The Journal of Foot & Ankle Surgery ■■ (2017) ■■–■■

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Case Reports and Series

Blood Flow Restriction Training After Achilles Tendon Rupture

Bobby G. Yow, MD [1], David J. Tennent, MD [2], Thomas C. Dowd, MD [2], Jeremy P. Loenneke, PhD [3], Johnny G. Owens, MPT [4]

[1]*Surgeon, Department of Orthopaedic Surgery, Walter Reed National Military Medical Center, Bethesda, MD*
[2]*Surgeon, Department of Orthopaedics and Rehabilitation, San Antonio Military Medical Center, Fort Sam Houston, TX*
[3]*Assistant Professor, Kevser Ermin Applied Physiology Laboratory, Department of Health, Exercise Science, and Recreation Management, University of Mississippi, University, MS*
[4]*Physical Therapist, Center for the Intrepid, San Antonio Military Medical Center, Fort Sam Houston, TX*

ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:
ankle plantarflexion
blood flow
muscle strength
rehabilitation
return to run
sports

ABSTRACT

Blood flow restriction (BFR) training is a technique shown to be safe and effective at increasing muscular strength and endurance in healthy fitness populations and is under study for its use in postinjury rehabilitation. BFR stimulates muscular strength and hypertrophy gains at much lower loads than traditional methods, allowing patients to begin the rehabilitation process much sooner. We report on 2 patients who incorporated BFR training into their traditional rehabilitation program after Achilles tendon ruptures. Patient 1 was a 29-year-old active duty soldier who sustained a left Achilles tendon rupture while playing competitive football. After operative repair and traditional rehabilitative measures, he was unable to ambulate without assistive devices owing to persistent weakness. The patient subsequently started a 5-week "return to run" program using BFR training. He experienced plantarflexion peak torque improvements of 522% and 108.9% and power gains of 4475% and 211% at 60°/s and 120°/s, respectively. He was able to ambulate without assistive devices at the 5-week follow-up examination. Patient 2 was a 38-year-old male soldier who experienced a complete left Achilles tendon rupture while exercising. After nonoperative treatment with an accelerated rehabilitation program, the patient still experienced significant strength and functional deficits. He was subsequently enrolled in a 6-week course of BFR training. He experienced plantarflexion strength improvements of 55.8% and 47.1% and power gains of 68.8% and 78.7% at 60°/s and 120°/s, respectively. He was able to return to running and sports on completion of 6 weeks of BFR-assisted therapy. Incorporating tourniquet-assisted blood flow restriction with rehabilitation programs can improve strength, endurance, and function after Achilles tendon rupture.

Published by Elsevier Inc. on behalf of the American College of Foot and Ankle Surgeons.

Persistent deficits after Achilles tendon rupture include significant strength and functional impairment at 2 years, irrespective of operative or nonoperative treatment (1). Consequently, maximizing early mobilization and functional rehabilitation when possible is recommended to improve long-term outcomes (2–6).

Blood flow restriction (BFR) by itself, or combined with submaximal exercise, has been shown to result in favorable adaptations to skeletal muscle by creating the requisite environment for muscle hypertrophy and strength improvement (7,8). BFR training involves applying a partially restrictive cuff at the proximal portion of the arms or legs to partially restrict vascular flow (9). Originally used in the Japanese fitness population, BFR training has more recently been investigated for its rehabilitation potential of both operative and nonoperative musculoskeletal deficits, because it allows for strength improvements when higher loads are either not attainable or contraindicated owing to surgical precautions (10–14). Furthermore, this intervention has recently shown promise in improving quadriceps strength and functional return to activities postoperatively after knee arthroscopy (15). The loads used with low-load resistance exercise, combined with BFR, are usually 20% to 30% of the patient's 1 repetition maximum (1RM), which is significantly lower than the traditionally recommended load needed for substantial increases in muscle size and strength (16,17). This method has been shown to be safe across various populations, with responses in blood pressure, coagulation, and delayed onset of muscle soreness similar to those seen with traditional resistance training (14,18–22). Together, the gains in muscle size and strength can optimize early postinjury rehabilitation and minimize the load on the soft tissue. We present the case of 2 patients who had sustained Achilles tendon rupture and completed a BFR protocol as a part of their rehabilitation efforts.

Financial Disclosure: None reported.

Conflict of Interest: None reported. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

Address correspondence to: Bobby G. Yow, MD, Department of Orthopaedic Surgery, Walter Reed National Military Medical Center, 8901 Rockville Pike, Bethesda, MD 20889.
E-mail address: bobby.g.yow2.mil@mail.mil (B.G. Yow).

1067-2516/$ - see front matter Published by Elsevier Inc. on behalf of the American College of Foot and Ankle Surgeons.
https://doi.org/10.1053/j.jfas.2017.11.008

Table 1
Patient 1: isokinetic results at 60° and 120°/s of ankle flexion

Patient 1	PF Position (°)	Uninvolved (°)	Involved (°)	Initial Deficit (%)	After Training (°)	Improvement of Involved (°)	Persistent Deficit (%)	Improvement of Involved (%)
Power (J/s)	60	56.30	0.80	98.60	36.60	35.80	34.99	4475
	120	65.60	18.00	72.50	56.00	38.00	14.63	211
Peak torque (Nm)	60	57.46	5.31	90.80	33.04	27.73	42.49	522.00
	120	41.45	14.09	66.10	29.43	15.34	29.00	108.90

Abbreviation: PF, plantarflexion.

Case Report

Patient 1

Patient 1 was a 29-year-old active duty soldier who had sustained a left Achilles tendon rupture while playing competitive football. He subsequently underwent primary Achilles tendon repair that was complicated by an infection requiring formal operative debridement 3 weeks later. He then began a nonoperative therapy regimen with evidence of clinical healing. At 6 months postoperatively, he continued to have severe functional weakness with dorsiflexion and plantarflexion. He demonstrated an antalgic gait and limited push off in terminal stance and required a single-point cane for assistance with mobilization. His range of motion was measured as 10° of dorsiflexion and 60° of plantarflexion.

The patient's ankle strength in dorsiflexion and plantarflexion was assessed at his initial physical therapy evaluation using a Biodex System 3 Isokinetic System (Biodex Medical Systems, Shirley, NY). After a 5-minute warm up on a stationary bike, the patient performed 5 repetitions of ankle dorsiflexion and plantarflexion at 60°/s, followed by a 90-second rest period. This was followed by 10 repetitions of ankle dorsiflexion and plantarflexion at 120°/s. The weight of the foot was measured for gravity correction, and strong verbal encouragement was given during testing. Compared with his contralateral side, his plantarflexion isokinetic peak torque strength deficit was significantly decreased (Table 1).

Because of his continued strength and functional deficits, he was enrolled in a BFR training program, which is a component of the "return to run" clinical pathway at our facility (23). Originally developed to assist soldiers with severe lower extremity combat injuries to return to high-level activities, this pathway consists of a multidisciplinary functional rehabilitation program that is tailored to the individual patient's deficits (23,24). A Delfi PTSii tourniquet system (Delfi Medical Innovations Inc., Vancouver, BC, Canada) was used with a Delfi Vari Fit Contour Tourniquet Cuff measuring 14 cm wide. A handheld portable Doppler probe (Imexdop CT; Nicolet Vascular, Madison, WI) was used to measure the patient's posterior tibial artery pulse. The tourniquet was gradually inflated until the complete limb occlusion pressure (LOP) was reached, defined as the absence of an arterial pulse. We then used 80% of the LOP throughout the duration of the BFR exercises to ensure that the patient was under partial BFR at all times. The patient's arterial LOP was 225 mm Hg; thus, he exercised at 180 mm Hg.

His regimen included leg presses and calf presses (with the knee in full extension and 90° of flexion). He performed all exercises for 4 sets with repetitions of 30, 15, 15, and 15, with a tourniquet inflated on his proximal thigh at 80% of the LOP. The patient's 1RM was determined as the maximum amount of weight he could perform for each exercise. Because of his significant weakness and postoperative complications, a true 1RM was difficult to obtain. Thus, the final amount of weight the patient felt safe lifting was recorded as his 1RM. For training, 30% of his 1RM was used.

At the end of 5 weeks, he had experienced large plantarflexion strength improvements, with a peak torque of 522% and 108.9% and power gains of 4475% and 211% at 60° and 120°/s, respectively (Table 1). Although he had experienced large improvement, he continued to have persistent deficits in strength and power compared with his contralateral, uninjured extremity (Table 1). He tolerated the BFR treatment well without any adverse events. On completion of the 5-week period, he was able to ambulate without assistive devices and had returned to a running program.

Patient 2

Patient 2 was a 38-year-old male service member who had originally sustained a right Achilles tendon rupture while sprinting. The rupture was treated operatively with primary Achilles tendon repair without augmentation. Postoperatively, he participated in an accelerated rehabilitation protocol and recovered slowly owing to persistent pain and stiffness. He denied medical problems, smoking history, or previous tendinopathy. At 8 months postoperatively, the patient reported feeling a "pop," with immediate pain in his previously unaffected left posterior heel when performing box jumps. His physical examination was consistent with an acute rupture of his nonoperative left Achilles tendon. He opted for nonoperative treatment of this injury, consisting of early immobilization, followed by an accelerated rehabilitation protocol. At 4 months postinjury, he denied pain and was able to ambulate without difficulty but was unable to run owing to persistent weakness in his left lower extremity. On examination, he had no tenderness about his Achilles tendons bilaterally. However, he was only able to perform 13 consecutive calf raises on his left compared with 36 on his right. Baseline isokinetic testing of his left lower extremity displayed strength and power measures that were greater than the contralateral side, possibly attributable to abnormal testing results for the operative contralateral extremity (Table 2).

He was subsequently enrolled in the "return to run" pathway and a 6-week course of BFR training for his left lower extremity consisting of 4 sets of 30, 15, 15, and 15 repetitions at 30% of his 1MR weight using the aforementioned tourniquet system around the proximal thigh at 80% of his LOP. The same methods for determining the LOP and same tourniquet system were used for all interventions. His exercises consisted of leg presses and calf presses (with the knee in full extension and 90° of flexion).

After 6 weeks of BFR training, he had experienced plantarflexion strength improvements of 55.8% and 47.1% and power gains of 68.8% and 78.7% at 60° and 120°/s, respectively, compared with his initial testing (Table 2). He tolerated the treatment well and had no side effects from BFR training. He was able to return to running and sports on discharge from rehabilitation.

Discussion

The Achilles tendon plays a critical role in proper lower extremity function and is crucial for a return to normal activities (25,26). Traditional rehabilitative efforts often result in an incomplete return to function, with strength deficits ranging from 10% to 30%, irrespective of the method of treatment chosen (1,5,27). Thus, rehabilitative