Doctor of Physical Therapy Program Case Reports

2017

The Use of Blood Flow Restriction Therapy in the Treatment of a Professional Baseball Player Status Post Meniscectomy: A Case Report

Ryan Tillma
University of Iowa

The Use of Blood Flow Restriction Therapy in the Treatment of a Professional Baseball Player Status Post Meniscectomy: A Case Report

Ryan R. Tillma

DPT Class of 2017
Department of Physical Therapy & Rehabilitation Science
The University of Iowa

Abstract

Background: Meniscal and cartilage injuries account for one the greatest amount of average missed time in professional baseball. Blood flow restriction (BFR) therapy may be a beneficial intervention in post-surgical patients to stimulate hypertrophy and strength gain while minimizing unnecessary stress on the surgical area and help facilitate a quick return to sport. The purpose of this case report is to examine the current evidence on the topic of BFR training and demonstrate the use of the intervention in a professional baseball setting. **Case Description:** The report follows a 19-year-old professional baseball pitcher following a meniscectomy. **Intervention:** A ten-week rehabilitation progression highlighting the use of BFR therapy in conjunction with conventional physical therapy. **Outcomes:** Following the ten-week progression range of motion in the right knee was measured at 0-145, this was equal when compared to the uninvolved side. The athlete's quadriceps and hamstring strength, single leg hop, and triple hop test were all found to be greater than 95% of the uninvolved limb. **Discussion:** This case study demonstrates the safe use of blood flow restriction therapy in a professional baseball setting and suggests it may be a beneficial adjunct to conventional therapy in this type of patient and injury.

Background and Purpose

Although less common in baseball than other professional sports, knee injuries still account for the 5th highest reason for missed time in all of professional baseball. Meniscal and cartilage lesions only account for about 9% of all knee injuries in major league and minor league baseball but result in the greatest amount of average missed time, 44 days per injury.[1] Like all professional sports, rehabilitation of injuries is aimed at maximizing the athletes function and performance while minimizing the time missed from sport. One intervention that may help to facilitate a quick return while optimizing performance is the implementation of low intensity exercise under blood flow restriction (BFR).

According to the American College of Sports Medicine position stand for resistance training published in 2009, training with loads between 70-100% of an individual's 1RM is required to induce hypertrophy and typically takes up to 6 weeks to see an increase in CSA.[2] These loads are typically not appropriate for those undergoing rehabilitation for an injury or post-surgery. BFR training uses specialized pressure cuffs placed at the most proximal location on a limb to partially occlude venous return from the distal muscles while maintaining arterial inflow to the muscles.[3] This has demonstrated strength and hypertrophy gains comparable to high intensity training while only using weight of 15-30% 1RM.[4,5] BFR may provide a better option to stimulate strength and hypertrophy early in the rehabilitation process without introducing unnecessary forces to the injured or healing structures.

The scientific evidence to support the use of BFR to facilitate hypertrophy and strength gains is numerous. However, only recently has evidence began to emerge for the use of BFR in rehabilitation or the musculoskeletal population with few high-quality studies currently available. A recent systematic review published in the British Journal of Sports Medicine only included 20 relevant research articles focusing on musculoskeletal conditions with 13 of those focusing on adults at risk of sarcopenia.[6] Also, the research for the use of BFR in an athletic population of highly trained individuals is still lacking. A review published in 2016 on the use of BFR in athletics resulted in only 11 articles.[7] The purpose of this case report is to examine the current evidence on the topic of BFR training and demonstrate the use of the intervention in a professional baseball setting.

Case Description

History

The patient was a 19-year-old right handed professional baseball pitcher who reported to the affiliate athletic trainer with complaints of lateral right knee discomfort in July 2017. The athlete reports a history of patellar subluxations in early March and missed about 2 weeks of his high school season with no formal physical therapy or rehabilitation at that time. The athlete reports that his pain increased as baseball activity increased and reported that the pain began about 2 months ago when he noticed a pop while pitching. He noted instant swelling and reported clicking, popping, and giving way with certain baseball activities since then. He had continued to pitch with discomfort during summer league. The athlete had completed a pre-draft workout and physical in June with no remarkable findings or concerns.

Examination and Evaluation

The athlete was evaluated by the team athletic trainer on July 2nd. The athletic trainer reported moderate effusion of the R knee, negative findings for all ligamentous tests, and an increase in the athlete's symptoms with active knee extension and passive flexion. Manual muscle tests for hip and knee muscle strength revealed no noticeable deficits compared bilaterally. The athletic trainer also reported an increase in symptoms with single and double leg squats. No other objective measures or special tests were reported at this time. It was determined by the medical staff that an MRI would be appropriate to further evaluate the integrity of the knee and determine source of pain and was scheduled for July 3rd.

The athlete visited with the team orthopedic physician on July 13, 2017 to discuss the results of the MRI and be further evaluated. The evaluation by the physician revealed a normal gait pattern and neutral knee alignment. The physician reported no palpable tenderness along either joint line, no quadriceps atrophy, a negative ligamentous exam, with trace effusion, and a positive McMurray's over the lateral joint line. Range of motion of the right knee was measured at 0-135 degrees. Contralateral range of motion was not reported by the physician at this time.

Diagnosis and Prognosis

The MRI revealed a lateral meniscus radial oblique tear of the anterior horn and a medial meniscus minor free edge blunting of the body. Additionally, the MRI revealed subchondral sclerosis of the posterior lateral weightbearing aspect and grade 2 chondral loss of the medial femoral condyle. The MRI revealed normal patellofemoral alignment and preservation of the patellar and trochlear cartilage.

The team physician determined that the source of pain was most likely the tear to the lateral meniscus. The physician discussed the implications of this with the athlete and how it may affect his short and long-term ability to pitch. They discussed operative management and the risks, benefits, alternative procedures, and expected outcomes of surgery. It was decided that a right knee arthroscopy and partial lateral meniscectomy would result in the greatest outcome. The athlete underwent a lateral meniscectomy 15 days after he first presented with knee pain to the athletic trainer.

Intervention

The athlete reported to the organizations rehabilitation facility on July 19th to begin physical therapy. The athlete presented ambulating with two crutches with mild discomfort and moderate swelling with no signs of infection. Range of motion was measured as lacking 3^o of extension with flexion to 113^o using standard goniometric technique. Patellar mobility was also limited with poor vastus medialis activation and noticeable atrophy of the right quadriceps when compared to the left.

As discussed previously BFR training allows one to adequately stress muscle tissue to stimulate hypertrophy and strength gain while minimizing stress on other tissues. This is a beneficial concept when treating an individual who is post-surgical, specifically surgery involving a weight bearing surface. In addition to previously cited research, a recent pilot study demonstrated the effectiveness of BFR training following knee arthroscopy.[8] Additionally, it has been proposed and studies have shown potential benefits for chondral and bone health with BFR training.[9,10] BFR may provide secondary benefits to the heeling of the remaining meniscus along with the sclerotic changes noted on the MRI. The patient's pre-surgical physician visit and preseason physical indicated he did not have any existing vascular or cardiopulmonary conditions that may increase risk of adverse effects from BFR training. Due to the surgery involving the articular surface and the post-operative deficiencies present, the physical therapy staff determined that the use of blood flow restriction therapy in conjunction with conventional physical therapy would be safe and beneficial to help the athlete return to preinjury level without complications.

Several lower extremity exercises were performed (see Fig 1 below) in the acute post-operative phase of rehabilitation while using BFR in an attempt to augment muscle strengthening and rehabilitation. The BFR was applied using the Delphi Personalized Tourniquet System for Blood Flow Restriction, currently the only FDA-approved device for BFR available commercially. This device can determine the specific limb occlusion pressure for each individual, making it generally more safe and precise than other marketed BFR devices. A tourniquet cuff was placed as proximal on the limb as possible, in this case on the lower extremity just distal to the inguinal crease, with a limb protection sleeve between the skin and cuff to protect skin integrity. The athlete then rested supine on the table while the machine calculated the patient's personalized tourniquet pressure or limb occlusion pressure.

For all lower extremity exercises for this athlete the limb occlusion pressure was set at 80%, which is the most common and recommended pressure used for the lower extremities within the current literature to obtain optimal results with minimal safety concerns. Evidence suggests that cuff pressures exceeding 200 mmHg are no more effective that more moderate pressures, closer to 150 mmHg.[11] 80% of the individual's limb occlusion pressure was generally within this range of 150-200mmHg.

The athlete performed the prescribed BFR exercise 3 days per week, the exact exercise progression is described below. This frequency of 3 days per week is thought to be more effective than a greater frequency according to a meta-analysis performed by Loenneke et al.[21] The athlete performed 4 sets of each exercise with repetitions of 30/15/15/15 for a total of 75 repetitions with a 30 second rest break between sets while maintaining tourniquet pressure. Each exercise was performed at a tempo of 2-second concentric and 2-second eccentric. The 30 second rest period has been shown to have a greater effect size than that of longer periods.[12] The total time to complete each BFR exercise was about 7 minutes. The optimal volume protocol has not been firmly established yet, however the protocol that we employed of 30/15/15/15 is generally accepted and widely used throughout the literature and thought to result in the greatest accumulation of metabolites within the session without maximal effort.[13]

Our protocol did not measure 1RM prior to exercise performance so it cannot be fully determined if the athlete was exercised at 15-30% 1 RM. It would not be recommended to perform maximal strength testing on our athlete shortly after surgery. Our protocol began with limb weight in open chain and body weight in closed chain exercise, and the load was progressed as tolerated. We believe that considering the weight of the limb during open chain and body weight during closed chain exercises, the loads were likely adequate to mitigate atrophy and increase neuromuscular activity early on and induce hypertrophy and strength in later stages.

Intervention Plan

Week 1

- Week one of rehabilitation focused on early range of motion, reducing swelling, quadriceps activation, and gait training with crutches
- The BFR exercise implemented during week one was non-weighted long arc quads, performed 3 days per week (Figure 1a)

Week 2

- Additional exercises were employed targeting the glutes, along with patellar mobilizations, a single limb balance progression, and upper extremity maintenance exercises
- Continued with non-weighted long arc quads with BFR

Week 3

- Progression of single leg balance, gait training without crutches, and additional upper extremity exercises
- Addition of two pound to long arc quad exercise with BFR

Week 4

- Addition of band walks and mini squat to current plan
- Increase weight of long arc quads with BFR to 4 pounds

Week 5

- Addition of single plane lunges to rehab plan
- BFR added to mini-squats with continuation to long arc quad exercise with BFR (Figure 1b)

Week 6

- Began introducing lower extremity exercise into his weight room routine under supervision of the strength and conditioning coach
- Progression of multi-plan lunges and jump training focusing on landing mechanics
- Full squat with BFR with body weight

Week 7

- Began interval throwing program three days per week to gradually return to pitching
- Continuation of current rehab plan including full squats with BFR and long arc quads

Week 8-9

- Progression of interval throwing program
- BFR lunges added to rehab program (Figure 1c)

Week 10

- Began throwing on mound and jogging in grass
- Performed outcome testing and determined athlete may return to sport

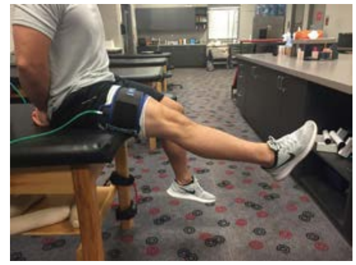
Week 11-12

- Participated in instructional league practice taking part in fielding drills and pitching live batting practice
- Began return to sprint program

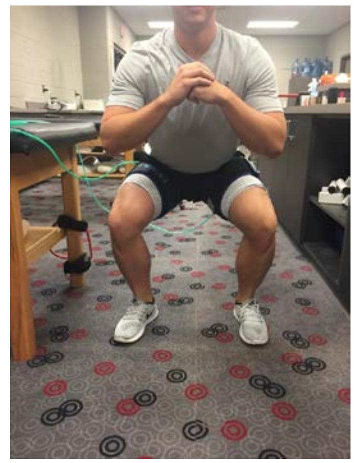
Week 13+

- Athlete discharged home, with an offseason strength program, following instructional league

a.



b.



c.

Figure 1. Demonstration of blood flow restriction exercises using the Delphi Personalized Tourniquet System. A) Short arc quad, B) Squat, C) Forward Lung

Outcomes

At the end of the ten-week period and prior to participation in instructional league, the athlete's range of motion was measured, strength was tested, and he completed the single leg hop and triple hop tests. Range of motion in the right knee was measured at 0-145, this was equal when compared to the uninvolved side. The athlete's quadriceps and hamstring strength were tested isometrically with the knee at 90^{o} of flexion using the Kiio force sensor. A recent study has shown that this device demonstrates excellent reliability, responsiveness, and validity compared with an isokinetic dynamometer.[14] The strength of the quadriceps was determined to be at 96.4% compared to the unaffected limb, and the hamstring strength was measured to be 95.6%. The athletes single hop for distance and triple hop test both measured >95% compared to the unaffected side. Due to these findings, the athlete was cleared to participate in instructional league and began a return to sprinting progression.

Discussion

The mechanism behind the positive response to BFR training is not fully understood. However, there is a large amount of compiled evidence and theories for the proposed mechanisms. One theory is the metabolite theory in which the tourniquet pressure limits the oxygen supply to the muscle resulting in a shift from aerobic to anaerobic metabolism, similar to high load training, causing the use of fast twitch fibers. A marker for this is the production of lactate as a byproduct which has been shown to rise with BFR training to similar levels as high intensity training.[15,16] This increase in lactate is thought to inhibit the contraction of surrounding working fibers, resulting in the recruitment of additional motor units to maintain force production.[15, 17,18] This increase in lactate has also been shown to cause a significant increase in growth hormone (GH) release by the pituitary gland, stimulating production of insulin like growth factor (IGF-1) which has been linked to hypertrophy in humans.[19,20] Multiple studies have shown an increase in both GH and IGF-1 following BFR therapy.[15,21] Additionally, research has shown a decline in myostatin, a protein that functions to inhibit myogenesis, following 8 weeks of BFR training similar to the decrease seen with traditional high intensity resistance training.[22] These factors may all play a role in an increase in muscle protein synthesis. A study by Fujita et al has demonstrated an increase in muscle protein synthesis of 46% 3 hours post training with BFR exercise at 20% 1RM compared to work matched controls.[23] These may all play an important role in the beneficial effects of BFR training and the positive outcomes observed in this case study.

The case study demonstrates the use of blood flow restriction therapy in a professional baseball setting. It provides as example of the safe use of the intervention and suggests it may be a beneficial adjunct to conventional therapy in this type of patient and injury. This patient returned to nearly full strength and range of motion within ten weeks with the use of BFR in addition to his exercise routine. While maximum strength testing was contraindicated immediately after arthroscopy, this case demonstrates that BFR may be beneficial even when using exercise loads typical of post-operative rehabilitation, such as body weight exercises. These may be a sufficiently high load early on to have beneficial results. However, as a case study we cannot determined whether the athlete would have also progressed similarly without the adjunct use of BFR.

To potentially further improve the results of the BFR training, we could have determined and tracked 1RM to target our exercise prescription to the 15-30% of maximum range. While traditional 1RM testing was not feasible, we could have used the Omnibus Resistance Exercise Scale (OMNI-RES) or Rating of Perceived Exertion (RPE). The OMNI-RES has been validated to track relative strength changes over a 12-week resistance program and RPE has been shown to have a high correlation with max volitional contraction.[24,25] Using one of these scales may have been beneficial to better determine exercise intensity than our approach of using standard rehabilitation exercise progression.

As a case report, we cannot presume the positive outcome seen for this patient would necessarily hold true for all meniscal injury patients. Further, the results of this case study may not be generalized beyond this population and injury type. BFR training is highly intense and some individuals may not be able to tolerate the seven minutes of occlusion that it typically takes to complete each exercise. Also, there are cardiovascular precautions that must be taken into consideration before utilizing this intervention. However, in a young generally healthy individual, this case study suggests that BFR may be beneficial to prevent disuse atrophy and facilitate early hypertrophy following an injury or surgical intervention.

References

1. Daum DL, Curriero FC, Camp CL. Epidemiology and impact of knee injuries in major and minor league baseball players. *Am J Ortho*. March/April 2016. E54-E62.
2. ACSM (2009) American College of Sports Medicine position stand. Progression models in resistance training for healthy adults*. Med Sci Sports Exerc.* 41(3):687–708.
3. Loenneke JP, Thiebaud RS, Abe T, Remben MG. Blood flow restriction pressure recommendations: the hormesis hypothesis. *Med Hypothesis*. 2014 May; 82(5): 623-6.
4. Takarada Y, Tsuruta T, Ishii N. Cooperative effects of exercise and occlusive stimuli on musclular function in low-intensity resistance exercise with moderate vascular occlusion. *Jpn J Physiol. 2004;54(6):585-592.*
5. Lowery RP, Joy JM, Loenneke JP. Practical blood flow restriction training increases muscle hypertrophy during periodized resistance programme. *Clin Physiol Funct Imaging*. 2014;34(4):317–321.
6. Hughes L, Paton B, Rosenblatt B, et al. Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. *Br J Sports Med*. 2017;51:1003-1011.
7. Scott BR, Loenneke JP, Slattery KM, et al. Blood flow restricted exercise for athletes: a review of available evidence. *J Sci Med Sport.* 2016;19(5):360-367.
8. Tennent DJ, Hylden CM, Johnson AE, et al. Blood flow restriction training after knee arthroscopy: a randomized controlled pilot study. *Clin J Sport Med*. 2017;27:245-252.
9. Karabulut M, Bemben DA, Sherk VD, et al. Effects of high-intensity resistance training and low-intensity resistance training with vascular restriction on bone markers in older men. *Eur J Appl Physiol*. 2011;111:1659-1667.
10. Loenneke JP, Young KC, Wilson JM, et al. Rehabilitation of an osteochondral fracture using blood flow restricted exercise: a case review. *J Bodywork Movement Therapies*. 2013;17:42-45.

11. Suga T, Okita K, Morita N, Yokota T, Hirabayashi K, et al. Dose effect on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. *J Appl Physiol.* 108(6):1563–1567.

12. Loenneke JP, Wilson JM, Marin PJ, et al. Low intensity blood flow restriction training: a meta-analysis. *Eur J Appl Physiol.* 2012;112:1849-1859.

13. Scott BR, Loenneke JP, Slattery KM, Dascombe BJ. Exercise with blood flow restriction: an updated evidence-based approach for enhanced macular development. *Sports Med*. 2015;45:313-325.

14. Grabowski P, Narveson M, Sigle S. Reliability, responsiveness, and criterion validity of the kiio sensor, a new tool for assessment of muscle function. *Military Med*. 2017;182:26-31.

15. Takarada Y, Takazawa H, Sato Y, et al. Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. *J Appl Physiol. 2000;88(6):2097-2106.*

16. Poton R, Polito MD. Hemodynamic response to resistance exercise with and without blood flow restriction in healthy subjects. *Clin Physiol Funct Imaging.* 2016;36(3):231-236.

17. Moritani T, Sherman WM, Shibata M, et al. Oxygen availability and motor unit activity in humans. *Eur J Appl Physiol*. 1992;64:552-556.

18. Yasuda T, Fukumura K, Fukuda T, et al. Effects of low-intensity, elastic band resistance exercise combined with blood flow restriction on muscle activation. *Scand J Med Sci Sports*. 2014;24:55-61.

19. Goto K, Ishii N, Kizuka T, et al. The impact of metabolic stress on hormonal responses and muscular adaptations. *Med Sci Sports Exerc*. 2005;37(6)955-963.

20. Morissette MR, Cook SA, Buranasombati C, et al. Myostatis inhibits IGF-I-induced myotube hypertrophy through Akt. *Am J Physiol.* 2009;297:C1124-C1132.

21. Takano H, Morita T, Iida H, et al. Hemodynamic and hormonal response to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. *Eur J Appl Physiol*. 2005;95:65-73.

22. Laurentino GC, Ugrinowitsch C, Roschel H, et al. Strength training with blood flow restriction diminishes myostatin gene expression. *Med Sci Sports Exerc*. 2012;44(3):406-412.

23. Fujita S, Abe T, Drummond M, et al. Blood flow restriction during low-intensity resistance exercise increases S6K1 phosphorylation and muscle protein synthesis. *J Appl Physiol*. 2007;103:903–910.

24. Robertson RJ, Goss FL, Rutkowski J. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc.* 2003;35(2):333-341.

25. Moishita S, Yamauchi S, Fujisawa C, Doman K. Rating of perceived exertion for quantification of the intensity of resistance exercise. *Int J Phys Med Rehabil*. 2013;1(9):1-4.