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Abstract:
Background: Achilles tendon ruptures are common musculoskeletal injuries. Treatment options include surgical repair and non-operative rehabilitation with outcomes being similar between both options. Despite extensive rehabilitation during both treatment options, functional impairments can persist for years following the injury. This suggests that current rehabilitation protocols could be improved. **Case Description:** The patient was a 68 y.o male who presented to physical therapy 7 weeks following a full thickness Achilles tendon rupture that was managed non-operatively. **Intervention:** The patient was seen once a week. During weeks 8 through 13 following the injury blood flow restriction (BFR) training was utilized. Starting week 14 treatment consisted of progressive closed kinetic chain (CKC) strengthening. **Outcomes:** Ultrasound measurements of the medial gastrocnemius bilaterally was used to determine the effect of the BFR training. **Conclusion:** This case describes the use of BFR training during the early stages of non-operative treatment of an older adult with an Achilles tendon rupture. In this case BFR was well tolerated and safe. Furthermore, this case highlights the potential for BFR training to decrease disuse atrophy during the early management of Achilles tendon ruptures.

Keywords: Physical Therapy, Rehabilitation, Blood Flow Restriction, Achilles Tendon, Rupture, Older Adult

Background

Achilles tendon ruptures are a common lower extremity musculoskeletal pathology with an injury rate of 2.5 per 100,000 person/years in the United States[1] and up to 21 to 100,000 in European countries.[2] Achilles ruptures have significantly increased in the last two decades with male individuals having the highest risk of Achilles tendon rupture between the age of 20-39 and females between 40-59. However, the age group with the largest increase in Achilles tendon rupture are males between 40-59 years old. Achilles tendon ruptures are more likely to occur in males compared with females. The increase in incidence has been attributed to a more active older population participating in recreational sports and activities.[2]

Multiple management options are available for acute Achilles tendon ruptures including operative and non-operative management. Following both strategies functional impairments and decreased physical activity can persist years after the original injury.[3,4] These functional impairments are associated with changes in the musculotendinous unit following the injury. Increased tendon length, reduced fascicle length and increased pennation angle have all been shown to be associated with decrease function during long term follow up after Achilles tendon rupture[5,6]. Older age at the time of initial injury has also been shown to be associated with decreased function following Achilles tendon rupture[7]. This may be due to changes in musculotendon unit morphology that commonly occur with age. Fascicle length decreases and pennation angle decrease with age. Tendons also become more compliant, transducing less force with older age[8]. The similarities between the changes of musculotendinous units with age and following acute tendon rupture highlight the difficulty in rehabilitating these injuries especially in the ageing population.

A recent long term follow up study following Achilles tendon ruptures showed that there are minimal improvements in function 1 year following the injury[3]. These findings place a greater emphasis on the need to optimize early rehabilitation in this population. Current protocols for both operative and non-operative call for early mobilization and weightbearing following the injury or surgery. However, there is no difference between these more aggressive rehabilitation protocols and more conservative approaches[9].

One potential novel rehabilitation technique that could be implemented early during rehabilitation is the use of blood flow restriction training (BFR). This type of training involves using an elastic wrap, tourniquet, or band to occlude blood flow in limb during exercise. The use of blood flow restriction training has been primarily discussed in athletic populations. However, it has extensively been researched in geriatric populations and its use in the population is growing[10]. Low-load resistance training augmented with BFR has been shown to induce greater hypertrophy compared with low-load resistance training alone[11]. BFR may provide a stimulus to prevent atrophy and functional decline early in the rehabilitation process. Despite the potential benefits of using BFR during the rehabilitation following tendon repair there is paucity of literature examining its effectiveness. Two previous case reports have been published on the topic. One examined the use of BFR following biceps tendon repair[12] and the other examined BFR training to target lasting functional defects following Achilles tendon repair[13]. Both cases suggested the potential benefits of added blood flow restriction training in the end stages of rehabilitation of tendon ruptures. However, the use of BFR in the early stages of rehabilitation or in an older adult have previously not been reported. Thus, the purpose of this of this case report is to describe feasibility of implementing BFR in the early stages of rehabilitation of an Achilles tendon rupture in an older adult to augment traditional non-operative protocols.

This case aims to discuss the use of blood flow restriction training during the early phase of non-operative rehabilitation of an older patient following an acute Achilles tendon rupture to improve function and return to sport activities.

Patient Case

History:

This case follows a 68 y.o male who tore his Achilles Tendon playing basketball. He presented to a local ER and was placed in a Controlled Ankle Motion (CAM) boot and given crutches and the instructions to non-weight bear until a follow up appointment with an orthopedic surgeon. He was diagnosed with an acute Achilles tendon rupture 4 days following the original injury with a palpable gap in the tendon and a positive Thomas test. The Thomas test was originally described by Dr. Thompson in 1962 where he claimed that it was positive in 100% of Achilles rupture cases[14]. More recently, patient history and clinical exam of palpable defect and a positive Thompson test was found to be more sensitive for full thickness tears than MRI[15]. During the initial visit he was given a 2.5 cm heel lift to approximate the tendon and told he could be weight bearing as tolerated. He transitioned to full weight bearing and no crutches over the course of 6 weeks.

He was first evaluated by an outside physical therapist at 4 weeks following the initial injury and started with gentle ankle PROM and ultrasound over the healing tendon. Following the 6 weeks follow up with his surgeon the patient decided to switch to our clinic for personal reasons.

Evaluation:

During his initial evaluation he was found to have grossly symmetric active range of motion (AROM) and passive range of motion (PROM) bilaterally for ankle inversion, eversion, and plantarflexion. He was able to actively dorsiflex to neutral but full dorsiflexion range of motion was not assessed to prevent separation of the healing tendon. Strength was 5/5 for eversion, inversion and dorsiflexion. Again, plantarflexion strength was not assessed to minimize risk of separating the healing tendon. As forceful contractions of the triceps surae was contraindicated formal strength measurements were unable to be performed.

Treatment:

During the first visit he completed ankle inversion, eversion, plantarflexion and dorsiflexion to neutral exercises with a red Theraband. He was also shown a general LE strengthening program including open kinetic chain knee extension and knee flexion, and Leg press to be completed with his boot on.

At the second visit BFR was initiated. A personalized tourniquet system (Delfi Medical Innovations) was applied to the proximal thigh and inflated to occlude 80% of the limb occlusion pressure (LOP). LOP is defined as the pressure of complete arterial flow occlusion. The patient then completed 1 set of 30 reps followed by 3 sets of 15 reps of plantar flexion in long sitting. This sets and rep method has been published previously and shown to elicit hypertrophy with low-load resistance training with BFR[13]. Over the course of the next 6 visits the resistance used during the BFR training was progressed from a red Theraband to a green Theraband representing a 25% increase in resistance.

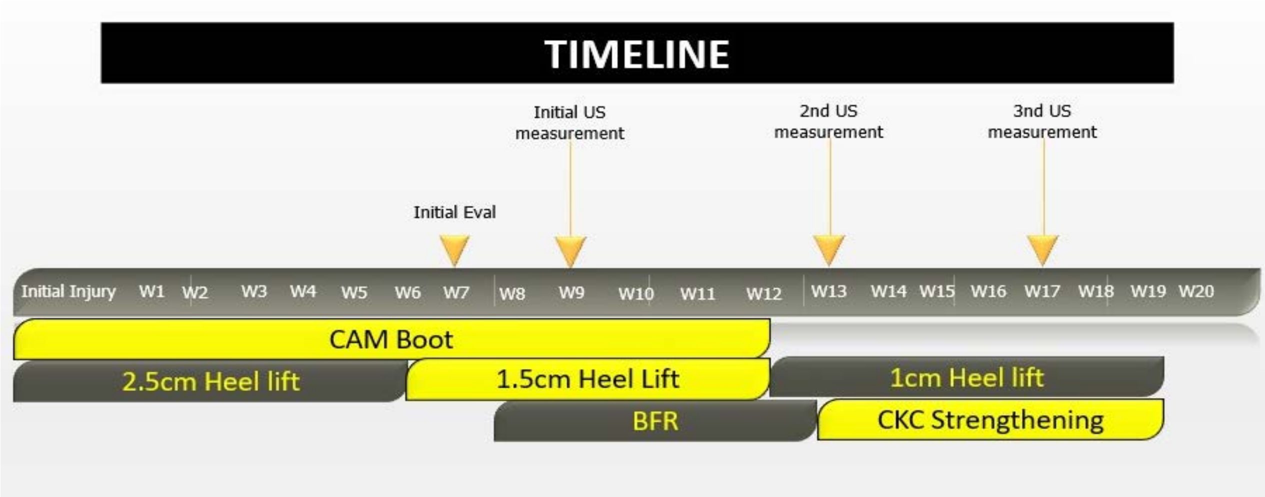

Figure 1. Timeline highlight time spent in CAM boot, transition of heel lift heights, and time spent with BFR training and start of CKC strengthening.

At week 12 post-injury the patient had a follow up visit with his orthopedic surgeon. During this visit he was released from the CAM boot and transitioned into a 1 cm heel lift in his tennis shoes. He also began to return to some low intensity golf specific activities such as chipping and putting. When he was able to start full weight bearing without the CAM boot at week 13 after the initial injury. We began CKC strengthening during his physical therapy treatments. This included partial squats working towards equal weightbearing between both of his lower extremities, bilateral heel raises, and gait retraining to restore a normal heel to toe walking pattern. He also continued progressing his general lower extremity strengthening program now without the use of the CAM boot. During the following visit 14 weeks after the injury the lower extremity strengthening was progressed. The patient began to perform lunges with his right lower extremity in the forward position. Partial squats were progressed to using a 12# medicine ball goblet squats. The leg press exercise was modified to a staggered stance to elicit more right lower extremity engagement and start the progression toward single limb activities.

Outcomes:

During the 3rd visit or week 9 following the initial injury ultrasound measurements of the thickness of the medial gastrocnemius were used as a surrogate measure of strength. These measurements were made by a physical therapy student following instruction from a physician with experience in musculoskeletal ultrasonography. Muscle thickness have shown to be a valid measure of muscle size and strength[16–18]. In this case tibial length was measured from the medial joint line to the tib of the medial malleolus. Muscle thicknesses were measured 1/3 of the tibial length distal to the medial joint line. 3 measurements were made, 2 in the long axis and 1 short axis and then the results were averaged.

The initial muscle thickness was 1.73 cm on the right and 2.21 on the left. During the next month the patient continued use of his CAM boot while undergoing BFR training during physical therapy. At week 13 the muscle thicknesses were 1.44cm and 1.83cm for the right and left medial gastrocnemius respectively. At week 17 following a month of closed kinetic chain strengthening described above the muscle thickness measurements were 1.52 cm for the right and 2.18 cm for the left.

The goal of the patient was to return to recreational golfing. Beginning week 12 the patient started participating in golf specific activities that were low in demands of his lower extremity. He started with putting and chipping two days a week. During the 15th week he felt a pop and felt as though he gained dorsiflexion range of motion. The following physical therapy visit he was reassessed for a palpable gap which was not present, and he had a negative Thomas test indicating his healing tendon was still intact.

Table 1. Mean muscle thickness measured in cm ± standard deviation measure weeks following initial injury.

	Week 9	Week 13	Week 17
Right	1.7 ± .08	1.4 ± .09	1.5 ± .13
Left	2.2 ± .04	1.8 ± .08	2.1 ± .15

Discussion:

Management of acute Achilles tendon rupture has been heavily debated in the literature and continues to be a controversial topic clinically. A recent meta-analysis of 29 studies highlighted the risks and benefits of surgical and non-operative management of Achilles tendon ruptures[19]. Surgical repairs decrease the likelihood of a rupture by augmenting the strength of the tendon and approximating the tear. However, surgical repair increased the risk of other complications such as infection, deep venous thrombosis, and sural nerve damage. Non-operative management has a slightly higher risk of re-rupture with re-rupture rates 1.6% higher when compared to surgical repair. Non-operative management also has the benefits of minimal other complications compared with surgical repair. When looking specifically at re-rupture rates surgical management is superior to non-operative management. If total complications are included into the analysis non-operative management is superior to surgical repair[19]. Despite the growing body of literature suggesting non-operative management is effective for functional outcomes and cost-effective, management strategies haven't changed in recent years. Older individuals are more likely to be treated non-operatively and younger individuals are more likely to receive operative management[20,21].

Rehabilitation protocols have been published attempting to establishing standardized rehabilitation process following Achilles tendon rupture. There has been some debate amongst rehabilitation professionals on the benefits and risks of early vs delayed weight bearing following surgical repair and non-operative management. Early non-operative protocols consisted of cast immobilization and non-weight bearing to encourage approximation of the tendon and to allow for healing. Early controlled motion is thought to create a healing stimulus to the tendon, but it comes with the risk of potential over lengthening the tendon early in the rehabilitation process. In trials comparing early motion versus delayed weightbearing and immobilization show that neither is superior[22]. Rehabilitation practices are varied and there is little consensus as to the optimal rehabilitation protocol[23]. Despite the low complication rates and relatively low re-tear rates functional deficits persist years following surgical repair and non-operative management[3,4].

BFR has been shown to illicit a similar but slightly smaller effect on hypertrophy and strength when compared to high load resistance training[10]. The direct mechanisms of this effect are not fully understood. Multiple lines of research have identified potential mechanisms. One mechanism is through activation of cellular signals that regulate skeletal muscle hypertrophy such as mammalian target of rapamycin (mTOR) pathways, and downregulation of forkhead box O (FOXO) and Myostatin pathways which regulate skeletal muscle atrophy[24]. It is believed that metabolic stress primarily mediates these effects compared to mechanical stress in traditional resistance training. There is also an increase in fast-twitch fiber recruitment during exercise in low oxygen environments which may play a role in the increased hypertrophic response in result of BFR[25]. Further research has shown that BFR may also influence peripheral vascular response to exercise this is potential mediated by increases in nitric oxide, and heat shock proteins which may lead to increased hypertrophy. Another potential mechanism is the release of systemic factors such as growth hormone, and insulin-like growth factor-1 (IGF-1) however, these have shown to directly stimulate hypertrophy in a blood flow restriction model[24]. Growth hormone (GH) and IGF-1 have also been linked to tendon health by increasing collagen synthesis within the tendon[26] but the direct effects of BFR on the mechanical properties is unclear with some studies showing no changes in tendon stiffness[27] and others finding similar changes when compared to high-load resistance training[28].

Multiple concerns about the safety of BFR have been brought up in the literature[29,30]. However, little research has been conducted on the overall risk of adverse events while training with BFR. Adverse events may include effects on the cardiovascular system such as thrombolytic events as well as effects on the exercise pressor reflex which regulates blood pressure. In one study on healthy Japanese adults found the most common adverse events to be subcutaneous hemorrhage, sensory paresthesia’s and lightheadedness. In a rehabilitation setting 3% of clinicians utilizing BFR reported an event of rhabdomyolysis and .8% reported a thrombolytic event[30]. While the reported rate of adverse events is low, there may be an underreporting in the literature. Clinicians should be aware of the potential adverse events especially the effects on the exercise pressor reflex as this could have serious long-term outcomes such as death[29]. In this case the only adverse event noted was moderate discomfort during the exercise due to the pressure of the cuff; it appears that BFR training was safe in this case.

Achilles tendon ruptures are common in middle-aged, active men. This case highlights the need for conservative management of load application in an older individual with an Achilles tendon rupture to prevent the over lengthening of the tendon during rehabilitation. Since the effects of ageing on tendons include risk factors of poor outcomes such as muscle pennation angle, and tendon compliance. It is possible that rehabilitation following an Achilles tendon rupture in the older population needs to be more robust to prevent poor functional outcomes. In this case we utilized early BFR training to slow the rate of disuse atrophy while the patient was using a CAM boot. This was targeted to prevent the need from progressive strength training later to decrease the risk of Achilles tendon lengthening during end stage rehabilitation.

Limitations:

A possible limitation to this case report was that due to traveling from far distances for his physical therapy care the patient was only seen once a week. It is possible at this was not a frequent enough dose of the BFR training to see a meaningful effect. We did observe less atrophy (change in muscle thickness/time) in the right side which was treated with low load BFR training compared with the left limb. However, we still observed an overall trend of atrophy in both limbs. Previous studies utilizing BFR have demonstrated a dose response relationship. This would explain the lack of effect due to blood flow restriction training seen in this case.

Ultrasound imaging has been shown to be operator dependent suggesting that inexperienced operators have more error and variability in diagnosis and measurements. The clinician using the ultrasound imaging had little experience with diagnostic ultrasound imaging. It is possible that this introduced error into the muscle thickness measurements and could explain the variability between time points.

Conclusion:

Rehabilitation during the non-operative management of an acute Achilles tendon rupture should be aimed at ensuring full healing of the tendon using heel wedges, progression of gastrocnemius and soleus strengthening to regain strength, but caution should be taken to prevent over lengthening of the tendon as increased tendon lengthening is associated with decreased function at long term follow up. One possible method of strength training early during rehabilitation while maintain tendon integrity is BFR training. This case demonstrated the safe and well tolerated use of weekly low load resistance training with BFR that may have reduced the amount of atrophy that occurs while the patient is unloaded in a CAM boot. There is a potential that this will allow the patient to return to normal strength more quickly without exposing the tendon to heavy loads that may stretch the tendon leading to a poorer outcome. Future research is needed to study the effectiveness of BFR in the early management of Achilles tendon ruptures.

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