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Alteration of the calf strength by heel cord lengthening, gastrocnemius recession through tenotomy or fasciotomy. A retrospective clinical force analysis before and after surgery

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ABSTRACT

Background: Indications for surgical corrections about the Achilles tendon are increasing as additional measures in reconstructive interventions about the foot. These indications include shortened gastrocnemii, which cause a so-called 'functional pes equinus' and secondary forefoot imbalances, as well as corrections of pes planus and cavus. Surgery about the heel cord may also be indicated for achillodynia and diabetic pressure ulcers. However, there is a lack of evidence that quantifies the results of lengthening procedures about the heel cord. The aim of this study was to quantify the exact changes in calf strength one year after elongating the triceps surae, by measuring flexion forces in 90 degrees knee flexion and knee extension.
Methods: This study involves 69 patients who were examined for calf strength preoperatively and 1 year after gastrocnemius release. A new device, the Leonardo Mechanograph® (Novotec Medical) was used to measure calf strength. Measurements were performed with the knee flexed and extended.
Results: The operated leg had an overall statistically significant reduction in strength after surgery. Changes were similar on the contralateral leg. The difference in force reduction between the operated and non-operated leg was not statistically significant
Conclusion: A correlation between measured plantar flexion forces of the foot after a reconstructive foot operation with or without a lengthening procedure about the calf musculature could not be established.
Level of evidence: Level III: retrospective cohort study.

1. Introduction

The surgical elongation of the Achilles tendon in cases of shortening and/or contracture for the treatment of spasticity in the lower leg in pediatric patients [1] was first described at the beginning of the 20th century. With increasing specialization in foot and ankle surgery, the complexity of surgical procedures has increased. In flatfoot surgery, reconstruction of the height of the arch and the increased calcaneal pitch implies the need for elongation of the tendon. Isolated gastrocnemius lengthening can be performed by tenotomy or anterior fasciotomy, while over-tension of the entire triceps surae requires lengthening of the Achilles tendon.

It is unclear to what extent the relative shortening of the Achilles tendon is a cause or consequence of a flatfoot, but it logically follows the equinus of the hindfoot. In addition, many other entities are observed with a short gastrocsoleus complex, such as chronic diffuse foot pain [2,3], diabetic foot ulcers [3] , midfoot/forefoot overuse syndrome, non-insertional Achilles tendinopathy [4], Charcot arthropathy of the metatarsus [5] and plantar heel pain [6]. The increasing use of techniques to elongate the Achilles tendon in addition to the aforementioned findings raise the question of whether the clinical function of the lower leg changes after elongating the heel cord. Elongating the Achilles tendon tension can be done in various ways, though the techniques described in the literature usually involve elongation of the gastrocnemius without tenotomy of the soleus [7].

Previous investigations relating to force after these procedures include measurements of peak torque force with a dynamometer [8–10] although the obtained data does not distinguish the force changes of the gastrocnemius and soleus muscle. The sample sizes of these studies are also limited. Only one study [10] obtained pre- and

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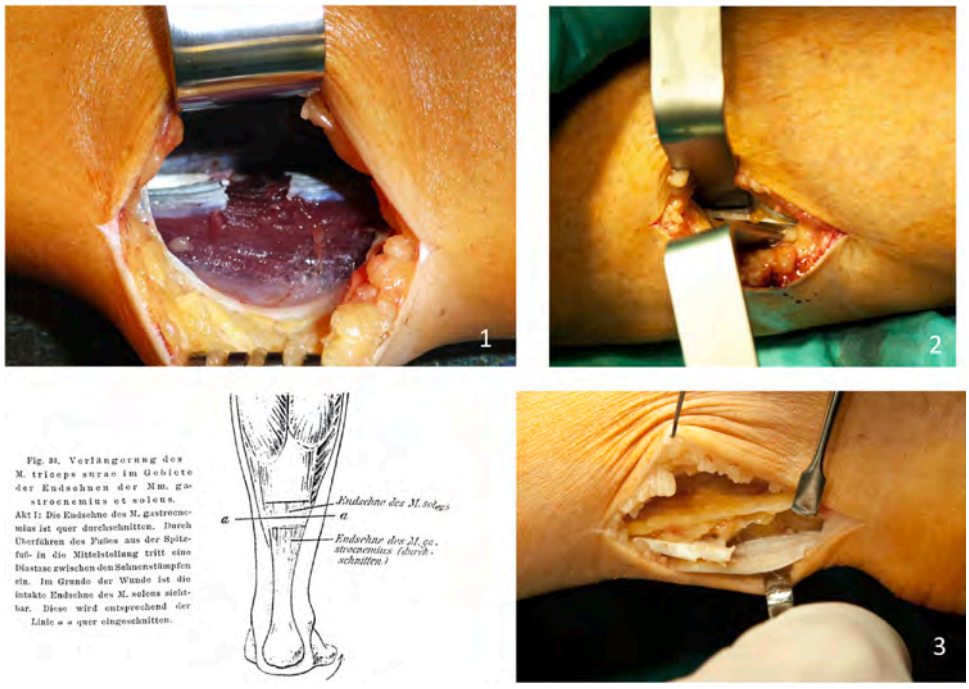

Fig. 1. Original design by Vulpuis and Stoffel (1913); The three techniques performed in this study 1. fasciotomy 2. gastrocnemius recession (before incision) 3. Z-shaped Achilles tendon lengthening.

post-operative measurements. The others [8,9] used the non-operated side as a reference.

The Leonardo Mechanograph® in the set up described below can distinguish the forces of the gastrocnemius and the soleus while isolated plantar flexion power of the hindfoot in a flexed knee or extended knee can be monitored. The method is new in investigations of medical trials though has been used previously in sports medicine and space exploration [11].

The aim of this study was to quantify the exact changes in calf strength one year after elongating the triceps surae, by measuring flexion forces in 90 degrees knee flexion and knee extension.

2. Materials and methods

In a group of 69 patients, all scheduled for various reconstructive forefoot or hindfoot surgery, calf muscle strength was measured with the Leonardo Mechanograph® prior to surgery. All patients had achilles tendon tightness observed in the preoperative planning.

The decision to perform triceps surae surgery was made during surgery. Patients in whom the intraoperative decision was against surgery on the sural complex were excluded.

Techniques used on the triceps surae in this study included (Fig. 1):

1. Gastrocnemius fasciotomy: medial incision over the gastrocnemius-soleus junction. Fasciotomy ventral to the gastrocnemius muscle belly.
2. Gastrocnemius release: medial incision over gastrocnemius-soleus union. Complete transection of gastrocnemius tendon.
3. Achilles tendon lengthening: medial incision 5 cm proximal to the Achilles tendon insertion. Z-shaped tenotomy within the frontal plane and fixation in extended position with sutures.

In the postoperative period, the leg was immobilised in a Jones dressing cast for 2 weeks. Patients were allowed to put weight on the leg according to the stability of the rest of the foot. After removal of the cast and sutures, a standard physiotherapy regime began, which included stretching exercises for the Achilles tendon. One year after surgery, a second measurement was performed in patients who had undergone triceps surgery (Achilles tendon lengthening, gastrocnemius recession or gastrocnemius fasciotomy).

The preoperative and follow-up measurements were performed bilaterally. On each leg, the force was measured once with the knee flexed and once with the knee extended. For the first measurement, the subject was placed on a bench attached to the Leonardo Mechanograph® GRFP (software Leonardo Mechanography STD v4.3). The knee was bent by 90° and the foot was placed on each of the two platforms. The knee was secured opposite the platform with a strap and the subject was asked to place the foot on the forefoot against the resistance of the strap. (Fig. 2).

Three peak ground reaction force values were obtained, and the highest value was used for data analysis.

Measurement of calf force with the knee extended was performed with the subject in a standing position with each foot on a platform. The subject was attached to the mechanograph with a strap across both shoulders. Ground reaction forces were measured as the subject stood on one leg and performed a heel raise test. The subject was allowed to support himself with one hand to ensure a secure stance. After three measurements, the highest value was used for data analysis.

Statistical analyses were performed to compare:

- Plantar flexor strength before and after surgery on the sural complex.
- Strength between both legs after a procedure on the triceps surae on one side.
- The influence of an intervention on the Plantar flexor strength during knee flexion and extension.

2.1. Statistical analysis

All tests investigated differences between pre and post surgery conditions in change values (deltas), which were tested if different from 0. To compare force changes ipsilaterally and contralaterally one year after surgery on the triceps surae in the knee flexion and

Fig. 2. Test setup: 1. measurement in knee extension 2. in knee flexion 3. fixation of the leg with a strap around the knee for measurement in knee flexion; ground reaction forces were determined over the two separate platforms for each leg.

knee extension positions, changes were filed as follows: more than −0.1 N: loss of force, between −0.1 N and +0.1 N change in force: no change, more than +0.1 N: increase in force.

Gaussian distributed variables were analysed using the t-test. Nonparametric variables were compared using the Wilcoxon test. Shapiro–Wilk test was used to test univariate normality.

The histograms for DELTA CONEXT and the results of the Shapiro-wilks test for the variable DELTA IPSFLX indicated doubts about the plausibility of the normality assumption we also conducted Wilcoxon tests for comparisons that involved these variables. All p-values reported are two-sided unless otherwise stated. For all analyses, p-values < 0.05 were considered statistically significant. The analysis was carried out using R Statistical Software v4.2.2 (R Core Team 2022). With an expected effect size of 0.4 we increased the sample size to 85. After data loss of 16, we were left with a required sample size of 69 to make reliable statements ($\alpha error = 0.05$, $Power = 0.95$) [12].

3. Results

3.1. Demographic data

85 patients underwent primary measurement before surgery. 9 patients were excluded because surgery was not performed on the Achilles tendon. 7 patients were excluded as they were not available for both measurements.

Data from the remaining 69 patients who had triceps surae surgery were analysed. The group comprised 61 females and 8 males with an average age of 52 years.

Seven surgical variants were performed which are shown in Table 1. Fifty-six patients (81 %) had gastrocnemius recession, 3 (4 %) had fasciotomy, and 10 (14 %) had Achilles tendon lengthening. There was no single surgery with an isolated procedure on the triceps surae alone.

3.2. Data Analysis

The force changes of the operated leg are shown in Fig. 3:

In the knee extension position, 40 % of subjects experienced a force reduction, 15 % experienced a force increase, and 40 % experienced no change in forces on the operated side compared to before surgery (DELTA IPSEXT). The mean force reduction was −24.6 % (p = 0.0005; 95 %CI: −0.1562 to 0.04586).

In the knee flexion position (DELTA IPSFLX) on the same leg, 55 % had no change, 32 % had a reduction, and 13 % had an increase in force. The reduction was −13.08 % (mean) (p = 0.0270; CI −0.07202 to −0.004473) with the knee flexed. The operated leg had an overall

Table 1
The surgical variations and their frequency involving the three different adaptations of the triceps surae.

	Adaptation type		
	Gastrocnemius Release	Gastrocnemius Fasciotomie	Achilles tendon lengthening
Intervention in tarsometatarsal region	45	3	1
Hindfoot correction	5	-	8
Forefoot surgery	6	-	1
Total	56	3	10

statistically significant reduction in strength after surgery (p = 0.0001;95 % CI: −02057 to −0.07289).

Changes were similar on the contralateral leg (Fig. 4): (DELTA CONEXT) in knee extension, 51 % had a decrease in strength, 20 % had an increase in strength, and 29 % had no change. The mean reduction was −24.09 % (p = 0.0007 CI −0.159 to −0.04421).

67 % of subjects had no change in strength on the contralateral side in knee flexion position (DELTA CONFLX), 17 % had a decrease and 16 % had an increase in strength. The reduction was 5.56 %. This reduction was not statistically significant (p = 0.1937). The overall reduction in plantar flexion forces on the non-operated leg was not statistically significant.

The difference in force reduction between the operated and non-operated leg was not statistically significant (p = 0.9814) while the knee was extended.

The mean force reduction on the operated side was (0.21KN) different (two tailed) / higher (one tailed) than on the non-operated side, but this difference was not statistically significant (two tailed p = 0.5017 one tailed p = 0.2509).

4. Discussion

A reduction in the power of the triceps surae after gastrocnemius release has been reported in the literature [9,10]. Molund et al [4]. tested the triceps surae and found no difference between operated and non-operated legs. However, the sample size was too small to show a statistically significant difference. The test consisted of 3 jump tests, 2 strength tests and 1 endurance test as described in the original study by Silbernagel et al. [13].

Gianakos et al [14]. showed in a review of 23 studies that only four reported any kind of strength outcome, which was generally

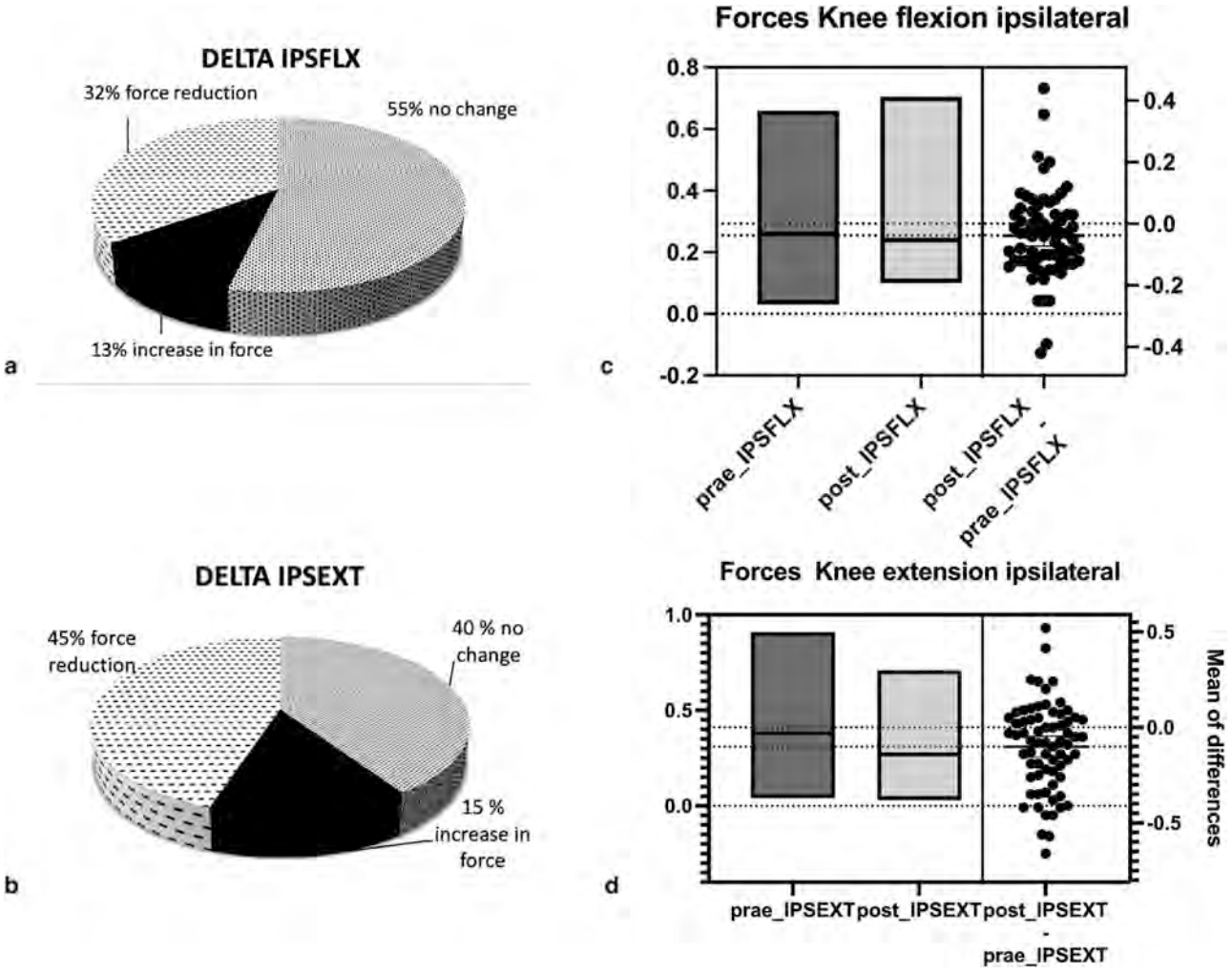

Fig. 3. Distribution of force changes in the knee flexion position a) DELTA IPSFLX and in the knee extension position b) DELTA IPSEXT of the operated leg. c) forces, the mean value of the forces and the mean value of the differences pre- and postoperatively in knee-flexion position (IPSFLX) and d) in the knee extended position (IPSEXT) on the operated leg.

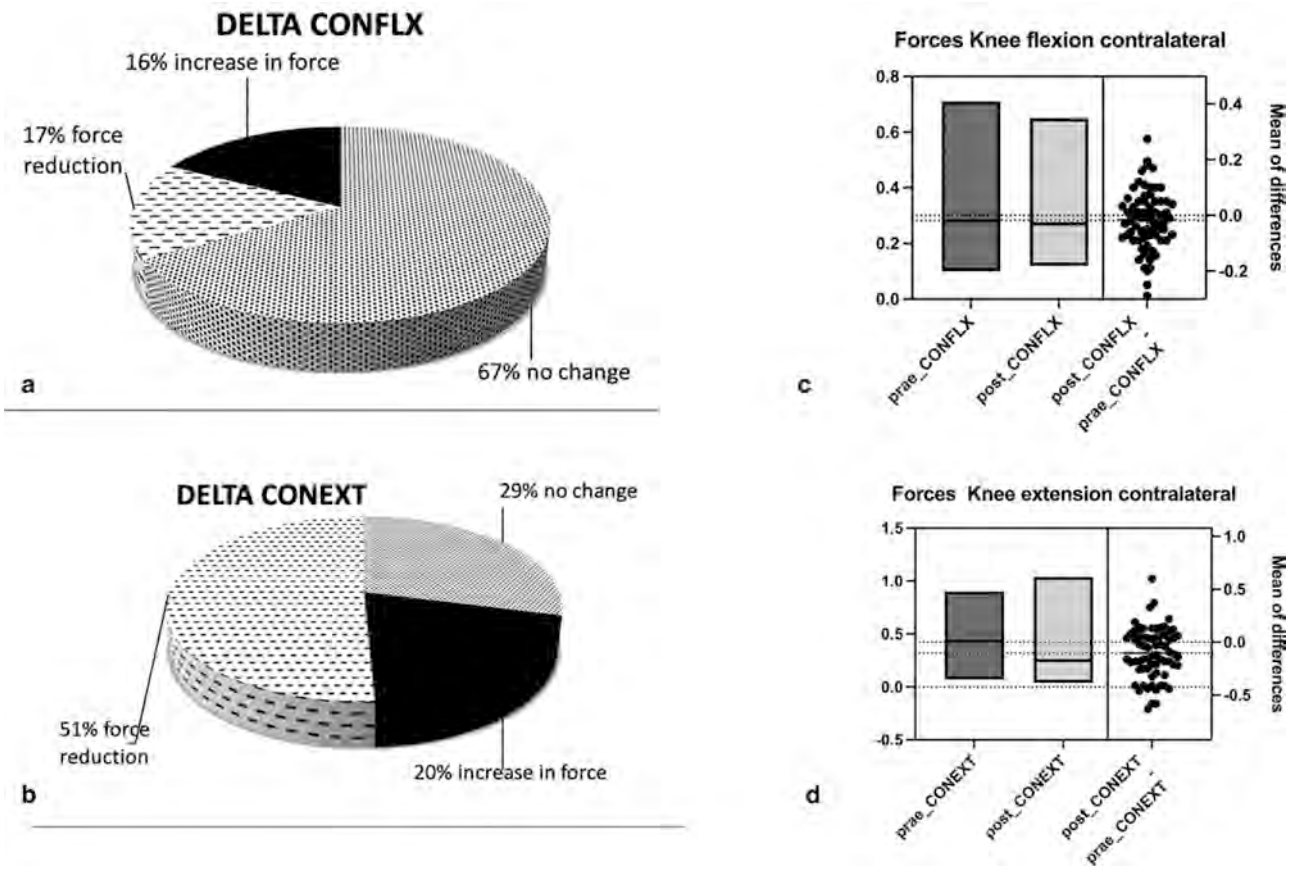

Fig. 4. Distribution of force changes in the knee flexion position a) DELTA CONFLX and in the knee extension position b) DELTA CONEXT of the non-operated leg. c) forces, the mean value of the forces and the mean value of the differences pre- and postoperatively in knee-flexion position (CONFLX) and d) in the knee extension position (CONEXT) on the non-operated leg.

subjective and based either on the ability to heel rise or on clinical assessment and patient discomfort. Biomechanical testing was performed in only three of the 23 studies. The review included only articles of evidence levels 3 and 4, with no randomized clinical trials reported in which the results of gastrocnemius recession were assessed. A low level of evidence for the observed changes was noted.

The current study has twice the sample size of other studies and thus offers a better basis for statistical analysis. It could be argued that forces other than calf strength, especially when measured in a standing position, influence the measured values. However, it can be assumed that the strength of the calf muscle, which is proven to be the strongest muscle in the body, significantly determines the value.

The data in this study shows that an operation on the sural musculature does not necessarily result in a reduction in functional forces. 55 % of the operated legs either had no change or demonstrated an increase in force in the most effected knee extension position. It can be speculated that the loss of muscle force in these cases is compensated by an overall raised activity level after a reconstructive foot operation.

A compensation of forces through increased power of the soleus muscle was not observed. It is likely that hypertrophy of the soleus may equilibrate the forces during stance on the level of the ankle joint. The reduced force of foot flexion when the knee is extended was similar for both sides (difference $p = 0.9814$). This observation suggests that there must be another factor with an influence on the plantar flexing forces of the sural muscles. That the force diminishes on both sides may not be due to the manipulation on the sural complex but simply the result of major foot surgery which leads to overall force reduction after recovery. The postoperative recovery time for these procedures can be as long as 2 years. General weakening of the forces on the operated side through the postoperative rest period may also weaken the non-operated but unused soleus.

Overall, our results do not show any correlation between surgery on the calf muscle and strength reduction when the knee is flexed. Strength reduction occurs in the extended knee but the difference in force reduction between the operated and non-operated leg was not statistically significant. In this position the modified muscle tendons have an unfavorable leverage for generating plantar-flexing forces. The reduced flexion force within the flexed knee may not be due to surgery on the gastrocnemius, but surgery on the foot.

A limitation of the present study is that it does not include a cohort of patients undergoing isolated surgery on the sural complex without reconstructive foot surgery. The authors are aware that these interventions can change the plantar flexion forces and that gastrocnemius tightness is not necessarily a pathologic entity [15,16]. Therefore, the indication for such techniques is always chosen after critical considerations.

5. Conclusion

After a reconstructive foot operation including lengthening procedures about the calf musculature, the plantar flexion forces of the foot decrease. We observed the changes on the operated and non operated side with no statistical significant difference, so there is no evidence that this reduction is due to treating Achilles tendon tightness.

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Conflict of Interest

None.

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