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Effectiveness of Early Functional Mobilization in Postoperative Rehabilitation Following Acute Achilles Tendon Rupture: A Systematic Review

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Abstract

Background. Acute Achilles tendon rupture (AATR) requires effective postoperative rehabilitation. The choice between early functional mobilization (EFM) protocols and traditional immobilization remains controversial in the medical community, mainly because of concerns about excessive elongation of the tendon scar and chronic muscle strength deficits.

Aim. Assessment of the influence of early mobilization on the functional and biomechanical outcomes and quality of life of patients after surgical treatment of acute Achilles tendon rupture.

Materials and methods. In accordance with the PRISMA 2020 guidelines, the PubMed and PEDro electronic databases were searched (during the period May-July 2026). Randomized

clinical trials (RCTs) comparing the effectiveness of early activation with immobilization after AATR surgery were included in the review. Three articles were subjected to detailed analysis.

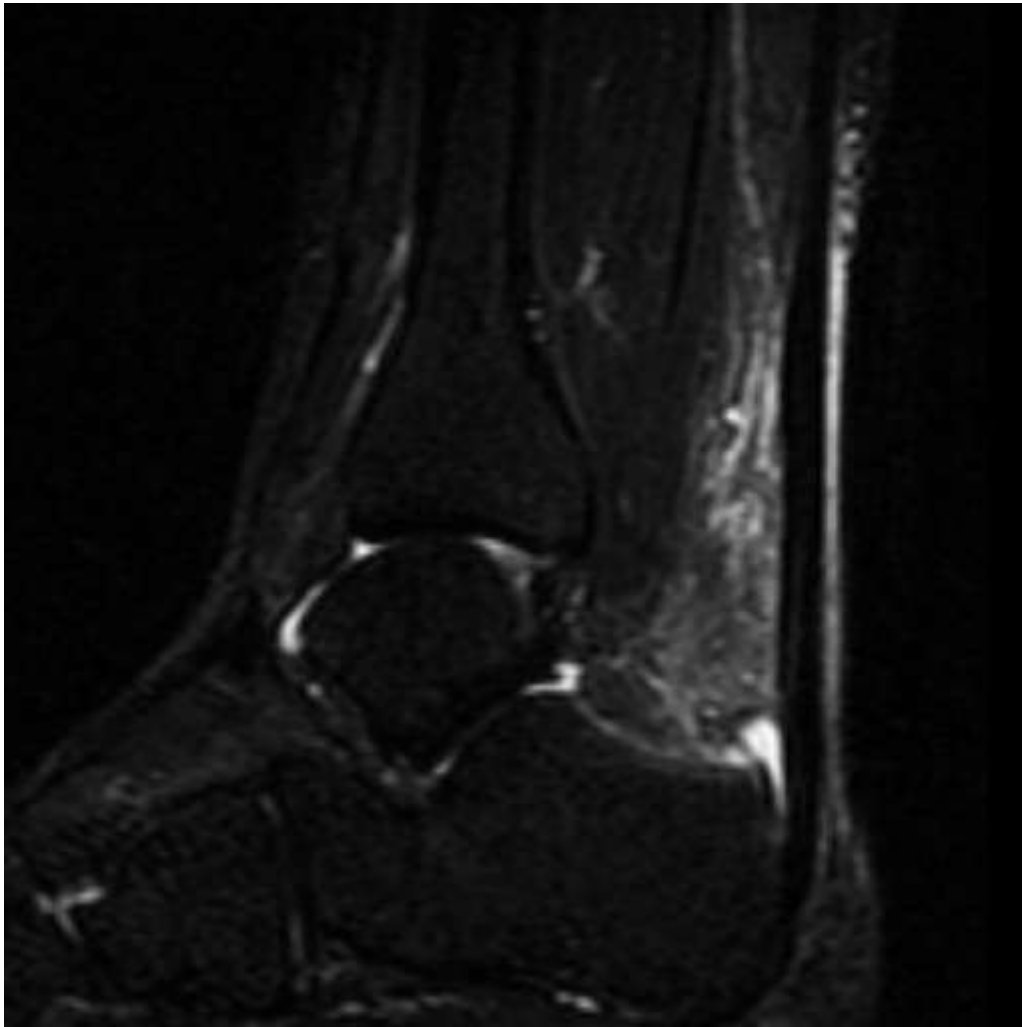
Results. The analysis does not show statistically significant differences in long-term (12-month) functional outcomes (e.g., ATRS, isometric strength) between EFM and immobilization. However, EFM protocols bring measurable short-term benefits (weeks 4-8): faster increase in plantar flexion strength, better plasticity of the musculotendinous junction, and higher patient vitality. Early weight-bearing does not affect excessive tendon elongation - this process progresses for up to 6 months regardless of the method. Complications (e.g., deep vein thrombosis) permanently worsen functional outcomes.

Conclusions. Early mobilization protocols (EFM) are safe, do not intensify tendon elongation, and accelerate initial psychosocial and strength recovery. In the long-term perspective, the effects of both methods become equal. Further objective multicenter studies (using MRI or EMG) are indicated.

Keywords: acute Achilles tendon rupture, early mobilization, postoperative rehabilitation, tendon elongation, systematic review.

Introduction

The Achilles tendon is an anatomical structure which, due to its location (constituting the common terminal tendon of the triceps surae muscle [gastrocnemius and soleus] and with the calcaneal tuberosity), is the thickest tendon structure in the human body (1). The anatomical function of the Achilles tendon is to transmit tensile forces caused by the muscles that connect along its course to the calcaneal tuberosity, which means a key role in ensuring stabilization of movement and control of load distribution during changes of position, i.e., walking, running, and jumping (1). The Achilles tendon is built of collagen fibers and elastin, and the spiral arrangement of collagen fibers ensures adequate tendon strength (2) and provides support in maintaining the loads to which the tendon is subjected during each of the above-mentioned movements, where the forces generated on this anatomical structure can reach a value exceeding ten times the body mass of the moving person (3). An anatomical advantage of the Achilles tendon that provides support in overcoming such large loads is the connective tissue sheath (paratenon) (4), covering the entire surface of the tendon (Fig. 1), and during movement stretching by approximately 2-3 cm, ensuring optimal tissue gliding during movement (1).



(5)

Fig. 1. Achilles tendon covered with a connective tissue sheath in an MRI image.

The Achilles tendon is the strongest anatomical structure in the human body; however, this does not change the fact that at the same time it is very exposed to injuries - most often in athletes practicing sports based on a large number of jumps or requiring regular running activity. Several types of Achilles tendon damage are distinguished:

- tendinosis - tendon damage not having the character of inflammation, characterized by its widened outline and degenerative changes confirmed 2 by imaging examinations. The cause most often consists of numerous microinjuries resulting from

- tendinitis - inflammation of the Achilles tendon in persons practicing sports characterized by frequent running or jumping. Tendinitis will not always have features of inflammation in histological examination. The mechanism of formation of this lesion has the character of numerous overload changes appearing during physical activity (6).

However, it should be noted that the above-mentioned injuries (i.e., tendinosis and tendinitis) are very specific concepts; in the sports medicine literature, the broader concept of tendinopathy, which combines both previously mentioned dysfunctions, is increasingly used. The commonness of tendinopathy results from the frequent difficulty in classifying Achilles tendon damage, because injuries often have features of both tendinosis and tendinitis, which makes classification difficult (7).

- AATR - acute tendon rupture; rupture can describe a larger group of injuries, within which partial tearing up to complete interruption of the tendon length is included. Most often, the injury occurs as a result of a large mechanical load or sudden turns (e.g., in basketball) while practicing both recreational and competitive sport (8). A healthy tendon rarely undergoes injury from the AATR group. Achilles tendon tendinopathy should be indicated as the main risk factor predisposing to tendon rupture injury. Degenerative changes reduce tensile strength, which, in combination with a sudden movement generating a large one-time load, may result in rupture (9).

In connection with the large loads to which the Achilles tendon is exposed, in recent years acute Achilles tendon rupture (AATR) has been indicated as a common sports injury primarily affecting active persons and middle-aged men (10). AATR manifests with limitation of plantar flexion and pain and, if untreated, may lead to permanent degeneration and impairment of ankle joint function, which is the basis of correct posture and load transmission during movement. (11). Tendon reconstructions are performed through open surgery or with the use of minimally invasive surgery (12), where the increasingly growing popularity of minimally invasive procedures is indicated; these show equally high effectiveness and provide the possibility of a

shorter period of postoperative immobilization, faster healing time of the postoperative scar, and faster return of the tendon to an optimal range of mobility (13).

Modern medicine is increasingly improving the procedures of surgical management in Achilles tendon rupture; however, there are still many controversies connected with assessment of protocol effectiveness - the dilemma between the duration of immobilization of the operated area and its early loading (14,15). Modern early functional mobilization (EFM) protocols include data concerning range of motion (ROM) in the early stages of physiotherapeutic management, but above all they draw attention to controlled body-weight loading (Early Weight-Bearing) (16). A problem concerning immobilization time and its influence on tendon strength and joint stiffness is indicated, while early loading of the Achilles tendon carries the risk of pathological elongation of the tendon scar, which directly means worsening of the range of motion and the strength of plantar flexion movement of the foot.

In connection with the above, the aim of this systematic review is to assess the influence of early mobilization on functional and biomechanical outcomes and the quality of life of patients after surgical treatment of Achilles tendon rupture.

Methodology

This systematic review was conducted and prepared on the basis of selected PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and MetaAnalyses) guidelines (17).

Only articles assessing the effectiveness of rehabilitation protocols after surgical treatment of acute Achilles tendon rupture were qualified for this systematic review. The inclusion criteria were as follows: controlled studies, randomized clinical trials (RCTs), publications with available full text, articles published in peer-reviewed scientific journals, publications written exclusively in English, and a publication date after 2016. Articles discussing the treatment and rehabilitation process in animal models or in the pediatric population were excluded from the review. In addition, review articles, conference reports, statistical analyses, and case reports were excluded from the analysis. The methodological quality of randomized clinical trials and the time frames of measurements assessing treatment effectiveness (time from completion of therapy or procedure to the follow-up measurement) did not constitute an inclusion criterion for this review.

To search for appropriate literature, the following electronic databases were searched: PubMed and PEDro, during the period from May 1, 2026 to July 31, 2026. The obtained literature items were then subjected to detailed analysis.

Search results

Following the application of appropriate keyword-based search queries to the PubMed and PEDro electronic databases, and the implementation of filters regarding language and publication date, a total of 317 articles were retrieved.

The results of the literature search and selection process, conducted in accordance with the PRISMA guidelines, are presented in Figure 2.

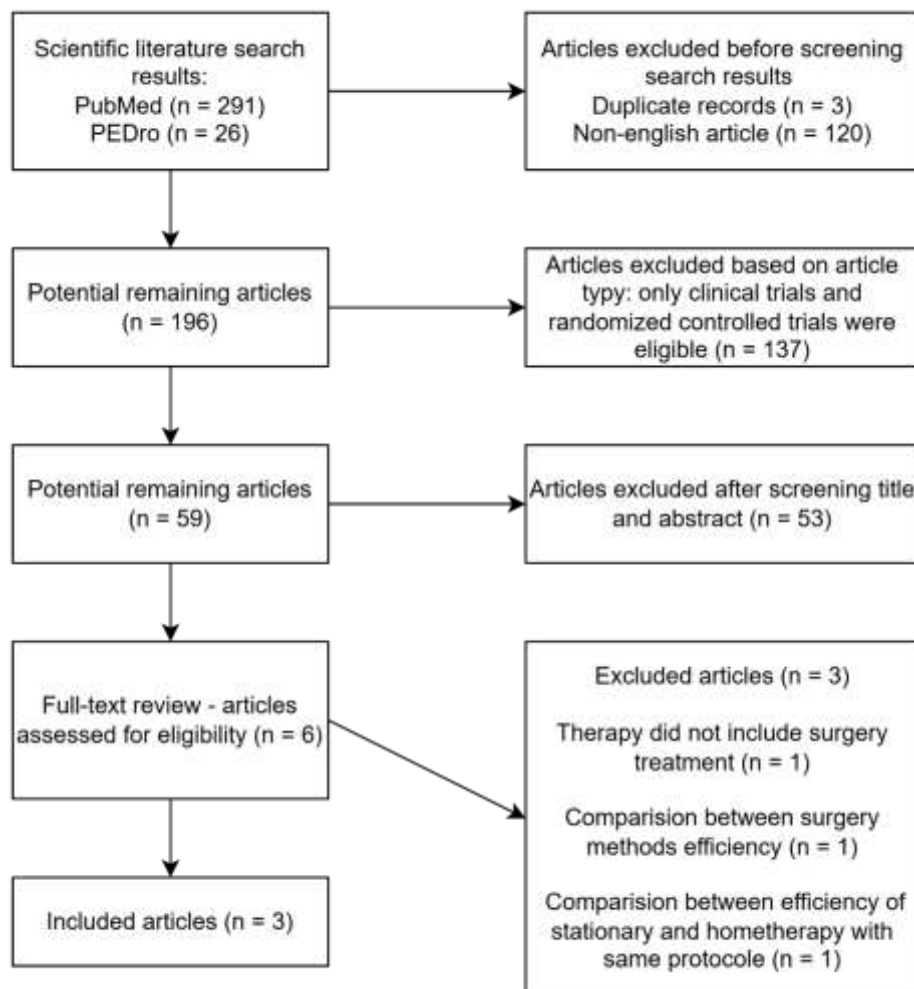


Figure 2. Literature search and selection

Publication	Aim of the study	Material and methods	Results	Final conclusions
De la Fuente et al., 2016, Chile (18)	Comparison of immediate activation of the Achilles tendon after surgical percutaneous reconstruction as a more effective form of therapy than therapy assuming earlier immobilization	A group of 26 examined amateur athletes (football) aged 42.3 ± 9.7 years and with a BMI of 29.5 ± 3.9 kg/m ² was randomly divided into two study groups (n1=13, n2=13) for a rehabilitation process lasting 84 days. Measurements of three values were performed, i.e., PFS (isometric plantar flexion strength), ATRS (Achilles tendon total rupture score), and MJD (displacement of the musculotendinous junction between maximum contraction and rest measured with	Measurements were performed after completion of each phase (at weeks 4, 8, and 12 after surgery). A normal statistical distribution was demonstrated. In the group subjected to immobilization after surgery, the following were demonstrated: at week 4, • PFS 162.5 ± 64.8 N, • MJD 4.1 ± 2.5 mm, • ATRS 18.6 ± 14.0; at week 8, • PFS 345.7 ± 141.1 N, • MJD 7.5 ± 2.0 mm,	It was demonstrated that the protocol of immediate rehabilitation of the Achilles tendon over a 12-week period shows a greater MJD value, which means greater plasticity of the neuromuscular system, while at the same time not indicating statistically significant differences between isometric flexion strength (PFS) and the ATRS scale. No statistically significant differences between the applied protocols

	on of the limb	ultrasound). The groups were divided as follows: Group I: immobilization of the limb immediately after surgery, beginning rehabilitation on day 29 after surgery. Age: 41.8 ± 11.5 years; height: 1.7 ± 0.1 m; weight: 89.8 ± 15.3 kg; BMI: 30.8 ± 4.4 kg/m²; ATRS (before injury): 95.5 ± 12.1; time from injury to surgery: 6.8 ± 3.0 days; PFS in the healthy limb: 529.8 ± 149.4. Group II: immediate activation of the limb; patients wore an orthosis (walking boot) and had early weight-bearing implemented (from 10 kg in week 1 to full weight-bearing in week 4). Age: 42.7 ± 7.8 years;	• ATRS 42.7 ± 14.6; and at week 12, • PFS 455.0 ± 127.3 N, • MJD 8.1 ± 1.4 mm, • ATRS 64.4 ± 19.4. In Group II subjected to immediate rehabilitation, already in the first phase the following were demonstrated: at week 4, • PFS 281.3 ± 103.3 N, • MJD 6.1 ± 1.7 mm, • ATRS 42.7 ± 12.2; at week 8, • PFS 418.0 ± 140.4 N, • MJD 9.2 ± 1.5 mm,	were demonstrated in the 12-week perspective.
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		height: 1.7 ± 0.1 m; weight: 82.5 ± 13.0 kg; BMI: 28.2 ± 3.3 kg/m²; ATRS (before injury): 98.6 ± 3.7; time from injury to surgery: 6.5 ± 2.6 days; PFS in the healthy limb: 552.1 ± 158.1. The physiotherapy program consisted of three phases ending with measurements: days 1-28, days 29-56, and days 57-84. The difference in management concerned only the first phase. Statistical analysis was based on multivariate repeated measures analysis of variance (ANOVA), taking into account the probability-of-benefit model with Bonferroni correction, where $p < .05$ determined significance.	• ATRS 60.4 ± 14.9; and at week 12, • PFS 490.6 ± 112.2 N, • MJD 10.2 ± 1.4 mm, • ATRS 74.2 ± 14.2. No significant differences in strength level at week 12 between rehabilitation models were demonstrated (490.6 and 455 N, respectively) - this means a lack of lasting benefits in isometric contraction at the end of the third month. However, protection in the early phase remains important. In week 4, benefits in favor of early implementation of treatment were demonstrated in terms of preventing later damage caused by	
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			excessive unloading of the damaged structure. Rehabilitation brought 10.2 ± 1.4 mm of MJD displacement for the immediate group after 12 weeks, which ideally coincides with physiological values of healthy patients in other population studies (~ 10-12 mm). In turn, the value of 8.1 mm in the traditional group is regarded as a manifestation of impaired plasticity of the neuromuscular system.	
Aufwerber et al., 2020, Sweden (19)	Comparison of effectiveness between early functional mobilization (EFM) and	A group of 135 patients aged 18-75 years who underwent surgical reconstruction of the Achilles tendon (open technique with a modified Kessler suture) was randomly divided into two groups in a 2:1 ratio ($n_1=89$, $n_2=46$). The following values	During the 6-month period, the EFM group obtained significantly higher scores in the general health and vitality subscales of the RAND-36 questionnaire ($p<0.05$) than Group II, the control group. It is indicated that EFM 6 did not negatively affect heel-rise function, which suggests no influence of EFM on	The accelerated protocol (EFM), consisting of immediate loading of the limb and early movement in the joint, results in better general health and vitality of patients at month 6 after surgery. In the long-term perspective (12

	management assuming unloading of the operated limb for a period of 2 weeks after surgery, with the possibility of full weight-bearing after its completion.	were assessed: ATRS, FAOS, RAND-36, PAS, the kinesiphobia scale, and a functional assessment using the heel-rise endurance test and vertical jump tests (at month 12). DVT was routinely assessed at weeks 2 and 6 using Doppler ultrasound. Group I (EFM): patients received a dynamic orthosis (VACOped), which was intended to enable immediate loading of the limb and a limited, controlled range of motion in the ankle joint (15° to 30° of plantar flexion for 2 weeks, then 5°-30°).	muscle and tendon regeneration. A difference in health-related quality of life (QoL) connected with differences in mobilization regimens between groups was observed, regardless of the occurrence of DVT; however, it was indicated that patients in whom DVT occurred during treatment showed greater impairment of general health and subjective disease-specific outcomes at months 6 and 12, regardless of the postoperative treatment regimen. No significant differences were demonstrated in all patient-reported measures and heel-rise test outcomes between the EFM and control groups. Scores on scales concerning quality of life and vitality after 12 months from surgical treatment do not show a statistically significant difference between groups, which indicates an	months), however, early mobilization does not show a significant advantage over traditional management assuming immobilization for regeneration of calf muscle function and in the assessment of ATRS results. The complication in the form of DVT constitutes an independent, strong factor permanently worsening the outcomes of functional treatment.
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		Age: 39.4±8.1 years; male sex: 67/75 (n/%); BMI: 24.9±2.6 kg/m²; active smokers: 19/21 (n/%); time to surgery: 3.7±1.7 days; DVT: 34/39 (n/%); PAS score before surgery: 4.7±1.0. Group II (control): standard management - 2 weeks of complete unloading in a plaster cast, followed by 4 weeks of moving in a stabilizing orthosis. Age: 39.7±8.0 years; male sex: 35/76 (n/%); BMI: 25.0±2.5 kg/m²; active	immediate effect of EFM therapy in the rapid period, but no higher effectiveness of immediate activation of the tendon area. Scores on scales concerning assessment of quality of life and pain complaints and differences between groups at month 6 after surgical treatment, without a statistically significant difference in assessment based on functional tests, indicate no advantage of EFM therapy over management assuming unloading of the limb after surgery. Patients with DVT showed significantly worse ATRS and FAOS scores both after 6 and 12 months, regardless of the applied postoperative protocol.	
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		smokers: 6/13 (n/%); time to surgery: 3.6±1.6 days; DVT: 14/30 (n/%); PAS score before surgery: 4.6±1.0.		
Eliasson et al., 2018, Denmark (20)	Assessment of whether loading of the limb in the early phase (0-8 weeks) of Achilles tendon healing after surgery, with a limited range of motion, has an influence	A group of 75 patients aged 18-65 years with acute Achilles tendon rupture was included in a randomized clinical trial. Ninetyseven percent of the examined persons sustained the injury during sports activity. Patients with previous Achilles tendon injuries or other injuries that could affect lower-limb function were excluded. Surgical repair of the Achilles tendon was performed in the patients. Patients were randomly divided into three groups:	No significant influence of interaction or group on tendon elongation was demonstrated, but a statistically significant influence of time ($P<0.0001$) on Achilles tendon regeneration was demonstrated. Elongation increased from weeks 6 to 12 ($P<0.01$) and from weeks 12 to 26 ($P<0.001$), but not from weeks 26 to 52. In the case of strain at 200 N, no group effect was likewise demonstrated, while a statistically significant influence of time was demonstrated ($P<0.0001$); strain decreased from weeks 6 to 26 ($P<0.001$), but not from weeks 26 to 52. The cross-	No statistically significant influence of earlier loading and mobilization on Achilles tendon elongation or on the remaining measurable long-term outcomes in patients was demonstrated. The process of elongation of the healing tendon continues uninterrupted for half a year from the intervention. Twelve months is indicated as the time needed to achieve appropriate Achilles tendon function, and clear deficits in

	on improving functional tendon outcomes and limiting tendon elongation, and comparison of the effectiveness of physiotherapeutic management protocols.	• Group I: LWB+IMMOB - complete prohibition of loading the lower limb until week 7 after surgery. • Group II: LWB+MOB - prohibition of loading the lower limb until week 7 after surgery plus mobilization introduced at week 3 after surgery. • Group III: EWB+MOB - early partial loading of the lower limb from day 1 after surgery, with progression to full loading of the lower limb in week 5, plus early mobilizations.	sectional area (CSA) of the tendon increased from weeks 6 to 26 ($P<0.001$) and decreased from weeks 26 to 52 ($P<0.001$). Muscle strength and muscle size: in the case of plantar flexion strength both at 0° and at 12°, no statistically significant influence of the allocated group was demonstrated; a statistically significant influence of time was demonstrated ($P<0.001$). All these parameters (including heel-rise index, heel-rise height, and range of motion) increased from weeks 26 to 52. The cross-sectional area of the medial and lateral gastrocnemius muscle increased from weeks 6 to 26. In the case of the soleus muscle, a decrease in cross-section from week 6 to 26 was observed.	muscle endurance (e.g., in the heel-rise test) are deficits of a chronic character.
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		The following parameters were assessed at weeks 2, 6, 12, 26, and 52 after surgery: elongation and stiffness of the Achilles tendon (weight-bearing X-ray), plantar flexion strength, heel-rise test, ATRS, and VISA-A.	Questionnaire results and complications: both ATRS and VISA-A results improved significantly over time (from weeks 12 to 26 and from weeks 26 to 52), but without a difference between groups. The time of return to full-time work and sport was similar in the examined groups. After 52 weeks, only 17 patients (24%) reported a return to their pre-injury sports level. Among 75 patients, 7 complications occurred: 2 reruptures (2.7%, both in the LWB+MOB group), one reoperation due to adhesions, one DVT, and 4 skin infections.	
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After performing an analysis of databases in accordance with the PRISMA guidelines, 3 articles comparing the effectiveness of rehabilitation protocols after 8 acute Achilles tendon ruptures were qualified for the systematic review. The above-mentioned works deal in a multifaceted manner with the dilemma between choosing a protocol of early functional mobilization (EFM) of the tissue after surgery and traditional management assuming unloading of the limb. The first study, conducted by De la Fuente et al. (18), addresses assessment of the effectiveness of immediate activation of the Achilles tendon compared with management assuming immobilization after percutaneous reconstruction in amateur athletes, assessing in the examined persons the values of isometric plantar flexion strength (PFS) and plasticity of the musculotendinous junction. The second article, by Aufwerber et al. (19), analyzes differences between early mobilization in an orthosis with gradual loading and two-week unloading in a plaster cast, assessing the functional outcomes of the examined persons: general quality of life of patients (including the RAND-36 questionnaire), and indicates the significant influence on the treatment process of complications such as deep vein thrombosis (DVT). The third of the qualified studies, prepared by Eliasson et al. (20), examines varied protocols of early loading and mobilization in comparison with a complete prohibition of loading, focusing on objective assessment of physical elongation (lengthening) of the tendon, its stiffness, and cross-sectional area in long-term, 52-week observation. None of the selected articles demonstrates a statistically significant advantage of modern protocols based on early activation and functional mobilization of the operated limb in long-term (12-month) functional outcomes compared with the traditional immobilization model. Objective strength parameters (e.g., in the heel-rise test) and results in specialist scales (ATRS) become equal over time in all examined groups. However, a statistically significant influence of early mobilization on noticeable differences in results in the initial period of tendon healing was demonstrated. In the study by De la Fuente et al. (18), immediate activation was demonstrated to result in better plasticity of the neuromuscular system and higher strength and functionality of the structure in the first 4-8 weeks after surgery. Aufwerber et al. (19) additionally demonstrated that EFM protocols positively affect vitality and subjective assessment of patient health during the first six months of recovery. In addition, the study by Eliasson et al. (20) effectively disproves concerns concerning the negative influence of early loading on excessive tendon elongation - this process progresses almost identically in each group, lasts uninterrupted for the first 6 months after surgery, and occurs regardless of the adopted rehabilitation model. The common denominator of the analyzed works is the final conclusion that return to full fitness proceeds slowly, awareness of existing complications (e.g., DVT) is necessary because they influence poorer

final outcomes, and strength deficits of a chronic character should be taken into account - it is indicated that 24% of patients managed to return to pre-injury sports loads.

Discussion

The analysis of the literature indicates a lack of clear statistical differences in long-term functional outcomes between protocols assuming early activation of the Achilles tendon and those based on strict immobilization. During the period of the first measurements, a statistically significant difference is demonstrated in subjective health and vitality questionnaires (e.g., RAND-36) in favor of protocols assuming earlier activation of the area. In a 12-month perspective, equalization of questionnaire values between the examined patients is demonstrated. Early activation of the Achilles tendon significantly influences the initial stages of healing, as demonstrated by musculotendinous junction displacement (MJD) (10.2 mm in the group treated according to the EFM protocol compared with 8.1 mm in the control group). At weeks 4 and 8 after surgery, patients loading the limb show significantly higher plantar flexion strength (PFS) and better ATRS questionnaire results (18). This indicates a significant psychosocial effect of early activation of the area after surgical intervention; however, the psychosocial effect is not confirmed by objective functional tests. During measurements performed at week 12 after surgery, equalization of isometric strength values and ATRS results is demonstrated between the EFM groups and the group on which limitations concerning limb loading in the first phases of healing after surgery were imposed. In long-term observation (12 months), no statistically significant advantage of early mobilization protocols is demonstrated in parameters of calf muscle regeneration measured using the heelrise test (19). It should be emphasized that, regardless of the protocol adopted for assessment, return to full function is a slow process, and strength deficits are chronic in character. It is indicated that one year after surgery, heel-rise test indices regain only 63-70% of the value of the healthy limb, and only 24% of patients return to the pre-injury sports level (20).

One of the key threats indicated by clinicians in physiotherapy, based on early activation of the operated area, is excessive elongation of the tendon scar, because it leads to a change in the resting length of the musculotendinous complex, which in turn affects a chronic and difficult-to-reverse deficit of plantar flexion strength of the foot. Studies using precise radiological markers demonstrate no statistically significant influence of varied protocols of loading or

mobilization of the Achilles tendon on measurable physical tendon elongation; elongation values remain at a similar level regardless of whether the limb was completely unloaded and immobilized in plaster or subjected to early, controlled body-weight loading in a walker-type orthosis (18).

A difference in previous assessments of elongation should be indicated, which, contrary to common beliefs, is not limited exclusively to the early postoperative phase. Changes in the physical length of the tendon continue uninterrupted for up to 6 months (26 weeks) from surgical intervention. The data show that only about 50% of total elongation takes place in the first three months after surgery, while the remaining significant part of the increase in length (from 5.5 to 8.2 mm) falls within the next three months (20). Intensive structural changes occurring 10 at the same time within the tissue itself should be indicated; i.e., the cross-sectional area (CSA) of the tendon, assessed using magnetic resonance imaging, systematically increases until week 26, only to undergo reduction again during the later period (up to week 52 after surgery).

In parallel with changes in length and thickness, reorganization of the mechanical properties of the scar progresses. During the period from 6 to 26 weeks, a statistically significant decrease in the susceptibility of the tendon structure to deformation processes is indicated, which proves its progressive increase in stiffness and appropriate remodeling of the collagen fiber arrangement. The fact that elongation processes last approximately 6 months indicates the groundlessness of the thesis suggesting a negative influence of aggressive surgical protocols on excessive elongation of the tendon scar; it does not influence worsening of plantar flexion function of the foot or gait quality after surgical intervention.

The articles indicated for the systematic review have limitations indicating the need to expand studies in order to optimize study quality:

- lack of randomization during measurements - the articles indicate that the investigators knew to which group the examined person was assigned. For objective reasons, full blinding of patients and therapists is not possible (orthosis, early loading);
- lack of reference points to the healthy limb; invasive measurements of tendon length (e.g., using tantalum markers and X-ray) and magnetic resonance imaging (MRI) examinations of cross-sectional area (CSA) were not performed on the healthy

contralateral limb. This makes it impossible to directly compare the structural parameters of the operated tendon with the healthy tendon in the healthy limb in the same patients;

- lack of standardization in different protocols; some studies assume measurements performed after 4 weeks, while some works perform measurements only in the period of 6 months, which demonstrates a lack of objective unification of clinical examinations performed in given periods;
- subjective assessment questionnaires and examinations: some works assume the use of subjective assessment questionnaires, which are always connected with poorer methodological quality due to their very nature. The literature indicates an insufficiency of multicenter studies and a lack of verification of muscle activity patterns using electromyography (EMG) and analysis of dynamic motor tasks in the early phase of treatment, which constitutes a clear field for improvements in future scientific projects.

Conclusions

The conducted systematic review of literature concerning management after surgical treatment of acute Achilles tendon rupture leads to a number of key clinical conclusions. The analysis of collected data demonstrates a lack of clear and statistically significant differences in long-term functional outcomes between innovative early functional mobilization (EFM) protocols and the traditional 11 model based on strict immobilization of the limb. From a twelve-month perspective, both therapeutic strategies resulted in similar values in subjective assessment scales (ATRS) and in objective parameters of isometric strength. Despite the lack of a long-term advantage, early activation of the operated area brings measurable benefits in the initial stage of recovery. In patients subjected to early loading, higher plantar flexion strength was observed at weeks 4 and 8 after surgery, greater plasticity of the musculotendinous junction (MJD) at the level of 10.2 mm compared with 8.1 mm in the control group, and it is also worth emphasizing the positive psychosocial influence of early activation of the operated area determined by statistically significant results of health and vitality assessment questionnaires compared with the group of patients with imposed unloading of the limb.

The lack of statistically significant data concerning the risk of excessive elongation (lengthening) of the tendon scar as a result of early loading should be indicated. Studies using

precise radiological markers demonstrate that varied loading protocols do not negatively influence the physical length of the tendon. The elongation process is continuous and lasts uninterrupted for up to 6 months (26 weeks) after the intervention, regardless of whether early activation is implemented or complete immobilization is maintained. At the same time, during the period up to week 26, there is a constant increase in the cross-sectional area (CSA) of the tendon and a decrease in its susceptibility to deformation, which indicates increased stiffness and correct remodeling of collagen fibers. It is again indicated that no influence of the choice of physiotherapeutic management protocol on a full return to full function was demonstrated, while the return itself is a slow process, and the chronic character of muscle strength deficits resulting from injury and recovery should be indicated. After one year, heel-rise test indices regain only 63-70% of the value of the healthy limb, and only about 24% of patients return to the pre-injury sports level. An independent, strong factor that permanently worsens functional treatment outcomes (including ATRS and FAOS) in short- and long-term observation is a complication in the form of deep vein thrombosis (DVT).

Attention should be drawn to significant methodological limitations of studies to date, which at the same time set the direction for future scientific projects. The main problems include the impossibility of full blinding of patients and therapists, lack of standardization of protocols with respect to the timing of measurements, and a strong emphasis on subjective assessment questionnaires, which, by their nature, are associated with lower methodological quality. A particular deficiency is the lack of a direct point of reference to the healthy limb in the same patients in invasive and imaging measurements (MRI).

Further studies should be conducted to expand diagnostics during the rehabilitation process, include radiological examinations of both limbs, potentially introduce electromyography (EMG) to objectify muscle activity patterns, and more effectively assess activation of muscle tissue in each examined period of postoperative treatment. To optimize the quality and processes of therapy, the introduction of combined studies between centers is recommended, for greater standardization of performed procedures and management.

Disclosure

Authors' Contributions Statement:

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All authors have reviewed and consented to the publication of the final version of the manuscript.

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