Abstract

Background

The transfer of Flexor Hallucis Longus Tendon (FHL) is an established method for the treatment of chronic Achilles tendon ruptures. An extensive examination of power, strength, endurance and complications related to this procedure is presented.

Methods

21 patients treated with open FHL transfer for chronic Achilles tendon rupture were studied retrospectively. Medical records were reviewed. The patients were examined with a test battery for triceps surae strength, functional tests and PROMs.

Results

The median maximal concentric strength was equal,1300 vs 1336 W, comparing affected with unaffected side. The endurance tests showed a larger difference, 219 J vs. 2398 J, respectively. The median AOFAS score was 87. 11 of 21 patients sustained one or more complications; the most common were infection, disturbed wound healing, and clawing of small toes.

Conclusions

Patients achieve almost normal maximal strength after open FHL transfer, but endurance is notably lower. The complication rate was high.

Keywords:

Chronic Achilles rupture. FHL tendon transfer. Functional outcome. Complications.

1. Introduction

Chronic Achilles tendon ruptures can be treated with fascia plasty or tendon transfers. The transfer of the flexor hallucis longus (FHL) tendon for chronic Achilles tendon disorders can both reduce pain and improve function [1, 2]. After FHL tendon transfer the maximum plantar flexion strength is reported to be reduced by 16-35 % [3, 4, 5, 6, 7] when compared to the contralateral extremity, and patients are reported to have reduced function for single- and two-leg heel-rise tests. However, there are no studies that report patients' return to work and their ability to walk or jump. One study [3] contains gait analysis after FHL tendon transfer without pathologic findings.

In the present study the results after FHL tendon transfer for Achilles tendinosis and chronic Achilles tendon rupture, with focus on function, are presented. We have used a new method for strength measuring and done a

comprehensive testing on both maximal strength and endurance, as well as functional aspects as jumping and walking. An understanding of anticipated effect and the possible complications is important for preoperative evaluation and counseling the patients prior to surgery.

2. Materials and Methods

This is a retrospective study of 34 patients treated at Oslo University Hospital with FHL tendon transfer due to chronic Achilles tendon rupture between January 2004 and January 2014. We did a review of the medical records and a follow-up with PROMs and functional tests. At follow-up two patients were dead. 32 patients were invited for study inclusion and 21 patients responded to the invitation. The inclusion criteria for study participation was chronic Achilles tendon rupture treated with a transfer of the FHL tendon. A chronic Achilles tendon rupture was defined as a rupture with a diagnostic delay of more than 4 weeks, re-rupture and ruptures with significant loss or degeneration of tendon tissue. Preoperatively, all patients reported severely reduced walking ability.

2.1 Surgical technique

The surgery consisted of an open FHL tendon transfer to the calcaneus. The standard method described by Wapner in 1993 [1] with a two-incision technique was performed in all cases, with small modifications. *A tenodesis between the distal FHL stump and the FDL was done. FHL was re-routed*

proximally towards the proximal stump of the resected Achilles tendon to which it was tenodesed. In this way the tendon transfer both allowed the FHL muscle and the triceps surae to act on the calcaneus. Care was given to attach the FHL tendon with suitable tension – allowing the foot to be brought up to approximately 15 degrees of plantarflexion by finger power. No other attempt to quantify the tension was made. Most interventions were done in teams of two or more surgeons.

Postoperatively, all patients were kept non-weight-bearing in a cast for 6 weeks. Between 6 and 12 weeks weight- bearing as tolerated in a walker boot was allowed. Patients who experienced difficulties doing the exercise program were offered support from a physiotherapist.

2.2 Follow-up.

The tests performed at the follow-up visit were mainly performed by a physiotherapist and an orthopedic surgeon present. The investigators were involved in the treatment of some of the study patients. Sneakers in different sizes were provided to ensure that all patients used the same footwear during the tests.

The follow-up visit included different tests regarding strength, a six-minute walk test, a one leg balance test and a sensation test for nerve function of the great toe. Two organ specific questionnaires, the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot score [8] and The Victorian

Institute of Sport tendon study group (VISA-A) questionnaire [9] and one general health questionnaire Short-Form Health Survey (SF-36) [10] were used. Additionally, surgery related complications, and return to work were registered. For each patient, the medical record was reviewed regarding complications and treatment.

2.2.1 Strength tests.

For an extensive testing of power and endurance we used a battery of tests developed and described by Silbernagel [11]. The test results were registered by the Musclelab tm (Ergotest innovation as, Porsgrunn, Norway) hardware and software systems. The hardware consists of a thread and a spool that records extension and time for a linear movement, and a “photocell carpet” that records the duration of time for the foot being off the floor during jump tests.

Briefly, the test battery included three jump tests and three heel rise tests (strength tests). In the jump tests there were drop counter jumps and standing jumps, both one leg at a time, in addition to a repeated hop test on the floor, one leg at a time.

The strength test included three different strength tests with heel rise. Plantar flexion concentric heel rise test, started with the ankle dorsally flexed, an eccentric test, starting on tiptoe with a quick dorsiflexion before the plantar flexion, and an endurance test performing a number of heel rises. The two

first tests were performed on each leg separately with increasing external load, and the last test was performed one leg at a time, but without external load. The number of repeats, acceleration, speed and maximal distance (heel rise in centimeters) were registered and the power (Watt, W) and total work (Joule, J) were calculated. If a patient was not able to perform a test, the specific test was skipped.

2.2.2 Other tests.

The patients were subjected to a six-minute walk test, as described by the ATS committee [12].

For the assessment of balance, it was measured for how long time the patients were able to stand on one leg. Standing on one leg for more than ten seconds without corrective movement in the upper body (torso or arms) was considered good. Additionally, the patients were interviewed about imbalance problems in daily life activities.

Thoroughly examination, interview and review of the medical records concerning wound healing problems, wound infection, and surgery related complications were recorded. Any reduced nerve function (loss of sensation) and clawing of the toes were recorded as complications.

The patients completed a form on work participation before and after surgery.

2.3 Statistical methods.

Statistical analyzes were performed using the Excel software, version 2010 (Microsoft Office, Redmond, Washington, USA).

For the evaluation of the functional tests, the values for the affected leg were compared with the values for the unaffected leg and are presented as a ratio of the healthy leg. The numbers are presented as median values and range. The results from the six-minute walk test were compared to age matched expected values and adjusted for height and weight using a calculator developed by the University of Oslo, department of medicine [13]. The median values with ranges are presented as percentage of expected walking distance.

Both the organ specific questionnaires (AOFAS and VISA-A) result in a score 0-100. Median and range values are presented. SF-36 is processed in a special program and presented as graphics in different health aspects compared to Norwegian norm values [10]. Incidence of complications is presented as real numbers and percentage.

3. Results

3.1 Biometrics.

21 of 34 patients were seen at follow-up (6 women and 15 men) at median 54 months (9-98) after surgery. Median age at operation was 54.5 years (32-77).

3.1.1 Indications for surgery.

Nine of 21 patients had had previous surgery for Achilles tendon related problems; eight patients had undergone previous surgery with Achilles tendon suture for acute rupture, and one had been operated for Achilles tendinopathy. These 9 patients had poor function due to an elongated tendon. Three patients had complications after the initial surgery with infection, one of these presented with an active infection and open wound at the time of surgery because of recent Achilles tendon surgery. This patient was treated with a free flap for coverage of the wound after the FHL procedure.

Twelve of 21 patients had no previous surgery; three experienced spontaneous Achilles tendon ruptures after cortisone injections for pain, and nine patients had old Achilles ruptures with poor function and reduced power after conservative treatment.

3.2 Functional tests.

The concentric strength (figure1) was median 1300 W (880-1890) in the affected leg and 1336 W (876-1996) in the unaffected leg. Fifteen patients were able to perform the tests on both legs. For the eccentric strength tests, data are mostly missing as16 patients were unable to complete the test according to protocol.

In the heel rise endurance tests (figure 2) the performances showed a marked difference between the number of repetitions for the affected side; 5.5 (1-38) and the unaffected side; 26.5 (3-103). We also calculated the total work

energy (J), which showed an even greater difference between the legs, the affected side was 219 J (24-1268) and unaffected side 2398 J (83-5357). The median ratio was 0.18 (0.03-0.77). Only 12 patients conducted this test completely. In addition, 6 patients managed to test the unaffected leg, but not the affected leg.

The amplitude of the new motor unit (the transferred FHL) was measured and found reduced compared to the unaffected side with intact gastrocnemicus - soleus complex (figure 3). This pattern was observed for several of study parameters. The concentric strength test was the most complete data set, and in this test we found a reduced amplitude in every patient (15 complete data sets). The amplitude for the affected side was median 7.35 cm (4.3-12.3) and (6.1-17.9) in the unaffected 13.7 cm. The ratio between affected and unaffected side was median 0.72 (0.37-0.93).

Single jump-test battery from standing position on the affected leg (figure 3) demonstrated a median jump height of 4.4 cm (1.32-11.86), and 7.85 cm (1.57-15.02) on the unaffected side. The median ratio was 0.70 (0.34-1.35). In single drop counter jump the patients performed 8.3 cm (3.63-14.01) on the affected leg, and 13.4 cm (4.15-19.33) on the unaffected leg. The median ratio was 0.79 (0.49-0.89). 18 patients conducted the singe jump test, but only 10 patients managed to fulfill the drop counter jump test.

The hopping test showed increased height (3.5 vs 4.1 cm) and flying time (4.5 vs 6.3 seconds) on the unaffected leg compared to the affected leg. The flying time is the sum of seconds without the foot contacting the ground.

In six-minute walk test (figure 4) the performance was median 609 meters (371-825) which is 110% (61-143) of the age matched expected walking distance, hence most patients performed better than expected according to their biometrics.

3.3 Scoring systems

Median AOFAS ankle-hindfoot score was 87 (60-100), median VISA-A score was 81 (37-99) (Fig. 3). Median SF-36 in the study group is compared to normative data for the Norwegian population [10] (Fig. 5) and demonstrates higher levels in the study group.

Five of the patients were retired or had disability compensation before surgery.16 patients were working before surgery. 13 of these were able to return to their former work, and three patients could not return to their former profession because of pain or malfunction of the affected leg.

3.4 Side effects / Complications.

None of the patients had problems with reduced balance when performing daily activity. When performing the balance test 17 patients managed more than 10 seconds on one foot. Four patients managed between 5 and 10 seconds. Three patients managed 5 seconds, and one patient managed for 3 seconds.

5 of 21 patients had reduced dorsal flexion of the ankle by approximately 10 degrees compared to the unaffected side.

11 of 21 patients (52%) sustained one or more complications. Five (24%) patients had infection, three of these were deep infections and one patient was in need of plastic surgery to achieve skin coverage. One of the patients with infection had a prolonged wound healing, of twelve months, although the functional outcome was excellent. None of the three patients who had an infection prior to the FHL transfer, had woundhealing problems or infection related to the FHL procedure. Two (10%) patients had prolonged wound healing without infection. Two (10%) patients had problems with claw toes and were operated with distal tenotomy of the flexor digitorum longus tendon. Six patients (29%) had areas with reduced skin sensation; two patients with affection of great toe, three patients had poor sensibility in the sural nerve area and one with reduced sensation in the heel pad. One (5%) patient had a new injury three months after the operation and suffered a rupture of the transferred FHL tendon.

4. Discussion

In the present study the main focus was the functional results after the transfer of the flexor hallucis longus tendon for chronic Achilles tendon rupture. 34 patients were operated on for a period of 10 years. 21 patients were seen at a follow-up study visit and were included in the study.

One of the most striking findings was the high incidence of complications. Only 6 of 21 patients did not suffer any complication. All wound complications healed, but they resulted in a prolonged healing time and additional surgery.

None of the patients in this present study were smokers. Other publications report complication rates ranging from 0 to 21%, and only minor complications are reported [1, 2, 3, 7, 14, 15]. Our patients had a high rate of preoperative soft tissue problems. 9/21 had previous surgery at the location of FHL transfer surgery. Re-operations generally have a higher complication rate. The three patients with former infection all healed well and in the tests these patients performed on the same level as the other patients. This is also a vulnerable area for surgery, the Achilles tendon and posterior parts of calcaneus have only sparse soft tissue coverage. Dissection of upper part of tuber calcanei for the drill hole may increase the risk of skin slough. There is one study comparing different attachment of the FHL transfer not showing any difference in functional outcome [5]. There are reports of good outcome with a possible weaker fixation through more gentle approach, with the FHL tendon graft fixated only with an anchor [16, 17] which appear as a reasonable modification of the method. Arthroscopic FHL transfers have also been described [18, 19] and could result in less wound complications.

Overall, the patients obtained a good functional outcome demonstrating an almost equal maximal strength compared to the un-operated side, but with reduced endurance. The patients underwent a comprehensive functional test battery for the evaluation of ankle function, mainly the plantar flexion in the ankle joint [11]. The test results demonstrated a maximal plantar flexion strength of 96% when compared to the unaffected leg. This is a smaller loss than in other studies, which reported a loss of strength of 16-35% [3, 4, 6]. These studies, however, solely report the results when testing the maximal strength and do not give any information concerning the endurance. In this

patient group, the Achilles tendon was tenodesed to the graft to obtain more power. The good power measurement in the study may origin from this construction,however, five patients who did not complete the tests, were excluded. The endurance for plantar flexion was notably reduced compared to the unaffected leg, demonstrating 34% of the number of heel rises performed and 18% of the total work given for the unaffected leg. There are no reports in the literature describing functional strength evaluated with maximum jump height and working distance (amplitude of the muscle-tendon system). We present a comprehensive view on power yield and we find that the new tendomuscular construction provide less lasting power with low endurance. Also the jump height is reduced to 79% of the unaffected leg. We observed a large difference in the performance between each patient.

At evaluation of the test results, the number of patients that were able to carry out the endurance tests on both legs were limited, which again may suggest that the endurance test results are overestimated in the study group and the performance is even more reduced.

The amplitude for the new muscle-tendon system is clearly shorter than the normal muscle-tendon system. There are several possible explanations for this. The FHL muscle has a shorter amplitude than the triceps surae muscle. Biomechanics are also less favourable compared to an unaffected leg, since the distance from the center of the ankle to the insertion point at the calcaneus is shorter than to the Achilles tendon insertion [20]. The diseased Achilles tendon and triceps surae muscles can also be infiltrated with scar tissue that reduces the amplitude. In this patient group, the Achilles tendon

was tenodesed to the graft to obtain more power, this may reduce the amplitude of the new graft complex.

Despite low endurance, the walking ability tested with six-minute walk test, showed normal walking capability compared to age- and BMI-matched normal population. A normal Achilles tendon with respect to power, ankle ROM or endurance is therefore not a prerequisite for a normal walking ability. During normal to fast walking, gait analysis has been performed in a study [3] with patients with FHL transfer, showing a normal gait. Our patients had severely reduced walking ability before surgery although no physical tests were done to measure that before the operation. Most patients also functioned in their work after surgery. The surgical intervention has consequently restored function in the study group.

The great toe is thought to have an important role in balance and especially the FHL who is the strongest flexor muscle for the great toe, should be important in this regard. No patient complained of reduced balance or power of propulsion. The great toe also has the flexor brevis muscle and in most cases had a distal FHL to FDL tenodesis was done, which may contribute to our findings.

An unexpected finding was the problem with clawing of the lesser toes. This is possibly caused by unintended tightening of the FDL tendon when performing tenodesis for the distal stump of the FHL tendon. This may also support that tenodesis at the level of the knot of Henry should be avoided, and also unnecessary [1].

Median AOFAS was 87 which is in accordance with previously published materials [7, 14, 15], consistent with a good functional outcome. For some patients there are a clear difference between AOFAS and VISA score, this is due to the different focus between these PROMs.

This material includes 21 patients, a patient series comparable to previously published materials. Our follow up time was in average 49 months which is the longest follow up time reported. However, the range in follow-up in the present study is wide. The study inclusion period is long. There are minor modifications of the performed procedure during the 10 year of study inclusion, and one must assume that the skills and preferences at the foot – and ankle service has evolved during this period, regarding the indication for surgery as well as operative technical details. No attempt to stratify the material based on the year of surgery was performed.

A limitation in this study is the low participation rate, in addition some patients were not able to conduct all the tests, and data from these patients are missing. This means that the function after surgery may be overestimated in this study, especially regarding endurance. On the other hand one can assume that well-functioning patients do not see the benefit of participating while patients with persistent trouble with their Achilles tendon tend to join the study to a larger extent. In that respect, our study may underestimate function and overestimate the incidence of complications. Our impression, though not studied objectively, is that young healthy patients perform better than older patients with co-morbidities.

An understanding of anticipated function and complication risk is important for preoperative judgement and when giving information and advice to the patients prior to surgery. The patient and the surgeon should be aware of that this method entails a substantial risk for soft tissue complications, in particular with a history of previous soft tissue problems. In conclusion the patients demonstrate normal gait function and maximal plantar flexion power, while endurance, numbers of repetitions and jump height are notably reduced after FHL transfer for chronic Achilles tendon rupture. We will use this information to improve the patient selection, give more accurate information prior to surgery and evaluate and modify the surgical technique.

4.1 Acknowledgements.

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Maximal concentric strength

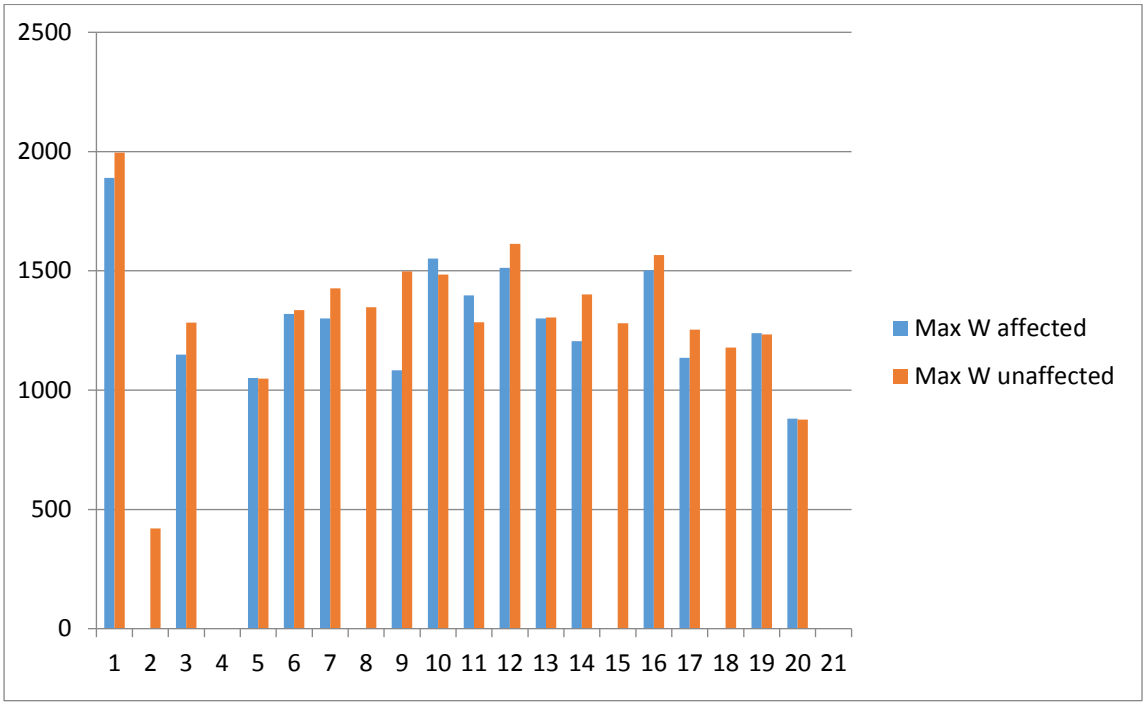


Figure 1: The figure demonstrates maximal concentric strength (power) in the affected side (blue columns) and unaffected side (red columns) in Watts (W). Patient number 2, 4, 8, 15, 18 and 21 do not have complete data sets and are excluded from the calculations.

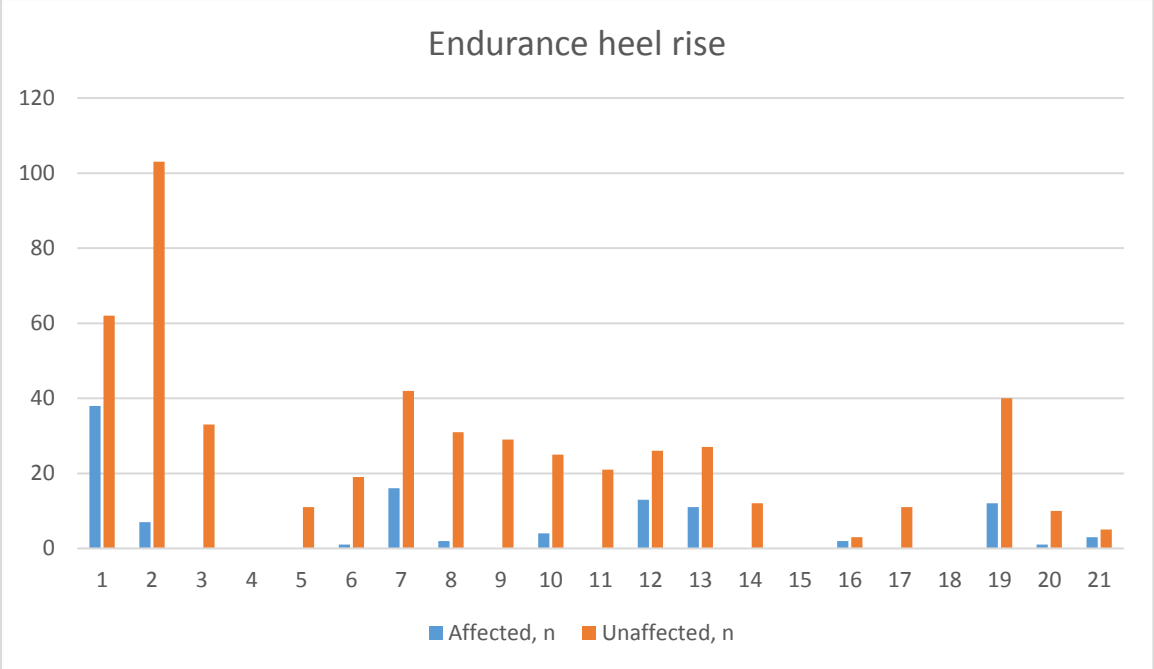


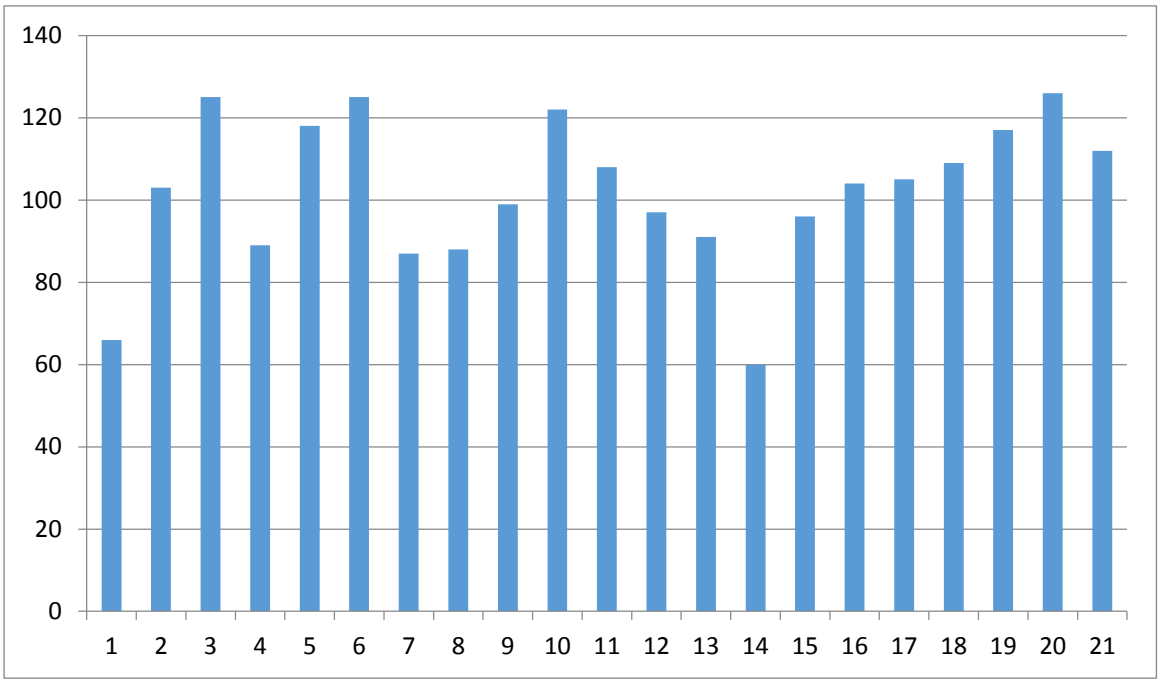
Figure 2: The figure demonstrates number of heel rises in the endurance test (affected side blue and unaffected side red). Nine patients could not complete this test, six of them performed on the unaffected leg only.

Functional tests.

	Affected side	Unaffected side	Median ratio
Max strength, W	1300 (880-1890)	1336 (876-1996)	0,96
Endurance, n	5,5 (1-38)	26,5 (3-103)	0,34
Amplitude, cm	7,3 (4,3-12,3)	13,7 (6,1-17,9)	0,72
Single jump, cm	4,4 (1,32-11,86)	7,85 (1,57-15.02)	0,70

Figure 3: Functional tests, median values and range. Only complete datasets are included (n=15).

448 Walking distance



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450 Figure 4: Walking distance for each patient presented as percentage of expected walking
451 distance corresponding to their biometrics.

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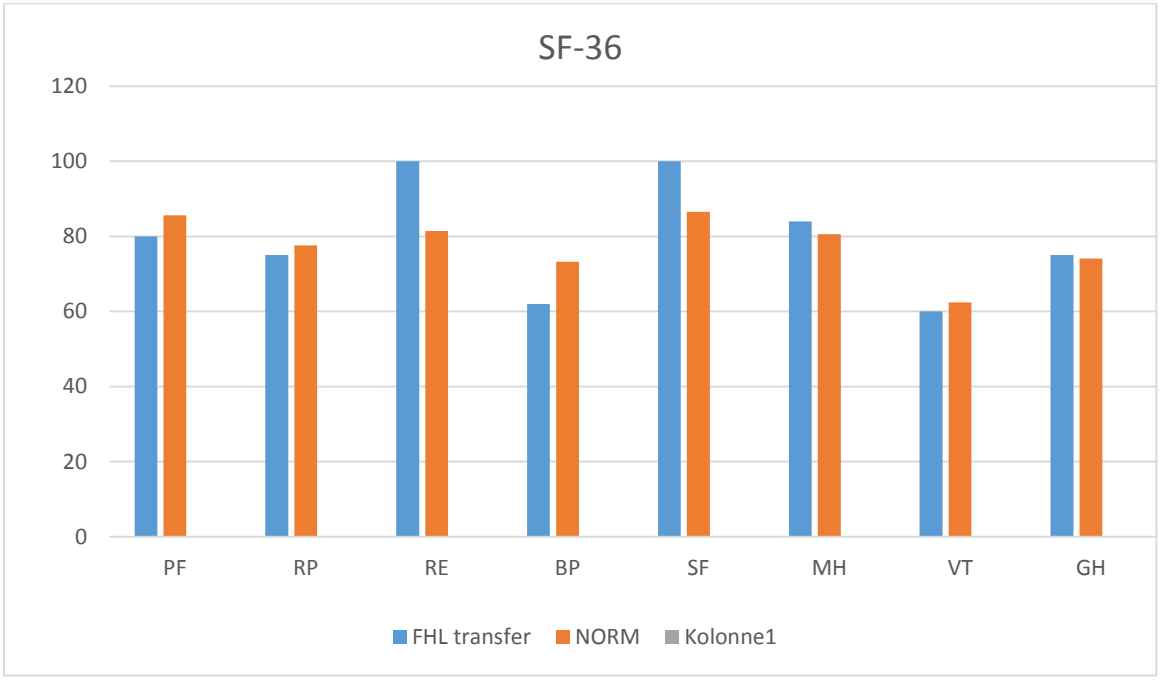

453

454 Figure 5: Short Form 36(SF-36) results in median (blue line) compared to normative data from
455 Loge (10) (red line). The different aspects are: PF physical functioning, RP physical role
456 functioning, RE emotional role functioning, BP bodily pain, SF social role functioning, MH
457 mental health, VT vitality, GH general health perceptions