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Correction of Planovalgus Deformity Through Rotational Reinsertion of the Lateral Layers of the Achilles Tendons in Ambulatory Children With Cerebral Palsy

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ABSTRACT

Symptomatic planovalgus deformity is a condition commonly seen in patients with cerebral palsy. The authors propose a new procedure for the management of this deformity through rotational reinsertion of the lateral layers of the Achilles tendon, and then they assess its benefit by comparing plantar pressure distribution patterns in children preoperatively and at 6- and 12-month intervals postoperatively. Pedobarographic measurements, range of motion of the ankle, and radiographic indexes were used to assess the outcome of the surgery. The functional abilities of the patients were assessed based on the Gross Motor Function Classification System. A total of 37 feet (22 patients) were included, with a mean ± standard deviation age at surgery of 11.8 ± 2.7 (range 9.1 to 14.5) years. All feet were managed through rotational reinsertion of the lateral layers of the Achilles tendon. Surgical correction of planovalgus has good outcomes. Significant changes were observed with statistical significance at the 5% ($p \leq .05$) level in plantar pressure distribution in children preoperatively and at 6- and 12-month intervals postoperatively. The results show that the proposed method of surgery is effective in the correction of planovalgus in ambulatory children with cerebral palsy.

Cerebral palsy (CP) is a common cause of disability in children. CP encompasses a group of permanent developmental disorders of movement and is caused by a variety of factors, such as genetic predisposition, spasticity or overactivity of peroneal muscles, ligament laxity, and muscular imbalance, among others (1,2). This condition affects 64% of diplegic and quadriplegic children, and it arises as an insidious collapse of the longitudinal plantarflexion of the talus, ankle valgus, and abduction of the forefoot (3–5). Common musculoskeletal problems in children with CP are deformities of the feet, with the most frequent being planovalgus (6–9). Planovalgus is characterized by median talus subluxation, valgus calcaneus, supinated forefoot, and external rotation relative to the midfoot. The foot deformity in question could be a cause of deviations in the patterns of human gait—an increase in the dynamic load, starting with the foot and ankle and ending with the cervical spine (5,10). One of the most important issues in orthopedics and traumatology is the accurate diagnosis and treatment of planovalgus deformity in children with CP. Early detection with the use of gait analysis (specifically, pedobarographic measurements) may effectively prevent further progression of the foot pathology and support clinical decision-making (11). There are many treatment options for planovalgus (9,12–21). Early injection of botulinum toxin into the overactive muscles may offer clinical benefits, from restoration of muscle balance during growth and prevention of progression to complete correction of the deformity (22,23). Another primary treatment of planovalgus is the use of orthotic insoles (11,14,24). The impact of their application in planovalgus feet, however, is not well documented scientifically. Surgery is indicated if the deformity is not reducible, if the patient cannot tolerate orthotics during functional activities, or if the foot is painful during gait (9). Several types of surgical procedures are used in planovalgus treatment: subtalar joint fusion, lateral calcaneal lengthening, triple arthrodesis, or variations of these techniques (9,12–19). The choice of treatment depends largely on the severity of the pathological process, which is primarily determined based on clinical characteristics and data obtained through radiographic examination of the patient. The authors propose a

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new procedure for the management of this deformity via rotational reinsertion of lateral layers of the Achilles tendon, and they assess its benefits by comparing plantar pressure distribution patterns in children preoperatively and at 6- and 12-month intervals postoperatively.

Patients and Methods

The present study was conducted beginning in January 2008. The patients were managed with different types of plantar orthoses until October 2017. Twenty-two patients with spastic CP (15 males [68.2%]) were identified and represented the study sample of 37 operated feet. The surgical procedure was performed by 1 surgeon (U.L.). Three examiners performed the data collection process. The first examiner (M.I.) checked the inclusion and exclusion criteria and recorded measurements by using a pedobarograph. Two additional examiners (J.P. and K.D.) collected and analyzed the demographic, clinical, radiographic, and foot pressure data of patients preoperatively and at 6- and 12-month intervals postoperatively. The primary aim of the study was to examine the effectiveness of surgery on the lateral layers of the Achilles tendons in correcting planovalgus deformity, measured based on changes in foot pressure parameters. The inclusion criteria for the planovalgus group were age of 4 to 17 years, no prior surgical intervention, flatfoot, ankle valgus, pain of varying intensity in the foot and lower limb after moderate physical exertion, fatigue in the lower limbs, being classified as having stage IV foot deformity (25), and rapid wear and deformation of casual shoes. The exclusion criteria were any disorders other than planovalgus that may affect the participant's gait and plantar pressure distribution, such as the dystonic, athetoid form of CP, marked contracture of the knee and hip joints in spastic diplegia, and quadriplegia. Medical records were reviewed and data were obtained on sex, age, height, weight, and CP type. Clinical assessment was based on measurement of the range of motion in the ankle and the subtalar joint. The Modified Ashworth Scale (MAS) was used to measure muscle hypertonia. The MAS scores were determined according to the level of resistance during passive movement of the antagonist muscles. The muscle groups tested were the hip flexors, adductors (knee extended), internal rotators of the hip, hamstrings, and plantar flexors (knee extended). The Gillette Functional Assessment Questionnaire was used to document functional change in children with CP (26,27). Ankle joint dorsiflexion was measured through weightbearing with use of a standard goniometer. Radiographic evaluations were performed by 1 investigator (U.L.). Three radiographic indexes were used in the study: lateral talocalcaneal angle, angle of the longitudinal arch, and intermetatarsal angle. Non-weightbearing radiographs were not used in the study. The patients were interviewed in person regarding pain, function, and problems with shoe wear. The data for the study were sorted chronologically into 3 groups: preoperative data and 6- and 12-month postoperative data. The study received ethical approval in accordance with the union of the medical community, the National Medical Chamber (registration number 1107799011979). All of the parents/legal guardians received full information about the study before providing signed consent.

Surgical Procedure

The study examines the outcomes of the surgical procedure used, rotational reinsertion of the lateral layers of Achilles tendon correction, as shown in Fig. 1.

The surgery was performed with the patient under general anesthesia in the prone position. A cross incision was made above the calcaneal tuberosity strictly in the skin fold. The Achilles tendon was cut lengthwise in half in strictly the sagittal plane. The external portion cut from the calcaneal tuberosity and the medial portion of the tendon were left intact. The external portion of the tendon was stitched with 2 sutures. At the anteromedial part of the calcaneus, in front of the place of attachment of the Achilles tendon, a groove was formed by removing a 5 × 6–mm cortical bone and replacing it with the external portion of the tendon, which was then fixed with a cross transosseous suture. In 9 cases, to increase supination of the tarsus, an additional incision was made along the lateral margin of the gastrocnemius muscle. From this incision, the gastrocnemius muscle was crossed twice, half of the largest diameter (≤3 cm) each time. The distance between the cross sections ranged from 3 to 4 cm. After the operation, a circular plaster cast was applied from the upper third of the thigh to the toes. The modeling of a longitudinal arch of foot with supination of a hindfoot and the plantar flexure in an ankle joint by 10° were performed simultaneously (19). Walking with a full load in the absence of pain was recommended for the second day. Sutures were removed after the tenth day,

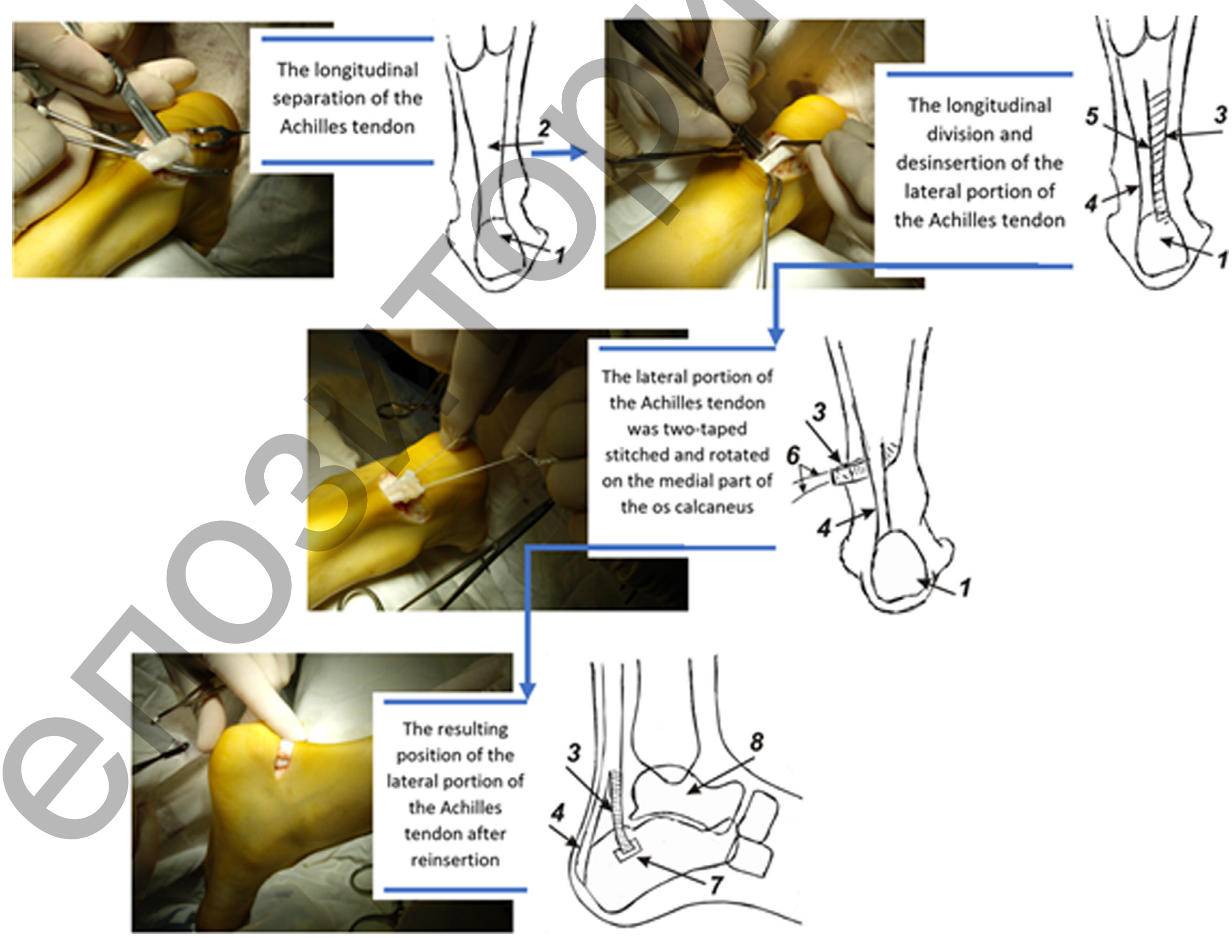

Fig. 1. Schematic of the surgical procedure: 1, os calcaneus; 2, Achilles tendon; 3, lateral portion of Achilles tendon; 4, medial portion of Achilles tendon; 5, the longitudinal division of Achilles tendon; 6, 2-taped stitches; 7, medial surface of the top of the os calcaneus; 8, os talus.

and the plaster cast was removed 6 weeks after surgery. The period of immobilization extended to 6 weeks. In the postoperative period, after plaster cast removal, rehabilitation procedures were performed, which included an active muscle contraction of the tibialis posterior, gastrocnemius, soleus, flexor digitorum longus and brevis, hallucis longus, and massage of the lower limb. The use of plantar orthoses and orthopedic shoes was recommended until the end of puberty, taking into account the state of the patient.

Foot Pressure Assessment

With the patient taking 1 to 3 steps, foot pressure data were recorded by using a pedobarograph (T&T Medilogic Medizintechnik GmbH, Munich, Germany) and shoe insoles with capacitive sensors (maximum of 240 SSR sensors per insole, depending on the size and shape) (T&T Medilogic Medizintechnik GmbH). Measurements were recorded with a sampling frequency of 60 Hz. To quantify plantar pressure distribution, we used a commercially available toolbox (as shown in Fig. 2) to measure the maximal magnitude of plantar pressure (peak pressure) under 7 anatomical masks: toes (mask 1), head of second through fifth metatarsals (mask 2), head of first metatarsal (mask 3), lateral arch (mask 4), medial arch (mask 5), lateral heel (mask 6), and medial heel (mask 7).

Maximal pressure was defined as the greatest pressure in each anatomical area of the foot in a single step, and these values were averaged separately for each mask for 1 to 3 steps. Trial replications were performed 3 times for the left foot and the right foot separately.

Statistical Analysis

The data were examined for normality by using the Shapiro-Wilk test. The mean ± standard deviation were used for continuous variables. To assess changes over time in each group, a repeated-measures analysis of variance was used. The Friedman test was used for nonparametric variables. To evaluate the overall outcome of surgery implying change over time in the study variables, a paired *t* test was used (Wilcoxon rank-sum test was used for nonparametric variables). The level of statistical significance was set at the 5% ($p \leq .05$) level. Statistica 12.5 (StatSoft, Tulsa, OK) software was used for computations.

Results

Study Subjects

The study sample consisted of 37 feet in 22 patients (25 feet of males [67.6%] and 12 feet of females [32.4%]). The mean patient age at surgery

Fig. 3. Planovalgus foot: (*A*) preoperative and (*B*) postoperative.

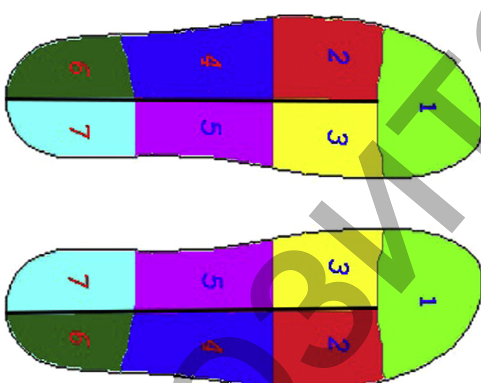

Fig. 2. Definitions of the different masks used in this study: mask 1, toes; mask 2, head of second through fifth metatarsals; mask 3, head of the first metatarsal; mask 4, lateral arch; mask 5, medial arch; mask 6, lateral heel; mask 7, medial arch.

was 11.8 ± 2.7 (range 9.1 to 14.5) years, and the average body mass index was 23.6 ± 6.2 (range 17.4 to 29.9) kg/m^2. Patients had preoperative pain: 15 (40.5%) feet were mildly painful, 12 (32.4%) feet were moderately painful after strenuous activities, and 10 (27.0%) feet was severely and almost constantly painful. Pre- and postoperative images of a foot in a patient with planovalgus are shown in Fig. 3. The radiographic indexes are listed in Table 1, and images demonstrating the preoperative condition and postoperative changes are shown in Fig. 4.

The radiographic measurements of the feet showed decreases in the lateral talocalcaneal angle, the angle of the longitudinal arch, and the intermetatarsal angle.

Dorsiflexion measurements were significantly greater postoperatively (32.1° ± 7.3° [range 24.8° to 39.4°]) compared with preoperatively (21.3° ± 6.9° [range 14.4° to 28.2°]) ($p < .05$). The spasticity of the triceps surae muscle on the MAS decreased from an average of 3.53 ± 1.42 (range 2.11 to 4.95) points preoperatively to 1.75 ± 0.65 (range 1.1

Table 1
Radiographic indexes (N = 37 feet in 22 patients)

Angle (°)	Preoperatively*	12 Months Postoperatively*	Comparison of Preoperative and 12-Month Postoperative Values	
			Difference	*p* Value
Lateral talocalcaneal	40.4 (15.5)	23.3 (11.5)	17.1	<.05
Longitudinal arch	163.0 (7.4)	139.3 (8.3)	23.7	<.05
Intermetatarsal	40.3 (9.6)	9.5 (7.4)	30.8	<.05

* Values given as mean (standard deviation).

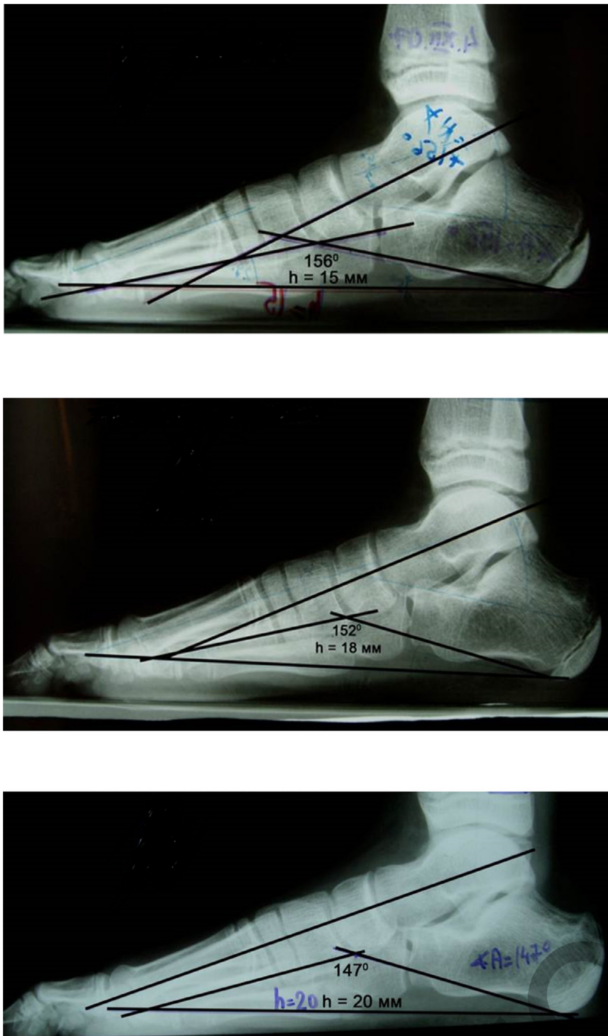

Fig. 4. Radiographic images: (*A*) preoperatively, (*B*) at 6 months postoperatively, and (*C*) at 12 months postoperatively.

to 2.4) points postoperatively. The Gillette Functional Assessment Questionnaire showed improvement of locomotion functions in all patients. Patients were either satisfied (n = 9; 41%) or very satisfied (n = 11; 50%) with the final results, and only 9% were partially satisfied with it.

Foot Pressure Assessment

Fig. 5 illustrates foot pressure for a child with planovalgus preoperatively, at 6 months postoperatively, and at 12 months postoperatively.

Pressure distribution of the measurement points under the 7 anatomical areas of the foot showed that the initial contact for all of the patients was heel strike with a visually normal heel-to-toe motion. Table 2 summarizes the parameters extracted from pedobarographic insoles during walking for patients preoperatively and at 6 and 12 months postoperatively.

The mean magnitude of plantar pressure under the head of the first metatarsal (mask 3) was higher by 15.1% and 16.9% at 6 and 12 months postoperatively, respectively. Significant differences ($p < .05$) were also observed for the magnitude of plantar pressure under the medial arch (mask 5) and the lateral arch (mask 4). Specifically, the mean magnitude of plantar pressure under the medial arch was reduced by 39.2% and 42.2% at 6 and 12 months postoperatively, respectively. The plantar

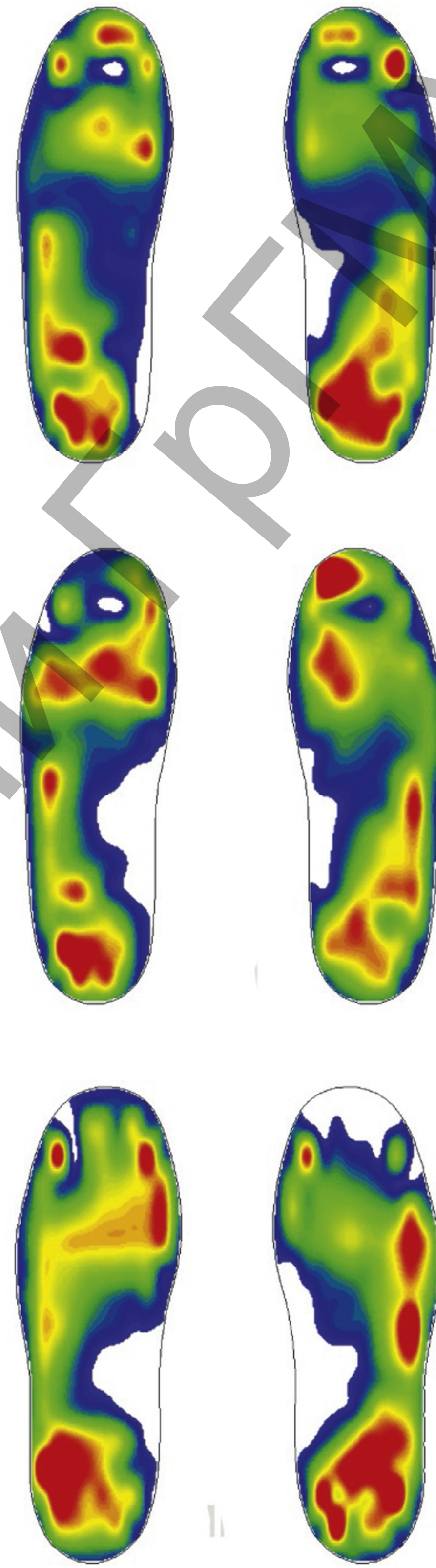

Fig. 5. Foot pressure for a child with planovalgus: (*A*) preoperatively, (*B*) at 6 months postoperatively, and (*C*) at 12 months postoperatively.

pressure reduction under the medial arch led to a significant increase under the lateral arch by 13.6% and 17.8% at 6 and 12 months postoperatively, respectively. On the same note, the results showed a significant

Table 2
Comparison of plantar pressure of planovalgus children (N = 37 feet in 22 patients)

Mask	Plantar Pressure (N/cm^2)*						
	Preoperatively	6 Months Postoperatively	12 Months Postoperatively	Preoperatively Versus 6 Months Postoperatively		Preoperatively Versus 12 Months Postoperatively	
				Difference	*p* Value	Difference	*p* Value
Toes (mask 1)	2.4 (0.9)	2.9 (0.6)	2.8 (0.6)	0.5	.1	0.4	.1
Head of second through fifth metatarsals (mask 2)	13.2 (4.3)	13.0 (6.3)	12.8 (3.6)	−0.2	.05	−0.4	.05
Head of first metatarsal (mask 3)	12.4 (3.9)	14.6 (2.2)	14.5 (3.4)	2.2	<.05	2.1	<.05
Lateral arch (mask 4)	11.8 (3.4)	13.4 (2.9)	13.9 (1.9)	1.6	<.05	2.1	<.05
Medial arch (mask 5)	10.2 (1.6)	6.2 (2.1)	5.9 (1.8)	−4.0	.1	−4.3	.1
Lateral heel (masks 6)	34.7 (12.4)	29.5 (8.3)	28.7 (5.7)	−5.2	<.05	−6.0	<.05
Medial heel (masks 7)	19.3 (8.6)	23.8 (5.4)	25.2 (5.6)	−4.5	<.05	−5.9	<.05

* Values given as mean (standard deviation).

reduction ($p < .05$) in the mean magnitude of plantar pressure under the lateral heel (mask 6) by 15.0% and 17.3% at 6 and 12 months postoperatively, respectively. However, the magnitude of pressure reduction under the lateral heel led to a higher magnitude of pressure under the medial heel (mask 7). After rotational reinsertion of the lateral layers of Achilles tendon correction, the maximal load under the forefoot (mask 2) moved to the first and second metatarsal heads (mask 3). The ratio of first to second metatarsal head pressure ($P^{M2/M3}$) between the maximal magnitude of pressure distribution under the head of the second through fifth metatarsals (mask 2) and the heads of the first and second metatarsal (mask 3) was determined. The foot correction is sufficient when the $P^{M2/M3}$ ratio was ≤ 1 (18). The results show that the mean $P^{M2/M3}$ ratio preoperatively was 1.06 ± 0.08 and was reduced to 0.89 ± 0.03 and 0.88 ± 0.04 at 6 and 12 months postoperatively, respectively.

Discussion

Planovalgus is a foot deformity that is of great concern to pediatric orthopedic clinicians because of its prevalence in children with CP (9). Patients with severe planovalgus foot deformities may experience difficulty with shoe fit. There are many treatment alternatives, such as anatomical correction, orthotic insoles, or surgical interventions (9,12–19,28). The primary treatment of planovalgus in childhood is orthotic control. The impact of the use of orthotics in planovalgus feet has a positive impact in almost all cases (29). However, with the increase in the child's weight, the planovalgus deformity may be a major contributor to stance phase instability; therefore, the use of orthotics is not desirable (30). The goal of surgical treatment is to improve gait function. Surgery is recommended in the presence of symptoms such as pain or breakdown in the region of the talar head (13). In older children, planovalgus becomes severe and its surgical treatment is difficult. Because planovalgus is a multiplanar and variable deformity, it is important to consider all aspects of the deformity when planning surgical correction. Calcaneal lengthening with concomitant peroneus brevis lengthening is an effective procedure for correcting planovalgus foot deformity (14,15). However, it should be noted that, for patients with the anteroposterior talus–first metatarsal angle of 23°, the lateral talus–first metatarsal angle of 36°, and the naviculocuboid overlap of 72°, additional procedures should be considered (15). In ambulatory children with CP, calcaneal lengthening is an effective procedure for the correction of mild to moderate planovalgus deformities. In nonambulatory children with severe planovalgus deformities of the foot, calcaneal lengthening cannot be recommended because of the high relapse rate in these patients. Although calcaneal lengthening may correct planovalgus deformity, active muscle force is required to maintain this correction; therefore, in the feet of children with hypermobility or severe muscle weakness, or poor motor control such as dystonia, fusion is required, as there should be no consideration of calcaneal lengthening in these situations (15,31). The aims of this study were to examine a surgical technique used in the treatment of planovalgus foot deformity in ambulatory children with CP and to assess its benefit by comparing plantar pressure distribution patterns between children preoperatively and at 6- and 12-month postoperative intervals. In the course of the study, 37 operations were performed on 7 feet according to the described methodology, with the aim of reducing planovalgus deformity. In general, the clinical appearance of the foot showed postoperative improvements with respect to hindfoot valgus and arch height. Moreover, most patients (or parents) were satisfied with the procedure and recommended it to other patients with the same disorder. In the study, radiographic evaluation showed improvement in the relationship between the talus and the calcaneus, especially decreases in longitudinal arch angle, the intermetatarsal angle, and the lateral talocalcaneal angle. This finding is consistent with the results reported by Cicchinelli et al (32) that demonstrated statistically significant differences in pre- and postoperative radiographic angles. Despite some investigations in the area of plantar pressure distribution in children with various foot problems (11,33), little is known about plantar pressure distribution in children pre- and postoperatively. Long-term studies of patients pre- and postoperatively with the use of a reliable, accurate, and reproducible method to assess the level of function are required. The pedobarograph, or foot pressure measurement, is one of the most objective methods for assessing severity or change over time (11,33). First, we performed pedobarometric surveys of the patients preoperatively, together with clinical and radiological diagnoses. Follow-up examinations were performed at 6 and 12 months postoperatively. In our experience, the pedobarograph is the most objective method for assessing severity or change over time.

Study Limitations

Even the effects on gait pressure distribution showed statistical significance (at the level of statistical significance of 5% [$p \leq .05$]), we believe that the relatively small sample size and short follow-up duration limited our ability to make more sensitive preoperative and postoperative analyses. However, this finding is consistent with the results reported by Wen-Dien et al (33) that demonstrated improvement in the coronal plane pressure index evaluation based on pedobarograph measurements before the second operation compared with the initial operation. No evidence of recurrence of the deformity or the development of instability on distal articulations was found in this study, but the average follow-up period was only 12 months, so the findings should be considered as preliminary results. A longer follow-up is also desirable.

In conclusion, the purpose of the treatment we described is to achieve the best possible correction of planovalgus deformity. We demonstrated quantitative improvement in gait measures that alter the biomechanics of the subtalar joint in all patients. Optimization of function of the subtalar joint, performed in childhood in patients with a growth potential, leads to significant subsequent anatomical and radiographic improvements as well as improvements in functional parameters of the foot. The surgical treatment in question is designed for patients with minimal motion and neurological dysfunctions caused by organic central nervous system damage, as well as for the patients with idiopathic planovalgus. The results show that the new procedure for the management of this deformity by rotational reinsertion of lateral layers of the Achilles tendon is effective. Measurements of foot pressure distribution prove to be useful for the assessment of surgery results pre- and postoperatively. Dynamic plantar pressure distribution gives important information on the load of the body on the foot in patients with various postural deformities and their methods of treatment.

References

1. Bennet GC, Rang M, Jones D. Varus and valgus deformities of the foot in cerebral palsy. Dev Med Child Neurol 1982;24:499–503.
2. Miller F, Bachrach S, Lennon N, O'Neil M, eds. *Cerebral Palsy*, Springer, New York; 2019.
3. Lam WK, Leong JC, Li YH, Hu Y, Lu WW. Biomechanical and electromyographic evaluation of ankle foot orthosis and dynamic ankle foot orthosis in spastic cerebral palsy. Gait Posture 2005;22:189–197.
4. Romkes J, Hell AK, Brunner R. Changes in muscle activity in children with hemiplegic cerebral palsy while walking with and without ankle-foot orthoses. Gait Posture 2006;24:467–474.
5. Karol LA, Ezaki M. Disorders of the brain. In: Herring JA, ed. *Tachdjian's Pediatric Orthopedics*, 4th ed, Elsevier, Philadelphia, 2008:1275–1404.
6. Da Silva LAA, De Barros Fucs PMM. Surgical treatment of planovalgus foot in cerebral palsy by Pisani's arthroereisis. Acta Ortop Bras 2010;18:162–165.
7. Kadhim M, Miller F. Pes planovalgus deformity in children with cerebral palsy: review article. J Pediatr Orthop B 2014;23:400–405.
8. Kadhim M, Holmes L, Miller F. Long-term outcome of planovalgus foot surgical correction in children with cerebral palsy. J Foot Ankle Surg 2013;52:697–703.
9. Sees JP, Miller F. Overview of foot deformity management in children with cerebral palsy. J Child Orthop 2013;7:373–377.
10. Miller F. Knee, leg, and foot. In: Miller F, ed. *Cerebral Palsy*, Springer, New York, 2005:667–804.
11. Pauk J, Ihnatouski M, Laskhousky U, Daunoraviciene K, Griskevicius J. Research of the spatial-temporal parameters and pressure characteristic in spastic diplegia children. Acta Bioeng Biomech 2016;18:121–129.
12. Gage JR, Schwartz MH, Koop SE, Novacheck TF. *The Identification and Treatment of Gait Problems in Cerebral Palsy*, 2nd ed, Mac Keith Press, London; 2009.
13. Turriago CA, Arbeláez MF, Becerra LC. Talonavicular joint arthrodesis for the treatment of pes planus valgus in older children and adolescents with cerebral palsy. J Child Orthop 2009;3:179–183.
14. Ettl V, Wollmerstedt N, Kirschner S, Morrison R, Pasold E, Raab P. Calcaneal lengthening for planovalgus deformity in children with cerebral palsy. Foot Ankle Int 2009;30:398–404.
15. Sung KH, Chung CY, Lee KM, Lee SY, Park MS. Calcaneal lengthening for planovalgus foot deformity in patients with cerebral palsy. Clin Orthop Relat Res 2013;471:1682–1690.
16. Wren TA, Cheatwood AP, Rethlefsen SA, Hara R, Perez FJ, Kay RM. Achilles tendon length and medial gastrocnemius architecture in children with cerebral palsy and equinus gait. JPO 2012;30:479–484.
17. Rutz E, Baker R, Tirosh O, Romkes J, Haase C, Brunner R. Tibialis anterior tendon shortening in combination with Achilles tendon lengthening in spastic equinus in cerebral palsy. Gait Posture 2011;33:152–157.
18. Lashkouski V, Boltrukevich S, Sycheuski L. Surgical treatment of flexible flatfoot in children and adolescents. J Vibroengineering 2006;8:57–60.
19. Lashkouski U, Marmish A. Method of surgical treatment unfixed pes planovalgus feet of a child with full Achilles. Patent BY 15805 C1 2012.04.30 A 61B 17/56 (2006.01).
20. Carr JB, Yang S, Lather LA. Pediatric pes planus: a state-of-the-art review. Pediatrics 2016;173:1–10.
21. Ford SE, Scannell BP. Pediatric flatfoot: pearls and pitfalls. Foot Ankle Clin 2017;22:643–656.
22. Boulay C, Jacquemier M, Castanier E, Giorgi H, Authier G, Pomero V, Chabrol B, Jouve JL, Bollini G, Viewhegger B. Planovalgus foot deformity in cerebral palsy corrected by botulinum toxin injection in the peroneus longus: clinical and radiological evaluations in young children. Ann Phys Rehabil Med 2015;8:316–321.
23. Domagalska M, Czupryna K, Szopa A, Nowotny J. Specific and alternative ways of treatment in children with cerebral palsy. J Polish Soc Child Neurologists 2005;14:7–16.
24. Wenger DR, Mauldin D, Speck G, Morgan D, Lieber RL. Corrective shoes and inserts as treatment for flexible flatfoot in infants and children. J Bone Joint Surg Am 1989;71:800–810.
25. Regulation of the Ministry of Defense of the Republic of Belarus and the Ministry of Health of the Republic of Belarus 61/122 of 21, Minsk, 2008.115.
26. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol 1997;39:214–223.
27. Novacheck TF, Stout JL, Tervo R. Reliability and validity of the Gillette Functional Assessment Questionnaire as an outcome measure in children with walking disabilities. J Pediatr Orthop 2000;20:75–81.
28. Marengo L, Canavese F, Mansour M, Dimeglio A, Bonnel F. Clinical and radiological outcome of calcaneal lengthening osteotomy for flatfoot deformity in skeletally immature patients. Eur J Orthop Surg Traumatol 2017;27:989–996.
29. Jafarnezhadgero AA, Shad MM, Majlesi M. Effect of foot orthoses on the medial longitudinal arch in children with flexible flatfoot deformity: a three-dimensional moment analysis. Gait Posture 2017;55:75–80.
30. Kadhim M, Holmes L, C Church Jr, Henley J, Miller F. Pes planovalgus deformity surgical correction in ambulatory children with cerebral palsy. J Child Orthop 2012;6:217–227.
31. Khamis S. Effect of feet hyperpronation on pelvic alignment in a standing position. Gait Posture 2007;25:127–134.
32. Cicchinelli LD, Pascual Huerta J, García Carmona FJ, Fernández Morato D. Analysis of gastrocnemius recession and medial column procedures as adjuncts in arthroereisis for the correction of pediatric pes planovalgus: a radiographic retrospective study. J Foot Ankle Surg 2008;47:385–391.
33. Wen-Dien C, Nai-Jen C, Hung-Yu L, Ping-Tung L. Changes of plantar pressure and gait parameters in children with mild cerebral palsy who used a customized external strap orthosis: a crossover study. Biomed Res Int 2015;2015. 813942.