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ORIGINAL PAPER

Biomechanical evaluation of patients after severe treatment of Achilles tendon Injuries using MIS procedure

Ocena biomechaniczna pacjentów po leczeniu operacyjnym uszkodzeń ścięgna Achillesa sposobem małoinwazyjnym

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Abstract

Introduction. Achilles tendon is the strongest tendon in the human body. In 1977 Ma and Griffith described the technique of percutaneous anaplasty of the damaged Achilles tendon as a compromise between surgical and conservative treatment. Choosing an operating method that gives "better" treatment results can facilitate the choice of a more effective treatment.
Aim. The aim of the study was to evaluate the biomechanics of surgical treatment of patients with Achilles tendon injury using minimally invasive method.
Material and Methods. The study material included 31 patients treated surgically for Achilles tendon injury in the Department of Orthopedics and Traumatology of CSK MSW in Warsaw in years 2011-2016. The research group consisted of 27 men and 4 women. Their average age was 40 years. The following research tools were used to evaluate the treatment results: 1. Measuring instrument for maximum force moments in ankle joint JBA "Staniek" 2. HUR stabilographic platform
Conclusions. 1 Patients presented a similar balance control on the stabilographic platform in research groups. 2. Higher values of maximum force moments in ankle joint were recorded in healthy limb.

Key words: Achilles tendon, biomechanics, MIS

Streszczenie

Wstęp. Ścięgno Achillesa jest najsilniejszym ścięgnem w organizmie człowieka. W 1977 roku Ma i Griffith opisali technikę plastyki przezskórnej uszkodzonego ścięgna Achillesa, jako kompromis między leczeniem operacyjnym a zachowawczym. Wybór metody operacyjnej, która daje „lepsze" wyniki leczenie może ułatwić nam podjęcie decyzji o wyborze skuteczniejszej metody leczenia.
Cel. Celem pracy była ocena biomechaniki u pacjentów leczonych operacyjnie sposobem MIS.
Materiał i metody. Materiał badawczy obejmował 31 pacjentów leczonych operacyjnie z powodu urazu ścięgna Achillesa w Klinice Ortopedii i Traumatologii CSK MSW w Warszawie w latach 2011-2016. Grupa badawcza składała się 27 mężczyzn oraz 4 kobiet, a średnia wieku wynosiła 40 lat. Średnia wieku pacjentów wynosiła 46 lat w pierwszej grupie oraz 48 w grupie 2. Do oceny wyników leczenia wykorzystano następujące narzędzia badawcze: 1. Stanowisko pomiarowe JBA Staniak. 2. Płyta Stabilograficzna HUR
Wnioski. 1. Pacjenci wracają w podobnym czasie do aktywności zawodowej i sportowej po operacji w obu grupach chorych. 2. Na płycie stabilograficznej pacjenci prezentowali podobną kontrolę równowagi w obu grupach kończynach. 3. Zarejestrowano podobne wartości maksymalnych momentów sił w stawie skokowym w grupie badanej.

Słowa kluczowe: ścięgno Achillesa, biomechanika, MIS

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Introduction

The Achilles tendon is the strongest tendon in the human body [1]. During the run, the tensile forces reach 9000 N. It is a structure that allows us to maintain a vertical position and provides a huge torque, so that we can run, jump, etc. It transfers the load from the triceps surae muscle to the heel bone by moving the ankle joint [2].

The Achilles tendon is the most commonly injured tendon in the body (constituting about 45% of all tendon injuries) [3]. Such an injury occurs more often than damage to the tendons in the hand. In recreational sports it constitutes approximately 4/5 of all tendon injuries, especially in sports that require sudden turns and rapid changes in speed such as basketball, volleyball, football, etc. [4].

The treatment of the Achilles tendon injuries can generally be divided into operative and non-operative. In Poland, the gold standard of treatment is still a classical surgical procedure, especially in young patients practicing sports. In 1977 Ma and Griffith developed a percutaneous suturing repair as an alternative between operative and conservative treatment [5]. This method reduces the incidence of wound healing complications which, depending on an author, may affect up to 20% of patients in the conservative treatment group [6,7]. The reduction of the scar size brings this percentage down to approximately 9.7% for minimally invasive treatment [8]. Additionally, the fact that the skin and the subcutaneous tissue above the tendon injury site is not open, that is the fact of preserving the continuity of the remaining microvasculature and the non-removal of naturally occurring growth factors in the hematoma, improves the conditions for healing of the damaged structures [9].

In the literature, we can find a lot of information about tendon reruptures after surgery or complications connected with wound healing. However, there is still insufficient information on the post-operation biomechanical assessment of patients. Those who most often sustain Achilles injures are men aged 30-39 engaging in amateur sports [10]. Therefore, a thorough biomechanical assessment allows an objective evaluation of whether patients treated with minimally invasive techniques can return to a similar intensity of sport practice as before the injury – how much does the operated limb lose in performance when compared to the other limb. In order to join this discussion, I have assessed the results of minimally invasive treatment of Achilles tendon injuries at the Department of Orthopedics and Traumatology of the Ministry of Internal Affairs and Administration Main Teaching Hospital [CSK MSWiA Hospital] from 2011 to 2016.

Aim

The aim of the study is to analyze the biomechanical results of the operative treatment of the Achilles tendon with a minimally invasive surgery.

This objective was based on the research questions set out below:

1. What is the difference between the maximum plantar and dorsal flexion torques in the ankle joint between the healthy limb and the operated limb?
2. What is the difference between the maximum deflection during a test on the stabilographic plate between the healthy limb and the operated limb?

Material and Methods

The research was based on retrospective analysis of the results of minimally invasive operative treatment of Achilles tendon ruptures at the Department of Orthopedics and Traumatology of the CSK MSWiA Hospital in Warsaw.

Between 2011 and 2016, 96 patients were operated on due to Achilles tendon injury. Forty-one patients were treated with minimally invasive technique Thirty-one patients participated in the study. The average age of the patients was 40 years The youngest person was 21 years old and the oldest was 53 years old. Men made up 87.1% of surgical patients.

Each patient was operated on using Ma-Griffith technique as modified by Carmont and Maffulli [11]. Four incisions were made on the proximal side of the lesion, each approximately 5 to 7 mm long, two on the medial side and two on the posterior-lateral side of the tendon (Fig. 1)

Fig. 1. Percutaneous suturing with a long needle and a 2:0 Ethibond suture (own material).

The modification of the Ma-Griffith technique consisted in that each of the incisions on the lateral side of the Achilles tendon was carefully dissected to expose the superficial sural nerve and the adjacent vessel. This prevents the structures from being pulled inward while suturing with hooks.

After discharge from hospital the patients were subject to one treatment scheme. They were discharged with a plaster splint and two elbow crutches. Longuette was replaced by a Walker-type shoe after removing the stitches, i.e. approximately 14 days after the surgery (Fig. 2).

Fig. 2. The leg two weeks after MIS procedure, cutaneous sutures are visible (own material).

Until the replacement of the orthopedic device, the patient was supposed to avoid load-bearing activities. In physical therapy sessions, if pain tolerance was good, one pad was removed weekly (there were 6 pads in total) to put the ankle in the shoe in an intermediate position 6 to 8 weeks after the surgery. During this period, the patient was allowed to apply load to the limb in a Walker orthopedic shoe until pain came on. About 6 weeks after the procedure, the patient reported for the first follow-up visit in outpatient orthopedic clinic. If there were no contraindications, the patient disposed of the shoes and elbow crutches in the 9th week after the surgery, on average. Rehabilitation lasted up to about 5 months after the surgery. Measurements were taken about 6 months after the surgery, on average.

To assess the mobility potential of the ankle joint a platform designed by JBA "Staniak" was used (Fig. 3) [12].

Fig. 3. A platform designed to measure the maximum torque in ankle joint when sitting on a chair (own material).

The main idea of the platform was to position a patient with both lower limbs flexed at the hip and knee joints to an angle of 90 degrees and the ankle joint in an intermediate position. The platform consists of a seat, thigh and foot stabilizing clamps and a torque measuring system based on two tensometric torque transducers. Each test was planned and performed according to a specific protocol. Before the test, the patient put on sportswear and did a 5-minute warm-up. It involved squats, bending, stretching of the leg muscles against the wall, and repeated exercises of standing on toes and heels. The patient was then seated at the platform. The limb to be tested was placed on a special measuring platform so that the rotation axis of the ankle was perfectly aligned with the line painted on the plate. Then, using the jacks and the clamps, the ankle was placed in an intermediate position, and the knee and hip joints were bent to 90 degrees and the limb was immobilized. The platform was connected to a laptop which calculated and saved the measurements in a dedicated software. By giving "start" and "stop" commands, the patient was informed that the maximum possible pressure on the platform between the commands should be demonstrated. The measurement concerned the maximum plantar flexion in ankle joint. The maximum pressure on the plate did not exceed 5 seconds. After about a minute, the test was repeated. A higher value of the plantar flexion torque was recorded. Additionally, with the limb stabilized in the clamps, the maximum torque of the dorsal flexion in ankle joint was measured. In between the "start" and "stop" commands, patients performed the maximum dorsal flexion in ankle joint within max. 5 seconds. The measurements were repeated after approximately one minute and a higher value was recorded.

To measure motor coordination a torque platform by a Finnish company HUR was used as well as dedicated software (Fig. 4).

Fig. 4. HUR platform (own material).

The square-shaped platform had 4 tensometric indicators symmetrically distributed on the sides of the device, linked to the computer to measure the resultant force of foot pressure. Each patient received thorough information on the test and was given instructions in order to perform the tasks to the best of his abilities. The center of the platform was marked using a marker. During the test the patient did not remove his footwear. The patient was instructed to step onto the outlined center of the plate with the limb in just one step. He then directed his eyes to a spot painted on the wall placed approximately along the line of sight. The contralateral limb was slightly bent, and the arms rested on the hip plates to better control the balance. After a few seconds, the "start" command was given and for 30 seconds the patient was supposed to maintain a vertical position with as little deflexion as possible beyond the center of gravity. Once the "stop" command was given, the test was completed. During the test the patient was allowed to support himself only once to avoid losing balance. Two instances of support meant the test failed. After approximately one minute, the second limb was tested following the same protocol [13].

Results

The maximum torque of plantar flexion in the ankle joint in the study group was 136N on average for the operated limb, and 152N for the healthy limb (Tab. 1).

The quotient of the plantar flexion between the operated and non-operated limb was also compared between women and men in the study group (Fig. 5). There is no statistically significant difference between the mean values of the tested characteristic for men and women at significance level of 0.05.

During the test the maximum dorsal flexion torques in ankle joint were also recorded to evaluate ankle antagonists. An average 60N of maximum dorsal flexion was recorded for the operated limb and 60N for the healthy limb (Tab. 2).

HUR platform was used to assess patients' motor coordination. 100% of patients were tested on the platform. In the study group, the mean deflexion path of the center of mass in relation to body axis was 741 mm for the operated limb and 631 mm for the non-operated limb (Tab. 3).

Table 1. The maximum plantar flexion torque for both limbs in the study group.

Maximum flexion torque (in N)	min	Q1	median	mean	Q3	max	standard deviation
Operated limb	20.0	121.0	136.0	132.0	150.5	247.0	48.76439
Non-operated limb	43.0	114.0	152.0	146.1	181.5	251.0	49.26996

Table. 2 Maximum dorsal flexion torque for both limbs for control group.

Maximum flexion torque (in N)	min	Q1	Median	Medium	Q3	max	standard deviation
Operated limb	17.00	49.00	60.00	57.65	69.50	85.00	16.40843
Non-operated limb	1.50	44.00	60.00	55.34	68.50	89.00	19.24483

Table. 3. Deflexion of center of mass in millimeters in the study group.

Maximum length (in mm)	min	Q1	median	Medium	Q3	max	standard deviation
Operated limb	102.0	127.0	741.0	562.0	891.5	997.0	382.7882
Non-operated limb	101.0	111.5	631.0	422.1	825.5	993.0	370.8218

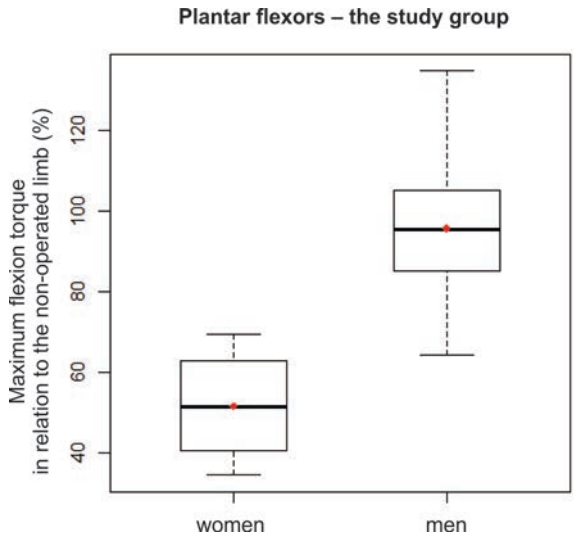

Fig. 5. Maximum plantar flexion torque for the study group for both sexes.

Discussion

The movement of lower limb is complex and involves mutual transfer of forces between the joints, depending on the movement phase. For reliable and comparable measurements, conditions for the biomechanics of joints should be laid down. The most important principles of measuring torques are moving or developing forces in one specific position of the body, and moving or developing forces according to physiological conditions of muscle function. The patient should be motivated and consciously develop maximum force with full involvement. In order to perform the ankle joint force test as accurately as possible, it should be stabilized, i.e., remaining joints of the tested limb should be immobilized so that they are not able to generate forces and transfer them, in this case, to the ankle joint. For many years, various authors have debated the most appropriate position of the patient to measure the maximum torque in the ankle joint. So far, measurement methods have been developed for hurdle seat position, standing position and sitting-on-chair position. In 1988 [**tu nazwisko**] published a study in which he measured the maximum mobility potential in the ankle joint depending on the position. Based on his research, the patient sitting on a chair was determined to be the position that best isolated the remaining joints and where the maximum plantar flexion torque was the highest [13]. Therefore, the JBA "Staniak" measurement platform was used to measure the motor potential of the ankle joint. The maximum torque values were greater for the healthy limb than for the operated one. This result was predictable. The operated limb was therefore weaker than the healthy one in both groups. Many patients during the tests reported that they were afraid to put maximum pressure of the operated limb on the platform. This is one of the possible causes of poorer results. The fear of a rerupture despite instruction and a proper warm-up resulted in submaximum pressure on the platform during the test.

When it comes to the maximum dorsal flexion torques in the ankle joints of both extremities, the results were identical. They were within 60N of the maximum dorsal flexion torque. This finding gives information on the correct functioning of the ankle antagonists in both limbs and equal load bearing of the limbs. This is also a result of the physical therapists' insistence on exercising both extremities during rehabilitation. In the previously cited work, he studied 110 healthy students at University of Physical Education [AWF] on an identical measuring platform. He obtained the following results: on average 240.5 N of plantar flexion in the ankle joint of the left limb and 245.7 N in the right limb. These results are completely different from those presented in my study and in the available literature [14,15]. The differences are likely to stem from the previously mentioned fears harbored by patient as regards the maximum pressure and tendon rerupture. Additionally, the AWF students are young, fit individuals who sustained no injuries and were accustomed to performing tests with maximum effort and commitment. The similar values of the dorsal flexion show reflect a certain regularity – a uniform distribution of forces and well-managed physical therapy. Despite differences in results, the vast majority of patients returned to the pre-injury sport practice after the operative treatment.

One method for assessing human motor coordination is the ability to maintain a vertical position when standing. Bober and Szydlak stated that coordination was the ability of the muscles to adapt to the external stimuli, which in turn influenced the performance of certain motor reaction by the body [15]. The ability to adapt to external stimuli can be measured by assessing the precision of the spatial response to a given stimulus and the speed of response to that stimulus. Gerbino thinks that the ability to maintain standing balance is about deflecting as little as possible [14]. The device can be used to measure the maximum deflexion as well as the entire deflexion path over time. The tests may be carried out under static conditions, on a variable surface, and under dynamic conditions such as a jump or sudden stop. Currently, the method that best illustrates the assessment of motor coordination is the method based on examining the properties of the displacement signal of the point where the resultant ground reaction force is applied while standing on the dynamometric platform. The tests can be carried out by measuring the deflection path of the patient's center of mass while standing on the dynamometric platform for a given time. The designed test protocol allows not only to estimate the mechanical value of the measurements, but also the reasons for poorer results. Poor stabilographic results with eyes closed, compared to a healthy person who performs the test also with eyes closed indicate a disturbance of deep sensation related to injuries or surgeries in the large joints of the lower limbs. Maintaining balance with eyes closed is difficult for the patient, and disturbances in balance are natural in such cases. On the other hand, the lack of motor coordination during eye control may indicate damage to the central nervous system, and specifically to the cerebellum.

Wychowański examined 135 healthy women and 148 healthy men - students at the University of Physical Education in Warsaw on a dynamometric platform. On this basis, he determined the norms of the maximum path of deflection of the center of body mass for patients, depending on body height. There was no correlation between sex, weight and body side. My research shows that for patients after operative treatment, these values change for each limb. The average path for a healthy 170-cm tall person is 820 mm. According to my research, the average path for a healthy limb was 700 mm in the study group. The average path for the operated limb was 631 mm in the study group. The results of patients after surgery are marginally better than those observed among healthy students of the AWF rehabilitation department. It is

quite surprising. This may indicate that physical therapists exert a lot of pressure on patients to work on motor coordination as a mechanism that protects against further injuries.

Conclusions

1. The plantar flexion force in the ankle joint is greater in the healthy limb. The dorsal flexion force in the ankle is identical for both limbs. The results are worse compared to healthy AWF students, who sustained no injuries.
2. Motor coordination in patients treated operatively is better than in healthy AWF students. The operated limb maintains the vertical position on the stabilographic plate better than the contralateral limb.

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