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Computerized gait evaluation in patients with surgically repaired Achilles tendon ruptures

Oana Suciu[1], Niţă Andreea[1], Alina Totorean[1,2], Roxana Onofrei[1]
[1]*Rehabilitation Department, University of Medicine and Pharmacy Victor Babeş, Timisoara, Romania*
[2]*Second Orthopedics and Traumatology Clinic, Clinical County Emergency Hospital, Timisoara, Romania*

Abstract. The aim of this study was to evaluate the gait of 15 patients with surgically repaired acute Achilles tendon ruptures, before and after the rehabilitation treatment and to demonstrate the impact of this evaluation in establishing functional treatment. *Material and Method*. We prospectively evaluated 15 cases of surgically repaired Achilles tendon ruptures. The assessment was made after cast removal and then after 1, 3 and 6 months of rehabilitation treatment. In order to evaluate gait we used a Zebris CMS-HS system, ultrasound-based system and a Zebris FDM system, a plantar pressure device. We also used the heel-rise test and measured calf circumference. *Results*. The results of the first assessment were the base in establishing the following rehabilitation treatment. After the first month of rehabilitation treatment there were some improvements in ankle mobility, calf circumference and gait parameters. After 6 months of rehabilitation treatment we noted a significant decrease of the step time and enhancement of the walking speed and cadence. The ankle mobility enhanced, especially plantar flexion during the supporting phase. There was a better load of the lateral border, metatarsal heads and hallux. The heel-rise test was significantly improved. Ankle stability increased after the rehabilitation treatment, in most patients. *Conclusions*. Zebris CMS-HS system allows quick and simple analysis of the most important gait parameters being a noninvasive tool. The rehabilitation treatment was important because it increased ankle stability increasing patients' confidence in returning to sports.
Key words: *tendon rupture, surgical treatment, rehabilitation, plantar pressure platform.*

Introduction

Rupture of the Achilles tendon is a relatively common injury which typically occur in males between the ages of 30 and 50 years, and account for approximately 40% of all operative tendon repairs (1-3).

Complete ruptures tend to occur in middle-aged patients and those without preexisting complaints. Partial ruptures occur in well-trained athletes and involve the lateral aspect of the tendon. Acute ruptures commonly result from eccentric overload on a dorsiflexed ankle that has chronic tendonitis (4).

The appropriate management of acute Achilles tendon rupture continues to be a controversial issue in the orthopedic literature. There are supporters for non-operative treatments and others for operative treatments (5). Both methods are used according to operative candidacy. Athletes usually undergo surgery with lower re-rupture rates and quicker return to previous activity.

The surgical treatment is also used for active patients. Conservative treatment is usually indicated in chronically ill patients, elderly patients with higher rates of re-rupture but lesser complications (4).

Rehabilitation after rupture of the Achilles tendon is slow with returning to sport in about six to nine months (6). Many patients have persistent symptoms for years. One of the factors that determine the outcome after rupture of the Achilles tendon is abnormality of gait (7). In many cases the cause is not exactly known and the rehabilitation of gait in these patients is not very well studied.

The main aim of this investigation was to quantify the acute changes in gait and plantar pressure measurements after rupture of the Achilles tendon surgically repaired. Another important objective was to demonstrate the impact of this evaluation in establishing functional treatment.

Material and Method

We prospectively evaluated 15 cases of surgically repaired Achilles tendon ruptures. The assessment was made after cast removal and then after 1, 3 and 6 months of rehabilitation treatment. All patients signed an informed consent before the first evaluation. There were 13 men and 2 women with an average age of 36 years (minimum 27, maximum 52). The tendon rupture occurred in sport activities in all patients.

The gait assessment was performed with a Zebris CMS-HS tridimensional analysis system, from Technical University of Timisoara, Mechanical Faculty (8). Zebris system allows simple and quick determination of temporal and spatial gait parameters analyzing markers trajectory on human body (9-11). Measurement method is based on determining spatial coordinates of miniature ultrasonic transmitters by measuring time between emission of the sonic wave from transmitters placed on the subject of study and reception by the microphones of the measuring sensors (fig.1). We have chosen this evaluation system due to its ultrasound – based operation system, which inflicts no damage on patients; therefore it was easily accepted by patients and relatively simple to use.

In order to evaluate plantar pressure of these patients we used a plantar pressure platform Zebris FDM running on capacitive forces sensors, arranged in a 208x56cm size matrix (fig. 1).

The systems are provided with software which processes the data and provides a report with suggestive images and a series of temporal and spatial gait parameters, therefore making them quick and efficient. Both feet of the patients were analyzed three times. The data obtained from the intact feet were taken as the control group.

The patients were also evaluated clinically using heel-rise test and calf circumference. We used only the heel-rise repetition parameter.

The heel-rise test was performed with the participant standing on an incline placing the ankle in 10º dorsiflexion. The subject had to raise the heel as much as he could at each heel-rise and then lower it down with a frequency of 30 repetitions/min. We counted the number of repetitions. The standing heel-rise test offers clinicians a reliable assessment of calf-muscle performance (13).

Calf circumference was measured at its widest point with a standard tape measure. Calf circumference was measured with the patient seated with the knee flexed 90º and hanging over the edge of the table, with the gastrocnemius relaxed.

In a first phase the foot was immobilized in a cast in equine position for a period of 3-4 weeks, then in a plaster with fixed ankle in neutral, still 3-4 weeks. After cast removal, a higher heel was used for tendon protection for a period up to 8 weeks.

Figure 1. Zebris CMS-HS system, marking anatomic points (left), Zebris FDM platform (right)

The rehabilitation program began after surgery and it was differentiated according to the time passed from the surgical intervention.
In the first 8 weeks the major objectives were maintaining physical condition, pain and swelling management, gait with devices without weight bearing for 4 weeks and then with progressive weight bearing.
The next 8 months the rehabilitation objectives were gait rehabilitation, increasing ROM and muscle strength, improving scar mobility. We used criotherapy, ultrasound, kinetotherapy with calf muscles stretching, isometric exercises, isotonic exercises with elastic bands.
The period between 17^{th} and 20^{th} week after surgery we emphasized on complete gait rehabilitation, easy running, strength improvement and balance and coordination improvement.
We continued with passive and active exercises, isometric and isotonic and have begun heel-raise exercises and balance exercises on balance board and one-leg exercises. The patients have started running and other sport activities (14).

Results

At first evaluation the average value of difference between calf circumference of the affected leg and the normal leg was 5 cm (2-8cm). After one month of rehabilitation the average difference between calf circumferences improved with 2 cm. The next evaluation showed an average improvement of 0.5cm in the difference of calf circumference. After six months of rehabilitation treatment the mean difference between calf circumferences was 1.5cm.
The heel-rise test showed a better improvement after six months. The first evaluation was made after one month of rehabilitation and the average of the heel-rise test showed 10 repetitions/min on the affected leg and 25 repetitions/min on the unaffected leg.
After three month of rehabilitation the number of repetitions on the affected leg had an average of 14 repetitions/min growing after 6 months at 20 repetitions/min.
There was a big improvement but even after six months there was still a difference between the affected and the unaffected leg.
Regarding the temporal and spatial parameters of gait, they suffered a great improvement after six months of rehabilitation.
The first evaluation revealed significant differences in stance time, swing period and step length on the affected leg compared with the unaffected leg. Thus the stance period was shorter on the affected leg with a longer swing time and the step length of the affected leg was also shorter. The single support period was shorter on the affected leg (table I).
The step length of the affected leg was longer and after 3 months was similar to that of the unaffected leg. The step time decreased significantly after 3 months of rehabilitation. There was an important increase of swing period after 3 months of rehabilitation.
After 6 months of rehabilitation treatment we noted a significant decrease of the step time, increase of step length and enhancement of single support on the affected leg. There were also some improvements regarding the gait periods thus the stance period decreased because the load response and the double support periods decreased.
We noticed that the spatial and temporal parameters began to improve after 1 month and after 3 months the mean values were almost the same as after 6 months of rehabilitation treatment, very close to normal values (table I).
The plantar flexion in swing period of the affected leg was much smaller than the plantar flexion of the unaffected leg. There were also some differences regarding plantar flexion during stance period and dorsal flexion during swing period of the affected leg, both smaller than those from the unaffected leg (table II).
After the first month of rehabilitation treatment there were some improvements in ankle mobility. After 3months the plantar flexion and dorsal flexion in swing period improved significantly and also the plantar flexion in stance period. After 6 months the ankle mobility enhanced, especially plantar flexion during stance phase (table II).
After 1 month of rehabilitation we assessed the plantar pressure in both feet and we noticed that there was a lower pressure on the forefoot with no pressure on hallux and lower pressure on the lateral border of the foot with an increased pressure on the hind-foot of the affected leg (fig 2).
After 3 months of rehabilitation we noticed that the pressure increased on the metatarsal heads but the pressure remained low on the hallux and lateral border of the foot (fig 2).
After six months of rehabilitation treatment there was a better load of the lateral border, metatarsal heads and hallux, the plantar pressure being similar on the affected leg with that on the unaffected leg (fig 2).

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Table I. Temporal and spatial parameters of gait in all the evaluations (mean values)

Parameter	Affected Leg				Unaffected Leg			
	First evaluation	1 month	3 months	6 months	First evaluation	1 month	3 months	6 months
Step time (s)	0,85	0,8	0,74	0,69	0,68	0,7	0,7	0,69
Step length (cm)	35	46	54,5	56	50,5	51	55	55
Stance period (%)	69	68,4	65,2	63,5	75	70,3	66	64,5
Swing period (%)	31	31,6	34,8	36,5	25	29,7	34	35,5
Load response (%)	19	17,5	16,7	16	26,3	24,6	18	16
Single support (%)	23,7	26,3	30	31,5	29,7	28,2	31,3	32,5
Preswing (%)	26,3	24,6	18	16	19	17,5	16,7	16

Table II. Ankle mobility in gait in all the evaluations (mean values)

Swing phase								
	Dorsal flexion				Plantar flexion			
	First evaluation	1 month	3 months	6 months	First evaluation	1 month	3 months	6 months
Affected leg	6,7	13	15,7	19	10,1	14	17	18,7
Unaffected leg	15,2	16	18	19,5	17	17,5	18	19,6
Stance phase								
	Dorsal flexion				Plantar flexion			
	First evaluation	1 month	3 months	6 months	First evaluation	1 month	3 months	6 months
Affected leg	21	24,5	26,4	27	8,5	10	12	16
Unaffected leg	26,4	26,7	26,7	28	16	17	18,5	19,5

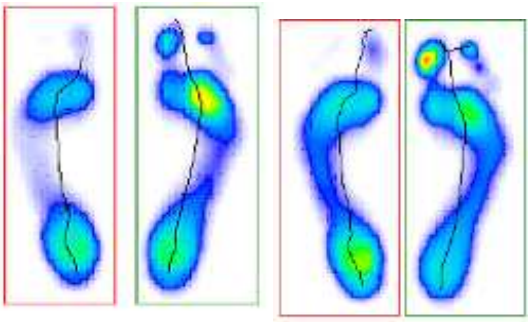

Figure 2. Exemple of plantar pressure of a patient with Achilles tendon rupture
1 month (left), 3 months (middle) and 6 months (right) after rehabilitation treatment

Discussions

We could not find studies with Zebris system analysis of gait in patients with Achilles tendon ruptures.

Most studies evaluate the outcome after Achilles tendon rupture according to the type of treatment, surgical or conservative. There are a lot of papers which point the benefits of early weight bearing in the treatment of Achilles tendon rupture (15-17). All of them pointed the importance of functional treatment in the recovery of patients with surgically treated Achilles tendon rupture that is the reason why we wanted to study the effects of rehabilitation treatment on patients with surgically treated Achilles tendon rupture.

We found many similar results: after 6 months of rehabilitation treatment patients were functionally well recovered.

We used a combination of different assessments which other authors used separately. Most evaluations of the outcome after Achilles tendon rupture have focused on strength measurements and complications. Clinical measurements of calf circumference, tendon width and ankle range of motion have also been included in most studies.

Tendon width and maximum calf circumference are among the most studied parameters after Achilles tendon rupture. In a previous study Moller and al. revealed that the number of repetitions of heel-rise test is more reliable for functional outcome than calf circumference and tendon width and usually the heel-rise test is still modified 1 year after surgical treatment (18). We found some similar results regarding the heel-rise test which is still modified after 6 months of rehabilitation (12, 18, 19).

Regarding the difference between calf circumferences we observed that there was still a difference between calf circumferences even after 6 months, similar results with other studies (20-22).

There are few studies with gait analysis after Achilles tendon rupture and most of the results from these studies were no different from ours.

Naim and al. noticed no significant difference in dorsiflexion, plantar flexion, the period of stepping phase, the duration of standing and floor reaction pressure after a medium of 16 months between the affected and non-affected leg (21). We noticed that even after 6 months of rehabilitation the gait and plantar pressure parameters were almost the same at the affected and unaffected leg.

Regarding the gait parameters and plantar pressure there were some studies about the use of orthosis in order to improve the functional outcome of Achilles tendon ruptures (23). In some studies there was an evaluation of gait after long immobilization with a poor outcome after one year (24). Costa and co. revealed in their study an increased pressure on the heel with a low plantar pressure on the fore-foot which is one of the results we obtained in our study (6).

Conclusions

Zebris CMS-HS system allows quick and simple analysis of the most important gait parameters being a noninvasive tool. Zebris is a very useful tool in evaluating the rehabilitation treatment.

Gait parameters were modified after surgical treatment and cast removal but they improved after 3 months and after 6 months they were very close to normal values. The heel-rise test was modified even after 6 months that is a reason for continuing rehabilitation program especially for calf muscle strength.

Taking into consideration that most of our patients were involved in sports as a hobby or professional, the rehabilitation treatment was important because it increased ankle stability increasing patient's confidence in returning to sports.

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Corresponding author
Berteu Oana,
Rehabilitation Department,
University of Medicine and Pharmacy Victor Babes,
Timisoara, Romania.
Em-ail: *oanabereteu78@yahoo.com*

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