CLINICAL FUNCTIONAL ASSESSMENT OF PATIENTS AFTER ACHILLES TENDON PERCUTANEOUS SUTURE
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SUMMARY
Introduction
Achilles tendon is the largest and most powerful tendon in the whole body. It transfers very large, constantly repeated loads, which often results in injuries. Achilles tendon injuries can be treated both, by limb immobilization or surgically. The preferred surgical method is minimally invasive percutaneous suture. The procedure involves approximating the tendon stumps with a single-stranded Bunnel suture through the small incisions in the skin. This technique allows for rapid rehabilitation.

Aim
The aim of the study was to present the results of clinical evaluation of patients after percutaneous Achilles tendon suture.

Material
Twenty-eight patients which underwent percutaneous suture of injured Achilles tendon were enrolled in the study.

WYNIKI KLINICZNEJ OCENY FUNKCJONALNEJ PACJENTÓW PO PRZEZSKÓRNYM SZYCIU ŚCIĘGNA ACHILLESA
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STRESZCZENIE
Wstęp
Ścięgno Achillesa to największe i najmocniejsze ścięgno w całym organizmie. Przenosi bardzo duże, wielokrotnie powtarzane obciążenia, w efekcie czego często narażane jest na uszkodzenia. Uszkodzenia ścięgna Achillesa można leczyć zachowawczo, unieruchamiając kończynę bądź operacyjnie. Preferowaną metodą operacyjną jest małoinwazyjne przezskórne szycie. Zabieg polega na zbliżeniu kikutów ścięgna wytrzymałym jednoniciowym szwem Bunnela przeprowadzanym przez małe nacięcia w skórze. Technika ta umożliwia szybkie podjęcie rehabilitacji.

Cel
Celem pracy było przedstawienie wyników klinicznej oceny funkcjonalnej pacjentów po przezskórnym szyciu ścięgna Achillesa.

Materiał
W badaniu wzięło udział 28 pacjentów operowanych techniką przezskórnego szycia uszkodzonego ścięgna Achillesa operowanych w latach 2011–2015. Średni wiek wynosił 41 (± 6,5) lat. Średni czas od operacji do czasu badania wynosił 34 (± 10,0) miesiące (od 12 do 57 miesięcy). Lewe

ścięgno Achillesa uszkodzone było w 20 przypadkach, w 8 przypadkach – prawe.

Methods

Three functional tests were used to assess Achilles tendon function: weight-bearing lunge test, heel rise endurance test and single leg hop for distance.

Results

The most important result of the study was finding of persistent functional deficits in the operated extremity after percutaneous Achilles tendon suture. The results of the weight-bearing lunge test showed a slight reduction in the extent of dorsal flexion in the operated limb when compared to the nonoperated limb. The results of the heel rise endurance test showed an asymmetry (18% difference) of the muscle strenght of the operated limb when compared to the unoperated limb. The single leg hop for distance test showed a negligible (3.5%) reduction in the ability of the operated limb muscles to generate power when compared to the unoperated limb. Despite functional deficits, 86% of patients returned to the full sport activity one year after the treatment.

Conclusions

Percutaneous Achilles tendon suture restores Achilles tendon function. The results of clinical functional assessment indicate a permanent reduction in the range of dorsiflexion and a decrease in endurance capacity of the operated extremity.

Metody

Do oceny funkcji ścięgna Achillesa zastosowano 3 testy funkcjonalne: test ścienny, test wspięcia na palce oraz skoku jednonóż.

Wyniki

Najważniejszym wynikiem z przeprowadzonego badania jest stwierdzenie przetrwałych deficytów funkcjonalnych w kończynie operowanej po przezskórnym szyciu ścięgna Achillesa. Wyniki testu ściennego (Weight-bearing lunge test) wskazały na niewielkiego stopnia ograniczenie zakresu ruchu zgięcia grzbietowego w kończynie operowanej w porównaniu do kończyny nieoperowanej. Wyniki testu wspięcia na palce wskazały obecność asymetrii w wytrzymałości mięśni kończyny operowanej na poziomie 18%, w porównaniu do kończyny nieoperowanej. Wyniki testu skoku jednonóż wskazały na nieznaczne (3,5%) zmniejszenie zdolności mięśni kończyny operowanej do generowania siły w sposób dynamiczny, w stosunku do kończyny nieoperowanej. Pomimo deficytów funkcjonalnych, 86% pacjentów powróciło do pełnej aktywności sportowej po roku od rozpoczęcia leczenia.

Wnioski

Przezskórne szycie ścięgna Achillesa przywraca funkcję ścięgna Achillesa. Wyniki klinicznej oceny funkcjonalnej wskazują na trwałe ograniczenie zakresu ruchu zgięcia grzbietowego oraz obniżenie zdolności wytrzymałościowych mięśni podudzia w kończynie operowanej.

Introduction

Achilles tendon is the thickest and strongest tendon of the human body, and yet it is very often damaged. In recent years increased incidence of Achilles tendon injuries have been observed in industrialized countries, probably due to the sedentary lifestyle, aging and increased physical activity of middle-aged people (Järvinen *et al.* 2005; Movin *et al.* 2005). Achilles tendon rupture frequency ranges from 18 to 100 000 per year (Sarman *et al.* 2016; Goren *et al.* 2005), however no data are available for the Polish population. Due to this fact, Achilles tendon is believed to be the most commonly ruptured tendon in the human body (Järvinen *et al.* 2005; Movin *et al.* 2005). The rupture incidents most commonly occur during sport activity (Järvinen *et al.* 2005; Movin *et al.* 2005), especially in 30–39 years old men (Skiba *et al.* 2006). Achilles tendon rupture causes sudden, severe pain and weakness of the calf muscles, which makes it impossible to climb on the toes of the injured limb.

The choice of treatment of Achilles tendon total rupture remains a topic of discussions between proponents of operative and nonoperative treatment (Movin *et al.* 2005; Khan *et al.* 2004). Nonoperative treatment requires immobilization of the foot in the gypsum dressing or crus-foot orthosis for about 6 to 8 weeks (Costa *et al.* 2006a). In many clinics, the surgical treatment is the treatment of choice. It is associated with the risk of postoperative complications (infections, problems with wound healing), however the risk of rerupture compared to nonoperative treatment is lower (Movin *et al.* 2005; Khan *et al.* 2004).

Regardless of the chosen method of Achilles tendon treatment, a prominent role in restoring the tendon efficiency is attributed to the proper loading of the treated limb. This procedure leads to faster reconstruction of the tendon and its strengthening, by targeting individual collagen fibers in the direction of the force being used (Costa *et al.* 2006a; Moller *et al.* 2002). On the other hand, lack of the load and consequently, lack of mechanical stimulation, leads to negative processes, reduction of blood supply, collagen fibers decay and reduction of a tendon strength. The ideal surgical technique of Achilles tendon suture would allow for immediate loading of an operated limb, with no risk of recurrence and the absence of postoperative complications. Studies aimed at investigation of the durability of different sutures indicate that single-stranded Bunnel suture is of the strongest (215–255 N) (Herbort *et al.* 2008). The use of the Bunnel suture allows for instantaneous leg loading in the crus-foot orthosis (Walker type boot with heel lift). This is due to the action of the Achilles tendon during the passive bending of the sole (from 20 to 100 N), while walking in an orthopedic Walker boot with or without a heel lift (190 N and 369 N, respectively) (Clanton *et al.* 2015).

The Achilles tendon percutaneous suture technique requires ten skin incisions, five along the lateral and five along the medial edge of the Achilles tendon. This enables use of a Bunnel suture, which results in strength gain, due to the possibility of early passive motion exercises in the ankle joint as well as loading of the operated limb immobilized in the plantar flexion.

Aim

The aim of the study was to present the results of clinical evaluation of patients after percutaneous Achilles tendon suture.

Material

The study involved 28 patients, from 19 to 61 years old, with documented transcutaneous surgical treatment of Achilles tendon injury. Patients were operated on from 2011 to 2015 in two distinctive clinics years in Poznań from 2011 to 2015. All patients were operated using the same surgical technique. The median age was 41 y. o. (± 6.5 years). The mean time from

the surgery to the study was 34 (± 10.0) months (from 12 to 57 months). Left Achilles tendon was damaged in 20 cases, the right one – in 8 cases.

Methods

The Achilles tendon function assessment was based on 3 functional tests: weight-bearing lunge test, heel rise endurance test and

Figure 1. Performance of the weight-bearing lunge test.

single leg hop for distance. Selection of the tests was dictated by the involvement of the Achilles tendon in their performance, repeatability, simplicity, safety and well-estimated value in the clinical judgment (Silbernagel *et al.* 2006; Olsson *et al.* 2014). The tests were preceded by a five-minute warm-up on a stationary bicycle.

The weight-bearing lunge test was performed for each limb separately. It was carried out as follows: the participant placed the examined lower extremity in the position that the foot was perpendicular to the wall and the knee had to be in line over the second toe. Afterwards, an attempt was made to touch the knee to the wall with the starting position stalled, that is without raising the heel from the ground (Figure 1). If it was possible to touch the knee to the wall, the foot was retracted back until the maximum range of the dorsiflexion in the ankle joint was reached. The tester stabilized the heel of the tested leg in order to record the moment of the heel rise. The maximum distance from the wall to the first toe of the examined foot measured in centimetres (with 0.5 cm accuracy) was taken as an outcome of the weight-bearing lunge test.
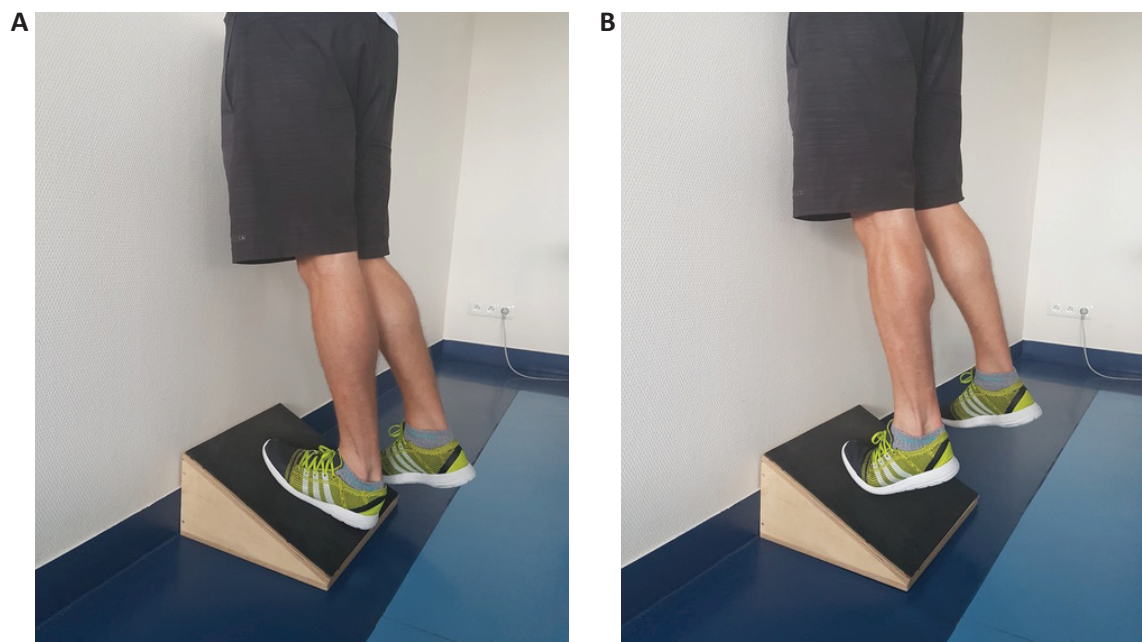

Figure 2. Performance of heel rise endurance test. (A) start position, (B) end position.

The heel rise endurance test was performed once for each limb separately. The examined foot was set on a 30 degree slope and the heel was below the level of the toes (Figure 2A). The test was performed as raising the heel above the level of the toes (Figure 2B). The number of repetitions performed was taken as an outcome of the test. The test was performed until the patient was unable to lift the heel above the toes level or refused to perform another repetition.

Single leg hop for distance(Figure 3) was performed 3 times for each lower extremity. The participant stood on the examined limb, performed a broad jump and landed on the examined extremity. The greatest distance from the three tests measured in centimetres (with 0.5 cm accuracy) was taken as an outcome of the single leg hop for distance.

Statistical analysis of the results was performed in the R environment. The level of statistical significance was set to $p < 0.05$.

This study was approved by the Bioethical Committee of the Regional Medical Council affiliated within Wielkopolska Izba Lekarska (opinion no. 191/2015, dated at 16.12.2015). All participants were informed about the objectives and scope of the study and signed the consent to participate in the study.

Results

86% of patients (24 out of 28) returned to full sport activity one year after the surgery. Four patients (14%) limited their activity after the surgery due to apprehension of another injury.

The results of the weight-bearing lunge test, heel rise endurance test and single leg hop for distance are presented in Table 1. The differences in performing the weight-bearing lunge test for the operated and nonoperated extremity were statistically significant ($p = 0.0015$). Average results of the weight-bearing lunge test obtained for the nonoperated limb was higher than

Figure 3. Performance of single leg hop for distance.

for the operated limb (Figure 4), which suggests significantly lower range of dorsiflexion in the operated limb. The largest difference recorded in the weight-bearing lunge test between the operated and non-operated extremity was 6 cm. The smallest difference was 2 cm and it reflects a greater range of dorsilexion in the operated limb. The reduction of the dorsiflexion of the ankle joint in the operated limb evaluated on the basis of the weight-bearing lunge test was observed in 20 out of 28 (71.5%) participants.

Weight-bearing lunge test result of the nonoperated (left side) and operated (right side) extremity. Boxes indicate the range from 25th to 75th percentile, thick central lines represent the medians, thin horizontal sections connected to the boxes are the limit values (minimum and maximum).

The differences in performing heel rise endurance test for the operated and non-operated extremity were statistically significant (p < 0.0001). The average heel rise endurance test scores for nonoperated limb was 6-repetition higher than the average for

Table 1. Functional tests results for operated and nonoperated limb.

	operated limb	nonoperated limb	p
weight-bearing lunge test [cm]	12,98 ± 2,51 (8,5 ± 19)	11,75 ± 2,74 (5,5 ± 17)	p = 0,0015
heel rise endurance test [number of repeats]	32,79 ± 11,91 (14 ± 72)	25,68 ± 8,54 (13 ± 41)	p < 0,001
single leg hop for distance [cm]	140,4 ± 25,65 (82 ± 178)	135,1 ± 24,09 (82 ± 175)	p = 0,0147

Values are presented as mean ± standard deviation. The minimum and maximum values are given in brackets.

the operated limb (Figure 5). The largest difference in number of repetitions was 44 (72 for the unoperated limb and 28 for
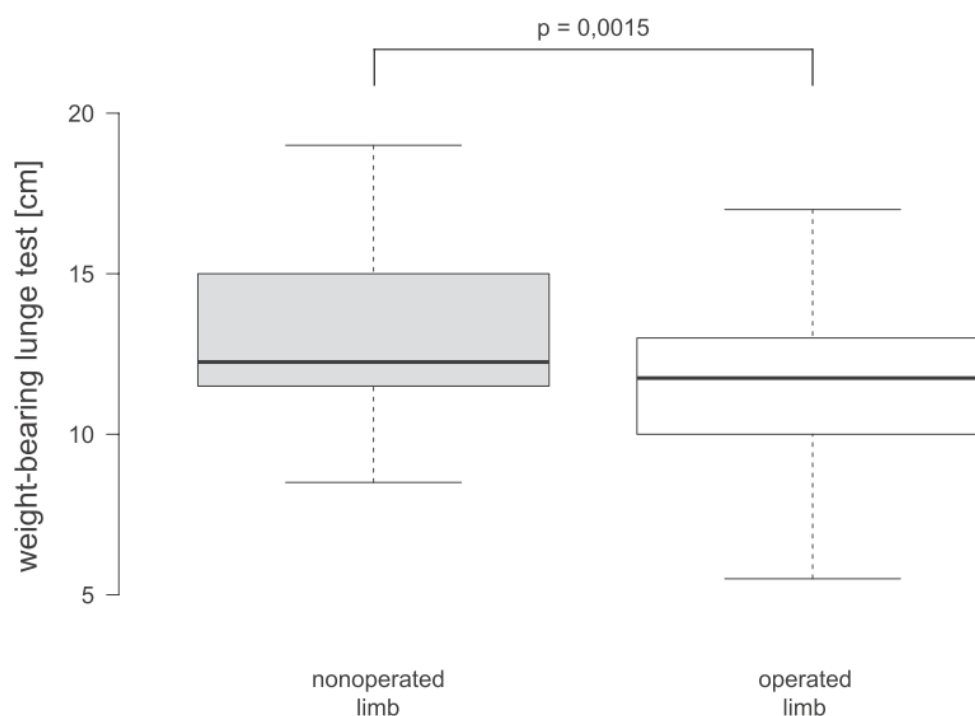

Figure 4. Distribution of the weight-bearing lunge test results for nonoperated and operated limb.

the operated limb). The smallest difference was 5 (41 for the operated limb and 36 for nonoperated one) and it reflects a greater number of heel rise repetitions for the operated limb. The reduction in number of heel rise repetitions for the operated limb when compared to nonoperated extremity was observed in 25 out of 28 (89%) patients.

Heel rise endurance test result of the nonoperated (left side) and operated (right side) extremity. Boxes indicate the range from 25th to 75th percentile, thick central lines represent the medians, thin horizontal sections connected to the boxes are the limit values (minimum and maximum).

The differences in performing single leg hop for distanc e for the operated and non-operated extremity were statistically significant (p = 0.0147). The average of the nonoperated limb jumping test results were greater of about 5 cm when compared to the results obtained for the operated limb (Figure 6). The largest difference recorded for single leg hop for distance was 24 cm (178 cm for unoperated limb and 154 cm

for the operated one). The smallest difference was 14 cm (96 cm for the operated limb and 82 cm for the unoperated one). The reduction in single leg hop for distance values for the operated extremity was observed in 21 of the 28 (75%) patients.

Single leg hop for distance result of the nonoperated (left side) and operated (right side) extremity. Boxes indicate the range from 25th to 75th percentile, thick central lines represent the medians, thin horizontal sections connected to the boxes are the limit values (minimum and maximum).

Discussion
The most important conclusion of the study was finding of persistent functional deficits in the limb operated with percutaneous Achilles tendon suture. Despite functional deficits, most patients returned to the active lifestyle.

One of the most important goals in orthopedic treatment is to restore the proper function of the body. There are several functional tests available for evaluating patients
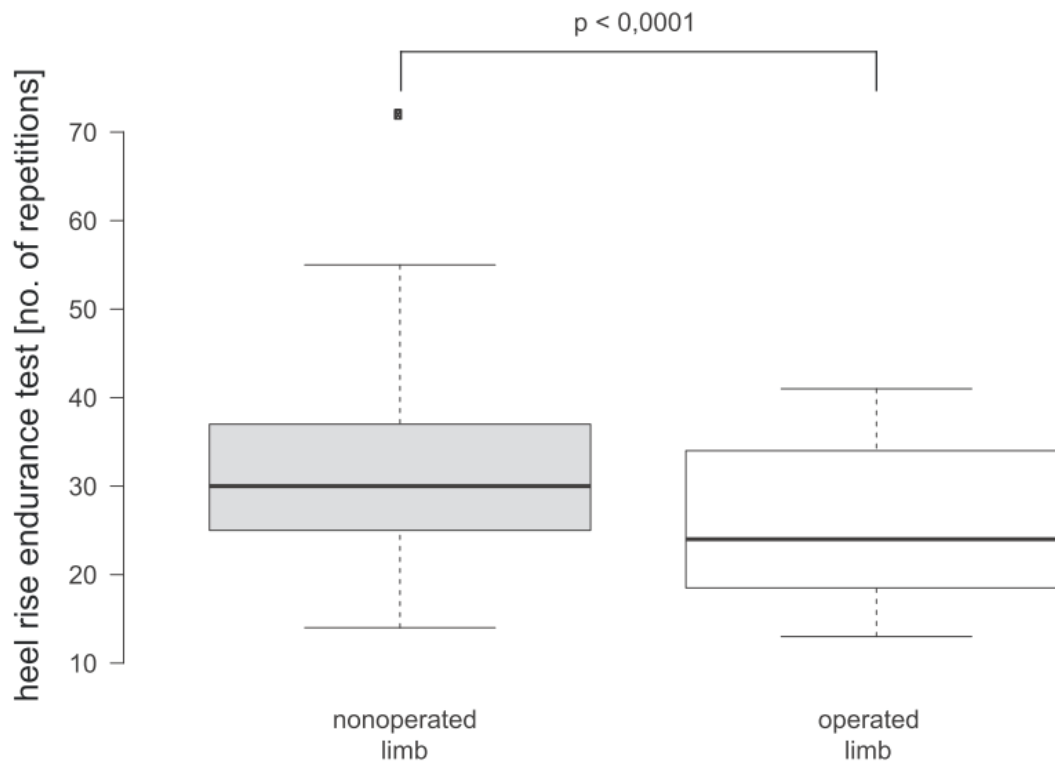

Figure 5. Distribution of heel rise endurance test for nonoperated and operated limb.
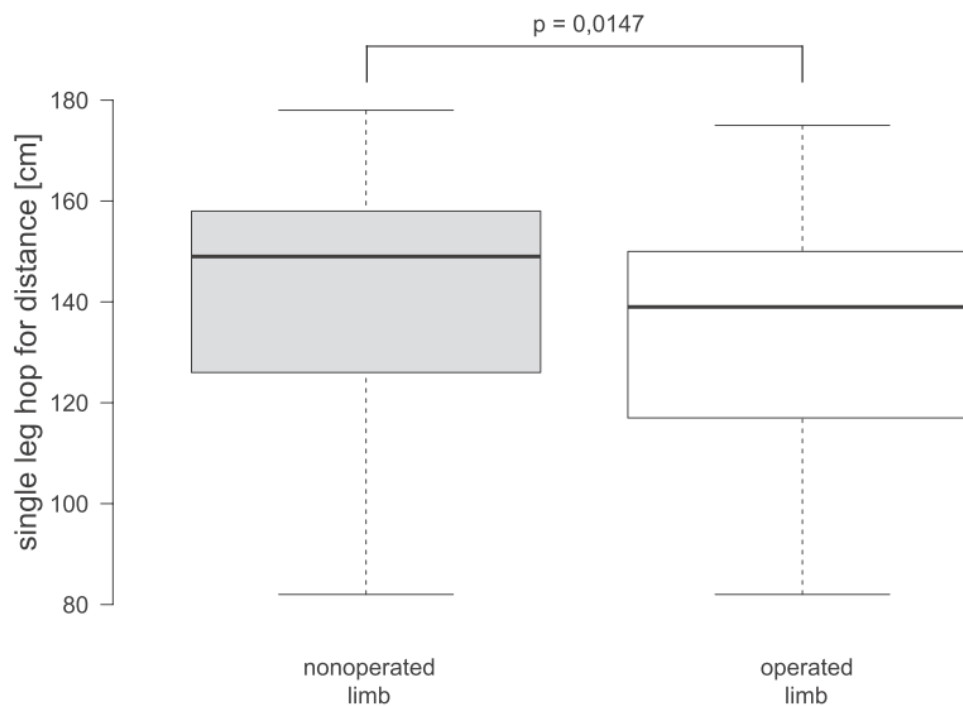
Figure 6. Distribution of single leg hop for distance results for nonoperated and operated limbs.

after Achilles tendon rupture (Silbernagel *et al.* 2006; Ollson *et al.* 2014; Costa *et al.* 2006b).

The results of the weight-bearing lunge test were used to evaluate the relative length of the Achilles tendon. Achilles tendon elongation of 1 cm has been reported to increase the incidence of dorsiflexion by approximately 12 degrees (Costa *et al.* 2006b), resulting in decreasing calf muscle strenght. The results of the weight-bearing lunge test in the examined group indicated a slight reduction of dorsiflexion in the operated limb when compared to nonoperated limb. The tendency to increase the incidence of dorsiflexion was not observed among the examined patients. As a result, no tendency for elongation the Achilles tendon was observed.

The results of heel rise endurance test indicated a decrease in the strength of the operated limb. The difference in average results was about 18% in favour of the nonoperated limb and was statistically significant. Asymmetry of muscle endurance at 18% indicates an increased risk of injury for patients active in sports (Carvalho *et al.* 2016). Therefore, it might be necessary to intensify exercises to improve muscular endurance after surgical treatment, with particular emphasis on functional aspects.

The results of single leg hop for distance indicated a slight decrease in the ability of the operated limb muscles to generate the force in a dynamic manner. The difference between the operated and nonoperated limbs was 3.5% on average. During the single leg hop for distance, stretching and shortening of muscles appears during a defined cycle (Silbernagel *et al.* 2006). In the first phase of jumping, a patient must bend the knee and lean forward, triggering the Achilles tendon stretch and the eccentric contraction of the calf muscles. In a hopping phase, a sudden, dynamic contraction of the calf muscles is required, which triggers their shortening. This mechanism occurs cyclically and is responsible for the normal function of the Achilles tendon muscle. Silbernagel (Silbernagel *et al.* 2006) noted that patients with Achilles tendinopathy present disorders in the stretch-shortening

cycle, which reduces the patient's functional capacity. Lack of such differences in the studied patients suggests the restoration of Achilles tendon functionality after surgical treatment.

In a randomized study with 81 patients, Olsson (Olsson *et al.* 2011) reported a significant reduction in the strength of the operated limb, which only slightly changed between 12 and 24 months after the surgery. This may implicate that the key period for the postoperative rehabilitation is the first 12 months.

Persistent weakness of the operated limb was noticed even in 11-year follow-up studies (Lantto *et al.* 2015). Lantto compared the postoperative protocol based on the immobilisation with a protocol based on early inclusion of motion in the operated limb. He did not notice the differences between the two groups, but the weakness of the operated limb was maintained 11 years after the treatment.

All of the above observations clearly indicate an issue of persistent weakness of the operated limb after the surgical treatment. This is of crucial importance in terms of patients return to sport activities. Reduced functional differences between limbs should be sought to minimize the risk of a subsequent injury. Therefore, the functional training or its components are particularly important elements of the rehabilitation protocol.

86% of patients in the studied group returned to the physical activity from before the Achilles tendon rupture incident. So far, it has been observed that the proportion of patients returning to the full physical activity ranged between 49% and 82% (Olsson *et al.* 2011). Some of the studied patients (4 out of 28) did not return to full sport activity or completely abandoned it. This issue might be clinically related to the apprehension of re-injury, which is a common phenomenon in orthopaedic patients (Olsson *et al.* 2014). Therefore, the problem of not returning to the full physical activity

cannot be underestimated. Positive aspects of motor activity have been discussed and analysed multiple times (Drygas *et al.* 2000) and one of the most important goals of orthopaedic treatment is a full return of the patient to sport activity.

REFERENCES

Carvalho, A., Brown, S., Abade, E. (2016) *'Evaluating injury risk in first and second league professional Portuguese soccer: Muscular strength and asymmetry.'* J Hum Kinet., 50(2), pp. 19–26.

Costa, M.L., Logan, K., Heylings, D., Donell, S.T., Tucker, K. (2006b) *'The effect of achilles tendon lengthening on ankle dorsiflexion: a cadaver study.'* Foot Ankle Int., 27(6), pp. 414–417.

Costa, M.L., MacMillan, K., Halliday, D., Chester, R., Shepstone, L., Robinson, A.H., Donnel, S.T. (2006a) *'Randomised controlled trials of immediate weight-bearing mobilisation for rupture of the tendo Achillis.'* J Bone Joint Surg., 88(1), pp. 69–77.

Clanton, T. O., Haytmanek, C. T., Williams, B. T., Civitarese, D. M., Turnbull, T. L., Massey, M. B., LaPrade, R. F. (2015) *'A biomechanical comparison of an open repair and 3 minimally invasive percutaneous Achilles tendon repair techniques during a simulated, progressive rehabilitation protocol.'* Am J Sports Med., 43(8), pp. 1957–1964.

Drygas, W., Kostka, T., Jegier, A., Kuński, H. (2000) *'Long-term effects of different physical activity levels on coronary heart disease risk factors in middle-aged men.'* Int. J. Sports Med., 21(4), pp. 235–241.

Goren, D., Ayalon, M., Nyska, M. (2005) *'Isokinetic strength and endurance after percutaneous and open surgical repair of Achilles tendon ruptures.'* Foot Ankle Int., 26(4), pp. 286–290.

Herbort, M., Haber, A., Zantop, T. Gosheger, G., Rosslenbroich, S., Raschke, M.J., Petersen, W. (2008) *'Biomechanical comparison of the primary stability of suturing Achilles tendon rupture: A cadaver study of Bunnell and Kessler techniques under cyclic loading conditions.'* Arch Orthop Trauma Surg., 128(11), pp. 1273–1277.

Järvinen, T.A., Kannus, P., Maffulli, N., Khan, K.M. (2005) *'Achilles tendon disorders: etiology and epidemiology.'* Foot Ankle Clin., 10(2), pp. 255–266.

Khan, R.J.K., Fick, D., Brammar, T.J., Crawford, J., Parker, M.J. (2004) *'Interventions for treating acute Achilles tendon ruptures.'* Cochrane Database Syst Rev., 2004(3), pp. CD003674.

Lantto, I., Heikkinen, J., Flinkkila, T., Ohtonen, P., Kangas, J., Siira, P., Leppilahti, J. (2015) *'Early functional treatment versus cast immobilization in tension after Achilles rupture repair: results of a prospective randomized trial with 10 or more years of follow-up.'* Am J Sports Med., 43(9), pp. 2302–2309.

Moller, M., Lind, K., Movin, T., Karlsson, J. (2002) *'Calf muscle function after Achilles tendon rupture. A prospective, randomised study comparing surgical and non-surgical treatment.'* Scand J Med Sci Sports., 12(1), pp. 9–16.

Movin, T., Ryberg, A., McBride DJ, Maffulli N. (2005) *'Acute rupture of the Achilles tendon.'* Foot Ankle Clin., 10(2), pp. 331–356.

Olsson, N., Karlsson, J., Eriksson, B.I., Brorsson, A., Lundberg, M., Silbernagel, K.G. (2006b) *'Ability to perform a single heel-rise is significantly related to patient-reported outcome after Achilles tendon rupture.'* Scand J Med Sci Sports., 24(1), pp. 152–158.

Olsson, N., Nilsson-Helander, K., Karlsson, J., Eriksson, B.I., Thomee, R., Faxen, E., Silbernagel, K.G. (2011) *'Major functional deficits persist 2 years after acute Achilles tendon rupture.'* Knee Surg Sports Traumatol Arthrosc., 19(8), pp. 1385–1393.

Sarman, H., Muezzinoglu, U.S., Memisoglu, K., Aydin, A., Atmaca, H., Baran, T., Odabas Ozgur, B., Ozgur, T., Kantar, C. (2016) *'Comparison of semi-invasive internal splinting and open suturing techniques in Achilles tendon rupture surgery.'* J Foot Ankle Surg., 55(5), pp. 965–970.

Silbernagel, K.G., Gustavsson, A., Thomee, R., Karlsson, J. (2006) *'Evaluation of lower leg function in patients with Achilles tendinopathy.'* Knee Surg Sports Traumatol Arthrosc., 14(11), pp. 1207–1217.

Skiba, K., Rutowski, R., Wiącek, R., Reichert, P., Dudek, K. (2006) *'Treatment of subcutaneous ruptures of the Achilles tendon in own material.'* Adv Clin Exp Med., 15(3), pp. 471–480.

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