerebral Palsy Computer Adaptive Test activity, lower extremity mobility, global, pain, and tired domains ranged between 53.2 and 58.7. The scores at the latest follow-up ranged between 60.7 and 64.7. See Table 2 for scores on the Cerebral Palsy Computer Adaptive Test at the different time points. Significant improvement was seen in all domains of the Cerebral Palsy Computer Adaptive Test: activity ($P = .017$), lower extremity mobility ($P = 0.005$), global ($p = .005$), pain (0.005), and tired ($P = .028$). See Table 3 for change of scores on the cerebral palsy computer adaptive test from baseline to the latest follow-up.

Discussion

The objective of this study was to evaluate the functional changes following a tendon Achilles lengthening procedure in children with spastic hemiplegia using the Cerebral Palsy Computer Adaptive Test. Performance-based and parent-reported measures such as the timed up-and-go, Gillette Functional Assessment Questionnaire, Gross Motor Function Measure, and Pediatric Outcomes Data Collection Instrument were used alongside the main outcome measure for this study.

The main findings of this study indicate that the use of a tendon Achilles lengthening procedure in children with spastic hemiplegia improved the child's gross motor skills, ability to engage in roles within the home and school environments, had less pain during activity and rest, and less fatigue during various activities, as well as improved the child's ability to sustain an activity in the home and school settings as measured by the Cerebral Palsy Computer Adaptive Tests. Significant improvement was also seen in the Gross Motor Function Measure standing domain and as measured by the physiotherapist and as reported by parents on the Pediatric Outcomes Data Collection Instrument mobility domain. This may be attributed to obtaining a more plantigrade foot following the tendon Achilles lengthening, which provides improved balance during standing. No change in the raw score of the walking, running, and jumping domains of the Gross Motor Function Measure was noted. This result is not unexpected as higher level gross motor skills such as running and jumping are still affected by the coordination deficits underlying the neurological impairment. Although an improvement of 10 points on the Pediatric Outcomes Data Collection Instrument sports domain was seen at the latest follow-up, this change was not statistically significant, probably attributable to the small sample size, thus limiting statistical power. Children with hemiplegia are community ambulators and have the potential to participate in sports at a pick up or recreational level, yet their level of participation in physical activities has been shown to be lower than that of typically developing peers.[35] Several factors are associated with sports participation in children with cerebral palsy,[36] with more severe gross motor limitations related to less participation diversity and intensity in physical activities.[37,38] Therefore, finding a trend for improvement in the sports

Table 2. Performance on the Various Outcome Measures.

Measures	Time Points, Mean (SD)			
	Baseline	6 Months	12 Months	24 Months
TUG	7.75 (1.86); n = 11	8.07 (2.28); n = 7	8.10 (2.56); n = 11	6.40 (1.25); n = 6
FAQ	9.17 (0.94); n = 12	8.57 (1.51); n = 7	9.00 (1.32); n = 9	9.67 (0.52); n = 6
GMFM-D	41.4 (18.7); n = 12	36.7 (2.23); n = 7	37.2 (3.22); n = 11	48.7 (25.2); n = 6
GMFM-E	68.3 (11.4); n = 12	62.9 (11.8); n = 7	65.3 (10.8); n = 11	73.2 (13.8); n = 6
PODCI-mobility	91.5 (10.8); n = 12	85.4 (10.3); n = 7	94.3 (4.09); n = 9	97.6 (3.91); n = 5
PODCI-sports	69.2 (21.6); n = 12	63.0 (21.9); n = 7	73.7 (18.0); n = 9	85.4 (11.7); n = 5
PODCI-pain	88.3 (18.6); n = 12	88.1 (20.8); n = 7	93.7 (8.06); n = 9	93.4 (14.8); n = 5
PODCI-global	83.2 (14.3); n = 12	78.7 (12.2); n = 7	87.2 (7.61); n = 9	90.8 (7.12); n = 5
CAT-activity	58.4 (8.38); n = 12	59.3 (6.03); n = 9	59.3 (7.83); n = 10	61.8 (4.26); n = 5
CAT-LE	58.7 (5.20); n = 12	59.4 (5.95); n = 9	60.5 (5.80); n = 9	61.9 (2.49); n = 5
CAT-global	56.4 (8.86); n = 12	59.2 (8.47); n = 9	63.8 (8.30); n = 9	61.2 (7.29); n = 5
CAT-pain	53.2 (8.86); n = 12	57.3 (7.36); n = 9	59.1 (6.69); n = 9	60.2 (3.78); n = 5
CAT-tired	58.4 (8.77); n = 12	59.5 (9.64); n = 9	62.2 (8.77); n = 9	64.0 (5.50); n = 5

Abbreviations: CAT, Computer Adaptive Test; FAQ, Gillette Functional Assessment Questionnaire; GMFM, Gross Motor Function Measure; LE, lower extremity mobility; PODCI, Pediatric Outcomes Data Collection Instrument; TUG, timed-up-and-go; SD, standard deviation.

Table 3. Change on the Measures From Baseline to Latest Follow-Up.

Measures	Baseline, Mean (SD)	Follow-Up, Mean (SD)	P Value
TUG (n = 11)	7.75 (1.86)	7.84 (2.79)	.919
FAQ (n = 11)	9.18 (0.98)	9.09 (1.22)	.655
GMFM-D (n = 12)	41.42 (18.66)	42.50 (18.37)	.02[a]
GMFM-E (n = 12)	68.33 (11.43)	67.42 (14.58)	.888
PODCI-mobility (n = 10)	90.40 (11.47)	95.80 (4.05)	.042[a]
PODCI-sports (n = 10)	67.50 (22.19)	77.20 (17.40)	.059
PODCI-pain (n = 10)	85.90 (19.70)	92.60 (11.99)	.343
PODCI-global (n = 10)	81.50 (14.90)	88.30 (7.76)	.113
CAT-activity (n = 11)	57.86 (8.59)	60.91 (7.38)	.017[a]
CAT-LE (n = 10)	58.20 (5.39)	61.35 (5.53)	.005[a]
CAT-global (n = 10)	56.23 (7.98)	64.55 (7.67)	.005[a]
CAT-pain (n = 10)	53.76 (6.93)	60.74 (5.56)	.005[a]
CAT-tired (n = 10)	58.70 (8.49)	64.66 (7.38)	.028[a]

Abbreviations: CAT, Computer Adaptive Test; FAQ, Gillette Functional Assessment Questionnaire; GMFM, Gross Motor Function Measure; LE, lower extremity mobility; TUG, timed-up-and-go; PODCI, Pediatric Outcomes Data Collection Instrument; SD, standard deviation.
[a]Significant change.

domain following a tendon Achilles lengthening in this study is very encouraging. No change was measured on the timed up-and-go and the Gillette Functional Assessment Questionnaire following the tendon Achilles lengthening procedure, which may be explained as the mean scores on these two measures were quite high at baseline, and therefore, these two performance-based measures do not appear to be sensitive enough to capture change following a tendon Achilles lengthening procedure in children with spastic hemiplegia.

While many studies have examined the effects of a tendon Achilles lengthening and other orthopedic procedures in children with cerebral palsy,[1,5,7,22] not many have considered functional outcomes following a tendon Achilles lengthening. This study considered the relatively new Cerebral Palsy Computer

Adaptive Test as the main functional outcome measure. The performance-based and parent-reported measures in conjunction with the main outcome measure focus on function and evaluate skills related to the child's daily function. This is a unique approach as compared to past research in which technical outcomes were the primary focus. This study provides information on the value of these traditional measures. For example, the timed up-and-go and Gillette Functional Assessment Questionnaire appear to have a ceiling effect in this population, whereas the Pediatric Outcomes Data Collection Instrument with subscales exploring participation in sports appears to provide unique information. The fact that significant improvement was seen in all domains of the Cerebral Palsy Computer Adaptive Test demonstrates that the Cerebral Palsy Computer Adaptive Test is indicated in research on children with spastic hemiplegia and is useful in clinical settings to set goals in rehabilitation. The domains of pain and tired are particularly relevant for the children with hemiplegia who are community ambulators but report issues with endurance. This tool will allow clinicians, families, and researchers to understand how endurance and energy level impact the daily function of children with cerebral palsy.

The main limitation of this study was that it was not powered to evaluate outcomes of surgical procedures and there was loss to follow-up. Even though recruitment was done through multiple sites, loss to follow-up was inevitable despite efforts to reschedule participants. This may have limited the power to detect significant changes on some of the outcome measures used. Although a per-protocol analysis was used, we still considered the demographic data of the patients lost to follow-up, which did resemble that of the studied participants. Not all participants came back for their 24-month follow-up; therefore, the latest follow-up time point, whether 12 or 24 month, was used. Of the 9 patients lost to follow-up, only 5 had assessments at the 6-month time point and none at the 12- or 24-month time points. Compliance to follow-up appointments in a high

functioning population may explain the dropout rate. This may have limited functional gains and undermined our findings, as improvements were observed up to 24 months in most participants. Future studies are warranted to evaluate the use of the Cerebral Palsy Computer Adaptive Test following other surgical interventions and treatment protocols to align best practice guidelines for children with cerebral palsy.

The clinical relevance of this pilot study is seen through the results obtained using the Cerebral Palsy Computer Adaptive Test. Significant change was seen in each of the 4 Cerebral Palsy Computer Adaptive Test domains, that indicated the effectiveness of the tendon Achilles lengthening in improving functional outcome in children with spastic hemiplegia, and the sensitivity of this measure to capture change in this population. This is important to orthopedic surgeons who strive to understand how the procedure not only improves range of motion but also the level of participation of a child with hemiplegia. Moreover, this has potential importance in the era of reimbursement and requirement of evidence-based medicine. Findings of this study indicate that the tendon Achilles lengthening improved functional outcome in these children as measured by tests of physical function, walking speed, and activity performance.

Author Contributions

ES contributed to design and analysis, drafted the manuscript, and agrees to be accountable for all aspects of work ensuring integrity and accuracy. ND-O contributed to conception, design, acquisition, analysis, and interpretation and drafted the manuscript. KM contributed to acquisition and interpretation. TB contributed to acquisition. RY contributed to acquisition and analysis. NB contributed to acquisition, analysis, and interpretation. MJM contributed to conception, design, acquisition, analysis, and interpretation. All authors critically revised the manuscript and gave final approval.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

This study was approved by the Medical Headquarters of the Shriners Hospitals for Children, Tampa, Florida, # PHL9904, and from every local institutional review board.

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