

## EFFECTS OF PLYOMETRIC EXERCISES IN POSTOPERATIVE PATIENTS OF RUPTURE OF THE CALCANEAL TENDON EFECTOS DE LOS EJERCICIOS PLIOMÉTRICOS EN PACIENTES POSTOPERATORIO DE ROTURA DEL TENDÓN CALCÁNEO

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### ABSTRACT

It is known about the rupture of the Achilles tendon since ancient Greece, which has been increasing in recent years, therefore, it seeks to implement better tools for its treatment, one of them being plyometric exercises. Meta-analysis type studies, randomized and experimental controlled trials observed that the application of plyometric exercises in most of the participants improved the quality of the tendon, increasing elasticity and decreasing its stiffness ( $p < 0.01$ ) in 14 studies and in the remaining 3 studies did not improve the structure of the tendon, however, it did improve its symptoms and functionality in late studies ( $p < 0.01$ ). The application of plyometric exercises is an additional tool to treat subjects undergoing an operation to rupture the Achilles tendon, which must be applied in the final stages of rehabilitation, improving tissue stiffness, increasing functionality and reducing chronic pain.

**KEY WORDS:** plyometric exercises, achilles tendon, calcaneus tendon, rehabilitation.

## RESUMEN

De la ruptura del tendón Aquileo se tiene conocimiento desde la antigua Grecia, la cual ha ido en aumento en los últimos años, por ende, se busca implementar mejores herramientas para el tratamiento de la misma, siendo una de ellas los ejercicios pliométricos. Estudios tipo meta-análisis, ensayos controlados aleatorizados y experimentales observaron que la aplicación de ejercicios pliométricos en la mayoría de los participantes mejoraba la calidad del tendón, aumentando elasticidad y disminuyendo su rigidez ( $p<0.01$ ) en 14 estudios y en los 3 estudios restantes, no mejoraba la estructura del tendón, sin embargo, mejoraba la sintomatología y funcionalidad del mismo en estudios tardíos ( $p<0.01$ ). La aplicación de ejercicios pliométricos es una herramienta adicional para tratar a los sujetos sometidos a una operación de ruptura de tendón Aquileo, el cual debe ser aplicado en estadios finales en rehabilitación, mejorando la rigidez del tejido, aumentando la funcionalidad y disminuyendo el dolor crónico.

**PALABRAS CLAVE:** ejercicios pliométricos, tendón aquileo, tendón calcáneo, rehabilitación.

## INTRODUCTION

Achilles or calcaneal tendon ruptures are a pathology that have been known since ancient times in ancient Greece, being Ambroise Paré who described this affection for the first time in 1575, frequently being the lesion from 2 to 6 cm proximal to calcaneal insertion (1).

Generally, the rupture usually appears due to a sudden and excessive increase in the pressure exerted on the tendon, with high-impact sports and repetitive jumps being the most prevalent, such as basketball, volleyball, tennis, some branches of athletics, among others. Some risk factors that predominate to suffer these injuries are age, sex, overweight and the use or application of some antibiotics such as the use of steroid injections (2).

In recent years, the injury has been increasing, having an annual incidence of 40 per 100,000 people, with men being the most affected in a peak range of 30 to 50 years of age, due to the fact that the population makes an effort to maintain an active life in aging (3). However, a recent study has shown that the incidence of this injury appears in all age stages, ranging from 10 years to 80 years (4). On the other hand, there are two treatments for this type of injury: surgical and conventional. Surgical is the most frequent, effective and quick to solve the problem; however, various complications may arise such as increased wound infection and prolonged rest of the affected limb. Conventional treatment consists of applying a Walker-type articulated ankle orthosis and applying progressive physiotherapy (5,6). On the other hand, plyometric exercises are a high-impact technique used mainly in sports patients or those who have a non-sedentary life, generating effects at the muscular and tendinous level, however, it has been found that this type of technique could negatively alter the fabric structure (7).

Taking into account the above, positive effects have been found that plyometric exercises can generate on the functionality of muscle and tendon tissues, in the same way, negative alterations have been found in the quality of

the tissue, however, it is important to determine if the Effectiveness of treatment is effective and adequate for the recovery of a calcaneal tendon rupture or similar affections already mentioned, in a postoperative stage. Therefore, the research question is: What are the effects of plyometric exercises in postoperative patients of an Achilles tendon rupture? Thus, based on this, the objective of this study is to determine if the effects of plyometric exercises would be adequate for rehabilitation in postoperative patients with calcaneal tendon rupture.

## **MATERIAL AND METHODS**

### Design

It has been implemented as a systematic review carried out in clinical trials obtained between January 2010 and January 2021 with a descriptive analysis of retrospective chronology in reliable, registered databases and with good research filters such as Pubmed, Scielo, Pedro, among others. The Articles that were included in this research had Helsinki ethical considerations (8), where the development of experimental research in living organisms, whether animals or humans, is proposed and moderated.

### Search strategy

This systematic review was carried out according to the recommendations of the Cochrane Collaboration for conducting and publishing qualitative and quantitative studies of the systematic review type, and qualitative studies of the meta-analysis type. Likewise, the compilation of studies was carried out under the considerations of the PRISMA Declaration (9) (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for meta-analysis and systematic review studies.

With the aforementioned, this search was developed from clinical trials in the PubMed and PubMed Central databases mainly. However, specialized journals were also reviewed, such as: the American College Sport of Medicine (ACSM), the American Physical Therapy Association (APTA), the World Confederation for Physical Therapy (WCPT). On the other hand, according to the descriptors and variables, the Boolean operators AND and OR, the search strategy was: ("plyometric exercise"[MeSH Terms]) AND ("calcaneal tendon rupture" OR "Achilleus tendon rupture"[MeSH Terms ] OR " tendon rupture ") AND ("patients"[MeSH Terms]) AND ("postoperative"[MeSH Terms]); thus, the search was carried out in English, Spanish, Portuguese, Chinese, and German, to avoid idiomatic identification bias.

### Selection of studies

The extraction and search of the articles was carried out by one author (J. D-S) and revised by a second (J. P-R). Regarding the selection criteria and explanation of data, the review was prepared by J. P-R – J. D-S independently.

The selected documents had to have a publication date between January 2010 and January 2021, in the same way, the methodology. The Study eligibility form was established according to the PICO10 system (P: Patients with tendon rupture, I: Plyometric exercises, C: No intervention with exercise, or another type

of intervention, O: Effects on post-operation of tendon rupture and others findings in these patients.) for the practice of Evidence-Based Medicine (EBM).

In addition to the above, no documents were filtered by population characteristics associated with sex, ethnicity, age or sociodemographic characteristics. On the other hand, one author (J. P-R.) verified compliance with the exclusion criteria described in the PRISMA diagram, which includes: duplicate studies, studies published in years prior to January 2010, experimental animal studies, type studies gray literature, inconclusive studies and studies that did not contribute to fulfilling the objective of this research.

#### Data collection and extraction

Data such as the type of population, intervention and control group, methodology, time and frequency of intervention, and results obtained were extracted from the studies collected and described through narrative synthesis. The data extraction was carried out through "Excel" spreadsheets and presented from tables in "Word" of the Office package.

Finally, data was discriminated based on demographic characteristics, sample size, number of patients included, follow-up period, intervention methodology and object of study. Regarding the results or impact measures, they were expressed according to the effects found, complication rates, injuries, clinical parameters, impact on quality of life, among others.

#### Quality evaluation

Reviewers J. P-R and J. D-S assessed the methodological quality of the research using the Cochrane Collaboration risk of bias assessment. Similarly, the selection bias of the information was determined (sources of obtaining the information, quantity, nature, handling of documents, among others).

In addition, the risk of bias was assessed using the PEDro scale (11) (in English, Physiotherapy Evidence Database). The PEDro scale consists of 11 sections that assess internal validity (criteria 2-9) and statistical information from clinical trials (criteria 10-11). Next, the present scale based on the Delphi list developed by Verhagen et al (12) (1998) assigns 1 or 0 points depending on whether or not it complies with the item being evaluated. Since the data obtained were analyzed and in the case of finding a difference greater than two points in the evaluation of the PEDro Scale and a new author made an assessment again to reach consensus.

#### Type of participants

Athlete, sedentary, apparently healthy patients with an age range of 15 to 50 years of age, female and male with a post-operative diagnosis of a rupture and partial injury without surgery of the calcaneal tendon, in acute or chronic stages, where no take into account prognosis or sociodemographic characteristics.

#### Type of studios

Meta-analyses, randomized or quasi-randomized controlled trials in which the effects of plyometric exercises were determined or compared in postoperative patients with calcaneal tendon rupture were selected. In the same way, reviews were taken into account that gave guidelines, recommendations or

guides for intervention based on plyometric exercises in patients who have suffered a calcaneal tendon rupture operation, with this, at the end of this article in case the evidence will demonstrate safety, suggest an appropriate exercise prescription for this type of population.

## RESULTS

They started with a total of 25 titles after the first search for experimental scientific articles. Found from different journals and databases such as: PUBMED, EMBASE, MEDLINE, ELSEVIER and Google Scholar. In addition, a second search was made to obtain more articles, which found 7 articles with the desired characteristics in the same research bases, obtaining a total of 32 articles. After carrying out the first filter, 8 were eliminated, as they did not have titles directly related to the research topic. Of the remaining 24 articles, 4 were excluded because they were articles that were too late, after performing the third filter, 3 articles were eliminated because they did not have complete or inconclusive conclusions. Having a total of 17 articles included in this research, in the same way, they were subjected to a methodological process using the PEDro scale based on the criteria of Maher C, et al. (11) who mention that all research with a PEDro post-scale result equal to or greater than 5/10 can be considered studies of high methodological quality and low risk of bias (Table 1). And likewise, the articles obtained are broken down in detail in Table 2 (13-29).

Laurent, C. (13) in his 2020 research with a population of 22 healthy subjects with an average age of 23 years used two plyometric techniques over a period of 10 weeks to identify if there were improvements in tendon quality, obtaining an increase in rigidity but improving its functionality. In another study by Houghton, L. (14) with 19 subjects with ankle sprain over a period of 8 weeks to see the quality of the tendon, a transverse increase in the tendon was obtained and improved functionality.

Fouré, A. et al. (15) took 19 healthy participants and implemented a program of explosive or plyometric exercises for 14 weeks, at the end of the program an increase in tendon stiffness and retraction sensitivity was observed. The same author, but in a study published in 2010 with the same population, obtained results of better transition of muscle tension and dissipated elastic energy storage recoil (16).

**Table 1. PEDro scale for the evaluation of the methodological quality of the studies included in the review (n = 17).**

Reference	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Total
Laurent C, et al. <sup>13</sup>	+	+	+	+	+	-	+	+	-	+	+	8
Houghton L, et al. <sup>14</sup>	+	+	-	+	+	-	+	+	-	+	+	7
Fouré A, et al. <sup>15</sup>	+	+	-	+	+	-	+	+	-	+	+	7
Fouré A, et al. <sup>16</sup>	+	+	+	+	+	-	+	+	-	+	+	8
Wu Y, et al. <sup>17</sup>	+	-	-	+	+	-	+	+	-	+	+	6
Nilsson K, et al. <sup>18</sup>	+	+	+	+	+	-	+	+	-	+	-	7
Yotsumoto T, et al. <sup>19</sup>	+	-	-	+	-	-	+	+	+	-	-	4
Ozkaya U, et al. <sup>20</sup>	+	-	+	+	+	-	+	+	-	-	-	5
Olsson N, et al. <sup>21</sup>	+	+	+	+	+	-	+	+	-	+	-	7
Fouré A, et al. <sup>22</sup>	+	+	+	-	+	-	+	+	-	+	+	7
Bogdanis GC, et al. <sup>23</sup>	+	+	-	+	-	-	+	+	+	+	-	6
Lantto I, et al. <sup>24</sup>	+	+	+	+	+	-	+	+	-	+	+	8
Rabusin CL, et al. <sup>25</sup>	+	+	+	-	+	-	+	+	-	+	+	7
Benito VA, et al. <sup>26</sup>	+	+	-	-	-	-	+	+	-	+	+	6
Grande del Arco J, et al. <sup>27</sup>	+	-	+	-	+	-	+	+	-	+	+	7
Brumann M, et al. <sup>28</sup>	+	+	+	+	+	-	+	+	-	+	+	9
Deng S, et al. <sup>29</sup>	+	-	-	+	-	-	+	+	-	+	-	5

PEDro (Physiotherapy Evidence Database): +Yes; - No.

P1: Selection criteria; P2: Random assignment; P3: Allocation concealment; P4: Similar groups at baseline; P5: Blinding of participants; P6: Blinding of therapists; P7: Assessor blinding; P8: Dropouts < 15%; P9: Analysis by intention to treat; P10: Differences reported between groups; P11: Estimated point and reported variability.

On the other hand, Wu, Y. et al (17) examined the functionality of plyometric exercises in the Achilles tendon in 21 healthy subjects, obtaining significant improvement in power as well as in tendon stiffness. In 2010 Nilsson-Helander, K et al. (18) wanted to observe if the conservative treatment was better than the surgical one and they managed to conclude that there was an improvement in the symptoms and then, Yotsumoto, T et al. (19) with patients who had subcutaneous Achilles tendon injury, implemented a 2-year protocol where he managed to improve the speed of return to sports activities.

Ozkaya, U. et al. (20) examined post-surgical patients and concluded that early intervention can improve joint ranges, reducing complications. Likewise, Olsson, N. et al. (21) obtained favorable improvements in recovery and Fouré, A. et al. (22) in a period of 14 weeks observed mechanical improvements in the tendon.

**Table 2. Characteristics of scientific articles (n=13).**

Author	N	Age	Type of studies	Disease	Intervention	Time	Conclusions
<b>Laurent C, et al. (13) (2020)</b>	22	23 ± 3	Clinical trials	Healthy Subjects	2 drop jump techniques of 20, 40 and 60 cm, jumps against movements in group 1 kept their legs extended and in group 2 they kept and made the jumps with bent knees.	10 weeks	The study indicated increased tendon stiffness after plyometric training when subjects performed jumping exercises with less knee flexion. However, jump height increased in the extended knee group compared to the flexed knee group 2.
<b>Houghton L, et al. (14) (2013)</b>	19	-	Experimental	Ankle sprains	The CG and the EG were divided into two groups, in which 8-week programs were used twice a week with half-turn time exercises, 5-meter sprint, long jump heights and vertical jumps.	8 weeks	Improved shuttle run times in cricketers and jumpers were obtained by increasing the cross-sectional area of the tendon, however further research is required to determine if this reduces the incidence of injury.
<b>Fouré A, et al. (15) (2011)</b>	19	22. ± 3.7	Experimental	Healthy Subjects	They were divided into two groups CG and EG: with 34 sessions in a period of 14 weeks with periods of one hour per session to culminate with a total of 6800 jumps at the end of the intervention.	14 weeks	At the end of the intervention, a greater sensitivity was observed in retraction of the tendon in plyometric exercises, increasing its stiffness of the tendon, however, more detailed studies are needed to evaluate the possible physiological adaptations of the tendon.

**Table 2. Characteristics of scientific articles (n=13).**

<b>Fouré A, et al. (16) (2010)</b>	19	22.1 ± 3.7	Experimental	Trained subjects	They were divided into two groups CG and EG: with 34 sessions in a period of 14 weeks in periods of one hour per session to culminate with a total of 6800 jumps at the end of the intervention.	14 weeks	Plyometric training improves the transition of muscular tension and recoil by storage of elastic energy dissipated by tendon structures, therefore, long-term plyometric exercise improves performance, but also increases muscle and tendon injuries.
<b>Wu Y, et al. (17) (2010)</b>	21	22.3 ±1.6	Experimental	Healthy subjects	The CG and the EG were divided into two groups, having plyometric exercise training in a period of 8 weeks with 2 sessions a week for one hour, doing 5-meter sprint techniques, vertical and longitudinal jumps, having 200 jumps per session. .	8 weeks	At the end of the intervention, an increase in power in the gastrocnemius muscles, tendon stiffness and use of elastic energy in the complex was observed, improving sports performance.
<b>Nilsson-Helander K, et al. (18) (2010)</b>	97	41	Experimental	Post surgery for Achilles tendon rupture with one year of evolution	The CG and the EG were divided into two groups, having an 8-week training protocol, 3 sessions per week of one hour, doing plyometric exercises with 5-meter sprints, unstable base jumps and explosive jumps.	8 weeks	At the end of the study, it was revealed that there is no significant evidence in the treatment with physical exercise, compared to the surgical treatment in the acute rupture of the Achilles tendon, however, it was observed that there is a great improvement in the symptoms due to early mobilization of the segment. .



**Table 2. Characteristics of scientific articles (n=13).**

<b>Yotsumoto T, et al. (19) (2010)</b>	20	43	Experimental	Patients with subcutaneous Achilles tendon injury	It was not divided into any control group, there was only an experimental group after the operation, it began with passive mobilizations for 2 weeks, at week 4 it began with full-support gait training, and began with its sports activities at the end of 12 weeks with exercises explosives and taking into account a follow-up of 3 years.	24 weeks	This protocol showed that starting physiotherapeutic treatment immediately after leaving the operating room can reduce movement restrictions without maintaining prolonged rest, generating a faster return to sports activities for patients.
<b>Ozkaya U, et al. (20) (2010)</b>	25	41	Clinical trials	Subjects who have had rupture of the Achilles tendon with a surgical intervention	A rehabilitation program was generated, starting with amplitude of the joint range of the first two weeks, where isometric and eccentric proprioceptive exercises were implemented, resuming sports activities before 3 months.	8 semanas	At the end of the study, evidence was provided that a rehabilitation protocol together with a minimal invasion of the Achilles tendon can significantly improve joint ranges and reduce its complications.

**Table 2. Characteristics of scientific articles (n=13).**

<b>Olsson N, et al. (21) (2014)</b>	100	39.8 6 ± 8.9	Experimental	Patients are partial rupture of Achilles tendon	Two groups were divided, the surgical group and the non-surgical group, the surgical group was treated conventionally with drugs and in the non-surgical group the affected limb was immobilized for 8 weeks, after which mobilizations and progressive heel discharges would be started, increasing each week the weight and generating jumps in unstable bases in a period of 12 months.	52 semanas	The results were favorable when intervening independently with rehabilitation in 49 patients who underwent the treatment, however, it did not generate different improvements against the surgical treatment.
<b>Fouré A, et al. (22) (2010)</b>	19	18.8 ± 0.9	Experimental	Healthy subjects	The CG and one EG were divided into two groups, which consisted of protocols already established in the literature with controlled squat jumps, jumping to lengths of 30cm, 40 and 80cm, and alternate jumps in randomized circuits.	14 weeks	El término de este estudio arrojó mejoras significativas en parámetros del tendón al utilizar ejercicios pliométricos a largo plazo, induciendo cambios en las propiedades mecánicas de las estructuras tendinosas, pero también aumentando el riesgo de lesiones musculares o tendinosas.

**Table 2. Characteristics of scientific articles (n=13).**

<b>Bogdanis GC, et al.(23) (2017)</b>	15	18.2 ± 25.8	Experimental	Healthy subjects	They were included in 12 sessions with a duration of 60 to 75 minutes, warm-up of 10 minutes jogging and stretching, starting from the first session with bilateral plyometric exercises in (GE1) and unilateral in (GE2) with an RM of 60% until reaching to 90%.	6 weeks	It was observed that there was a better power gain in the jump and a better performance in unilateral work compared to bilateral plyometric exercises.
<b>Lantto I, et al. (24) (2016)</b>	60	40	Clinical trials	Subjects with partial rupture injury of the Achilles tendon	The 60 participants were randomly distributed into surgical and non-surgical groups, the segment was immobilized for 6 weeks, starting week 1 with controlled movements without weight, with change of orthosis and increasing the joint range every week, after week 7 it started with supervised loading exercises at home.	77 weeks	At the end of the 18-month follow-up due to surgery, a great improvement was obtained with the rehabilitation treatment, improving their strength between 10% and 18% at the end of the study and improving the quality of the tendon.
<b>Rabusin CL, et al. (25) (2019)</b>	92	-	Experimental	Patients with bilateral tendinopathy	Two groups were divided, the CG and the EG, in which eccentric exercises were included twice a day for 7 days, with the heel resting on a 10-centimeter platform. The participants had a backpack that started with 5 kilograms and increased with 5 kg more.	12 weeks	At the end of the study, significant improvements were found in the treatment of tendinopathy and symptoms were significantly improved.

CG: control group; EG: Experimental group.

Bogdanis, GC et al. (23) observed that subjects who performed plyometric exercises had an improvement in unilateral and bilateral exercises ( $3.4 \pm 8.4\%$ ,  $p = 0.80$ ). Lantto, I. et al. (24) in subjects with partial injury to the Achilles tendon, an increase in strength of 10 to 18% was obtained and at the end of 18 months an increase in the tendon, the results were excellent in 28% of the surgical patients, 38% were good and 34% obtained regular results. Rabusin, CL et al. (25) in a period of 12 weeks applied plyometric exercises on unstable bases with load and without load using the VISA-A questionnaire scale.

Benedict VA. et al. (26) in their experimental study and Grande del Arco, J. et al. (27) with an initial systematic review with 576 articles managing to demonstrate the benefits of plyometric exercises. Similarly, Brumann, M. et al. (28) in their 2014 study concluded that using accelerated rehabilitation does not generate a risk of a complication as long as the treating physician performs a prior evaluation. Finally, Deng, S. et al. (29) in their meta-analysis compared the conventional treatment with the active treatment, obtaining that in group A (conventional) in the test for overall effect it had a result of 0.71 ( $p = 0.47$ ) compared to group B, 0.29 ( $p = 0.77$ ).

## DISCUSSION

The purpose of this study of this review was to obtain, analyze and compare various scientific articles that discussed the different variables of the application of plyometric exercises in patients who underwent surgical treatment of an Achilles or calcaneus tendon injury. Which are estimated to generate positive effects in this type of population.

A study by Popovic N, et al. (30) in 1999, has stated to have certain differences in the results obtained, the author showed that the application of the non-surgical conservative protocol increases the incidence of injuries, being the immobilizing surgical method the one with the best functional results. However, different studies (19-24) have shown that the application of plyometric exercises at an advanced stage and the early application of rehabilitation greatly improve the functionality of the segment, increasing its strength by 10% to 18% after the exercises. 18 months of treatment.

Also Benito VA. et al. (26) had similar and positive results in the application of plyometric exercises, reducing the incidence or relapse of the injury in sports patients who underwent early and specialized rehabilitation of the injury. However, Silbernagel KG, et al. (31) does not agree that the application of plyometric exercise is adequate to apply to this type of population, he suggests implementing eccentric overload exercises with greater results by reducing injury relapse and improving chronic Achilles tendon pain.

On the other hand, DiGiovanni, et al. (32) in a study carried out in 2003 mentions that the application of stretching exercises without load significantly improves the symptoms of plantar fasciitis related to an Achilles tendon injury. Similarly, Porter, et al. (33) in his study mentions that the application of sustained and intermittent stretching improves the symptomatology and the elasticity of the tendon, in comparison with two of the studies added to our systematic review that mention that with dynamic eccentric and plyometric exercises with load, one has an improvement in symptoms and functionality (18,25).

## **CONCLUSION**

The application of plyometric exercises is an additional and useful tool to treat subjects who underwent an Achilles tendon rupture operation; which must be applied in the final stages of rehabilitation. In addition, it was possible to show that plyometric exercises improve tissue stiffness, increase functionality and reduce prolonged chronic pain in post-surgical patients with Achilles tendon rupture. However, it is important to highlight that experimental articles on the benefits of plyometric exercises in this type of population are still scarce and further research on this topic is recommended.

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