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The Effect of Blood Flow Restriction Training on Improving Knee Extensor Strength in Patients with Knee Osteoarthritis

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ABSTRACT

Background/Purpose: Knee osteoarthritis (OA) is one of the most prevalent musculoskeletal disorders in the world. Current guidelines for the non-surgical management of knee OA include the recommendation of quadriceps strength training. Current recommendations for strength training include high load resistance training at 60-80% 1RM, which is often not feasible in patients with OA due to the pain associated with the high compressive forces in the joint from the high loads. Low-load blood flow resistance training (LL-BFRT) is an emerging area of interest in research as a means that may provide similar results without eliciting pain. The purpose of this analysis is to determine if LL-BFRT is as effective as high-load resistance training at increasing knee extensor strength in patients with knee OA.

Case Description: The patient is a 62-year-old male referred to an outpatient orthopedic physical therapy clinic for the evaluation and treatment of symptomatic left knee OA. The patient is otherwise healthy and continues to be active. The patient's chief complaint is knee pain during occupational and recreational activities. The patient's goal is to reduce his pain and to delay or avoid a total knee arthroplasty (TKA).

Outcomes: All 8 studies showed an increase in knee extensor strength with the intervention, although some only minimally. The studies included subjects with either radiographic knee OA, symptomatic knee OA, anterior knee pain, or post TKA secondary to knee OA.

Discussion: LL-BFRT has been shown to be effective at increasing knee extensor strength with less associated pain than high-load resistance training. However, protocols and higher quality studies are needed as well as studies including individuals with co-morbidities to determine the true safety and efficacy of this intervention.

1. INTRODUCTION

Background and Purpose:

The term osteoarthritis (OA) is used to imply, "Articular cartilage damage, boney osteophyte formation, and sclerosis of the subchondral bone, and in advanced cases, subchondral cyst formation," regardless of underlying mechanisms[1]. Osteoarthritis is the leading cause of disability in the United States, with the knee being one of the most commonly affected joints[1,2]. It is a chronic, degenerative condition that often leads to surgical interventions, such as total knee arthroplasties. It has a prevalence of 33.6% (12.4 million) in adults ≥65 years of age, with women having a higher prevalence (42.1%) compared to men (31.2%) in the United States[1].

There are many risk factors associated with knee OA including age, gender, obesity, activity, and past injury[3]. Quadriceps muscle weakness has been shown to be predictive of symptomatic knee osteoarthritis,[4] with a stronger association in women,[5] however, it does not seem to be predictive of radiographic knee OA[4]. The associated muscle weakness and knee pain often leads to a functional decline, which may induce a self-perpetuating cycle. In the presence of radiographic knee OA, the current shared belief is that if knee extensor strength can be maintained or improved, the symptoms of knee OA will be delayed or diminished, which will preserve function and ultimately reduce healthcare costs, lost wages, and burden of care.

The American College of Sports Medicine currently recommends resistance training with high to moderate loads, which correlates to 60-80% of an individual's 1 repetition maximum strength (1RM) for strength gains[6]. However, in a clinical population, with symptomatic knee OA, it can be difficult to achieve this level of intensity due to the pain elicited in the pathologic joint from compressive forces. Furthermore, knee OA is strongly correlated to age and obesity, which are highly correlated to many other co-morbidities[3], and training at the recommended

intensity may be contraindicated in instances where those co-morbidities exist. Although many patients can participate in traditional rehabilitation, those who experience exacerbation of symptoms are often prescribed an exercise regimen with low-load resistance training or do not adhere to their exercise prescription. In many instances, this practice is ineffective because the exercises need to be performed to muscular fatigue in order to elicit strength gains[6].

Low-load blood flow restriction training is an emerging area of interest that researchers believe may solve the dilemma of increasing strength in patients who cannot use traditional high-load resistance training as a means to do so, particularly in the case of patients who have experienced a prior knee injury that led to OA without the associated risk factors. This type of training originated in Japan in the late 1960s, termed KAATSU ("additional pressure" in Japanese) training, and has become more popular since 2008 when the training devices became readily available outside of Japan[6]. In research, it is also known as partial vascular occlusion training, tourniquet training, and occlusion training.

The theory behind this method of training is that the occlusive device, that is either a tourniquet-style cuff that can be manually tightened or a pneumatic cuff that can be inflated, placed at the proximal aspect of the exercising limb will occlude venous flow while continuing to allow arterial inflow causing sufficient muscle fatigue to elicit strength changes[6]. The pneumatic devices utilized in research range from specialized cuffs to a manual blood pressure cuffs,[14] which all outpatient clinics should have, making it a cost effective and readily available option. The load commonly used with this training method is 20-30% of a person's 1RM[2,6,7,12-16,19].

In order to reduce pain, maintain function, and reduce health care related costs in specific patients with knee osteoarthritis, a rehabilitation protocol that will promote adherence and

maximize outcomes is needed. The aim of this review is to answer the following PICO question: Is low-load resistance training with concurrent blood flow restriction as effective as traditional resistance training at increasing knee extensor strength in patients with knee OA?

2. CASE DESCRIPTION

The patient is a 62-year-old, active, otherwise healthy, male referred to an outpatient physical therapy clinic for evaluation and treatment of left knee osteoarthritis. The patient's chief complaint includes left knee pain with occupational and recreational related activity. For the past 40 years the patient has worked, and continues to work, as a painting foreman, which requires him to stand for long periods of time, lift objects weighing up to 80 pounds, ascend/descend ladders, and stoop. His recreational activities include boxing, karate, swimming, and light weight lifting. The patient reported that he used to run, but was told by his doctor to never run again after seeing the radiograph of his knee. He states that he has experienced progressively worsening left knee pain and difficulty with his occupational and recreational activities.

The patient was referred to physical therapy by his primary care provider four years ago following his diagnosis of knee OA. The patient received traditional physical therapy for an extended amount of time, reporting only minimal pain relief and return to function despite following through with all scheduled sessions, home exercises, and recommended activity modifications. The patient states he has also received cortisone injections in his left knee to manage his pain but found them to be only minimally effective and did not believe the benefits outweighed the potential risks or side effects. The patient's goal is to return to pain

free activity and reduce the progression of the osteoarthritis in order to delay or avoid a total knee arthroplasty, so he has chosen to participate in physical therapy again.

The patient presents with:

- Slight left genu varum
- Decrease ROM
    - Decreased hip extension L
    - L knee 5-111 degrees
- Decreased balance with decreased ankle strategy during single limb support bilaterally
- Decreased strength
    - Knee extension: Left 4/5; Right 5/5
    - Glute max: 3+/5 bilaterally
    - Glute med 3+/5 bilaterally (pain noted on L knee)
- Positive Thomas test bilaterally
- Decreased flexibility
- Decreased A/P tibiofemeral glide on left
- Limited superior/inferior patella glide with crepitus on left
- Gait
    - Trendelenburg L
    - Decreased L terminal knee extension
    - Knee flexion during stance on L
    - Decreased step length bilaterally with decreased stance time on L

3. EVIDENCE BASED ANALYSIS

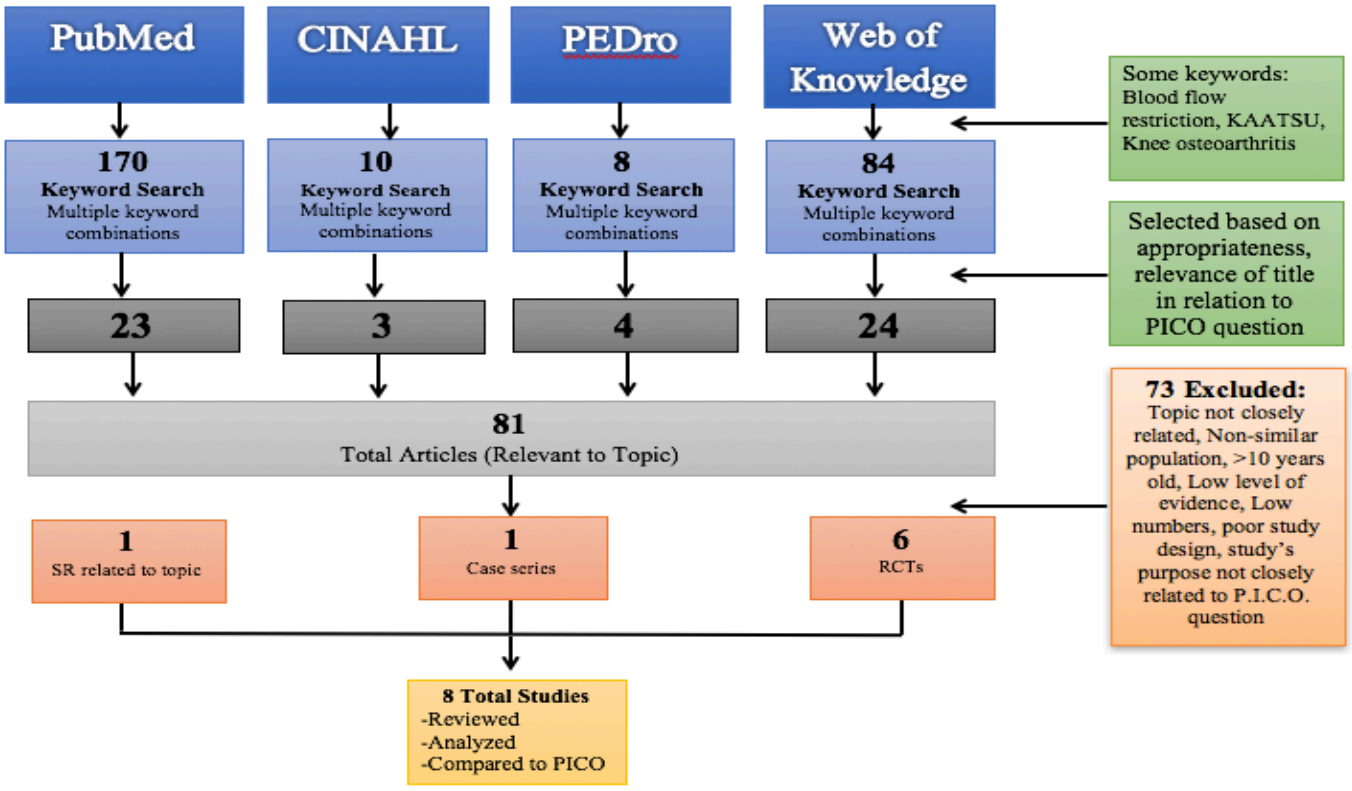
Methodology of Search:

A methodological search was performed to answer the following PICO question: Is low-load resistance training with concurrent blood flow restriction as effective as traditional resistance training at increasing knee extensor strength in patients with knee OA? PubMed, CINAHL, PEDro, and Web of Knowledge were the databases searched using the following search terms: “Blood flow restriction training”, “blood flow restriction training AND knee osteoarthritis”, “KAATSU training AND knee osteoarthritis”, “partial vascular occlusion training AND knee osteoarthritis”, “physical therapy”, and “rehabilitation” (Figure 1).

Selection Criteria:

Articles were eligible for inclusion if (1) participants were ≥45 years of age, (2) a primary outcome measure of knee extensor strength was used, and (3) the publication date was within the last 10 years. Exclusion criteria for articles selected included: (1) participants with a diagnosis of an inflammatory form of arthritis, (2) 1RM for knee extensor strength not measured or estimated, and (3) articles published in a language other than English without an English translation.

Figure 1. Article search methodology



The articles below were selected to be analyzed. Refer to Appendix A for detailed article analysis worksheets.

Article Summaries:

Article #1 (Reference #2): Segal, N., Davis, M., Mikesky, A. (2015). Efficacy of blood flow-restricted low-load resistance training for quadriceps strengthening in men at risk of symptomatic knee osteoarthritis. *Geriatric Orthopaedic Surgery & Rehabilitation,* 6(3), 160-167. DOI: 10.1177/2151458515583088

Level of Evidence

- **Oxford: 1b**

Purpose: The purpose of this study is to assess the effectiveness of LL-BFRT for increasing lower limb strength in men who are at risk of developing symptomatic knee osteoporosis.

Methods: 44 men ≥45 years old met inclusion criteria and were included. BP prior to testing needed to be <180/100 and HR 40-110 bpm. Subjects were randomly assigned to either LL-RT (control) or LL-BFRT (intervention) using a random number generator.

Results: There were no statistically significant differences between the groups for isotonic bilateral knee press or isokinetic knee extensor strength, but leg press 1RM did increase significantly in both the control (13.5 ±16.8 kg, $P = .001$) and the intervention group (11.3 ±14.0 kg, $P = .003$). Statistically significant increases in isokinetic knee extensor strength (7.0 ±3.0 Nm, $P = .026$) and KOOS scores (5.6 ±11.7 points, $P = .042$) were seen in the control group but not in the intervention group (-0.1 ±3.3, $P = .987$; and 2.9 ±10.0, $P = .220$ respectively).

Critique/Bottom Line: Based on the results of this study, it would be more beneficial to perform LL-RT without BFR. However, these findings may have been the result of insufficient training time and lack of control for outside physical activity. These factors need to be addressed in future studies in order to more accurately determine which approach is superior.

Article #2 (Reference #12): Segal, N., Williams, G., Davis, M., Wallace, R., Mikesky, A. (2015). Efficacy of blood flow-restricted, low-load resistance training in women with risk factors for symptomatic knee osteoarthritis. *PM&R: the journal of injury, function, and rehabilitation,* 7(4), 376-84.
doi: 10.1016/j.pmrj.2014.09.014

Level of Evidence:
- **Oxford 1b**

Purpose: The purpose of this study was to assess the efficacy of a LL-BFRT, over four weeks, to improve knee extensor strength, quadriceps muscle volume, and lower extremity muscle power in women who are at risk of developing symptomatic knee OA. The secondary purpose of this study was to assess if the training program adversely impacted knee pain, ADLs, or QOL.

Methods: 45 subjects were randomized into either a LL-RT group or a LL-BFRT group. Each completed 4 weeks of training, performing leg-press resistance training 3x/week. The BFRT group wore a pneumatic cuff that progressively restricted blood flow over the training period.

Results: 8/24 control and 5/21 BFR participants had radiographic knee OA ($P = .4819$). Isokinetic knee strength was unchanged in the control but increased in the BFRT group($P = .0048$). There was a statistically significant greater increase in the BFR training group compared to the control group in 1RM isotonic leg press ($P = .0385$). There were no other statistically significant intergroup differences, however, both groups improved significantly in stair climb power (control $P < .0001$; BFR $P = .0163$).

Critique/Bottom Line: LL-BFRT is effective and safe at increasing knee extensor strength, leg press 1RM, and stair climb power without exacerbating knee pain. This method may be effective for increasing knee extensor strength and reduce the risk of developing symptomatic knee OA in. Lack of hypertrophy may have been due to the short training length and the fact that there was not enough power to identify a statistically significant increase. More research with longer studies and more participants is needed to assess hypertrophy.

Article #3 (Reference #13): Bryk, F.F., dos Reis, A.C., Fingerhut, D., Araujo, T., Schutzer, M., Cury, R.P., Duarte, A., Fukuda, T.Y. (2016). Exercise with partial vascular occlusion in patients with knee osteoarthritis: a randomized clinical trial. *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSK,* 24(5), 1580-6.
DOI 10.1007/s00167-016-4064-7

Level of Evidence:
- **Oxford 2b**

Purpose: The purpose of this study was to assess if women with knee OA would exhibit the same results in quadriceps strength, pain relief, and functional improvement with LL-BFRT compared to a high-load resistance training without BFR.

Methods: 34 women with knee OA were assigned to a conventional or an occlusion group. Subjects were screened by a vascular surgeon. The groups participated in treatment sessions 3x/week for 6 weeks. The HL-RT group performed 70% estimated 1RM for the quadriceps exercises and the LL-BFRT group performed 30%. The cuff was set at 200 mmHg during the quadriceps exercises.

Results: No significant group-by-time interaction for strength, function or pain. A significant time effect for strength ($P = .001$), function in Lequesne ($P = .001$), Tug ($P = .006$), and NPRS ($P = .001$) but not significant group effect. A significant between group difference was observed for NPRS during quad exercises – less anterior knee discomfort with LL-BFRT ($P = 0.01$).

Critique/Bottom Line: It would be beneficial to use LL-BFRT in patients who have knee OA. Participants in the occlusion group showed the same functional outcomes and a slightly higher quadriceps strength increase with lower reported levels of anterior knee pain. However, this lower reported anterior knee pain may be due to the fact that group had a lower NPRS score during activity at the beginning of the study although this was not a statistically significant difference.

Article #4 (Reference #14): Hughes, L., Paton, B., Rosenblatt, B., Gissane, C., Paterson, S.D. (2017). Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. *British Journal of Sports Medicine,* 51(13), 1003-1011. DOI 10.1136/bjsports-2016-097071

Level of Evidence:

- **Oxford 2a**

Purpose: The purpose of this study was to examine the efficacy of LL-BFRT in clinical rehabilitation of musculoskeletal disorders. It also aimed to perform a SR to examine the quality of studies and reporting, focusing on the safety and application of the BFR device

Methods: A search was performed for studies carried out between January 1, 1990 and March 1, 2016 on SPORTDiscus, PubMed, and Science Direct. Articles using BFR as a rehabilitation tool for musculoskeletal weakness were selected. The studies were required to use BFR concurrently with exercise. 13 studies were included and analyzed in the meta-analysis and 20 were included in the systematic review.

Results: Data was extracted from 8 studies comparing LL-BFRT to the same training without BFR and found that the BFRT had a moderate effect on increasing muscle strength in those who had musculoskeletal weakness (Hedges's g=0.523, 95% CI 0.263-0.784, P<0.001). The I^2 statistic showed moderate heterogeneity at 49.8%. Data was extracted from 5 studies comparing LL-BFRT to HL-RT. The HL-RT had a moderate effect on increasing muscle strength compared to LL-BFRT (Hedge's g=0.674, 95% CI 0.296-1.052, P<0.001). Minimal heterogeneity was revealed by the I^2 statistic at 0%. A total Hedge's g=0.52 shows that LL-BFR, 69% of the population will experience greater muscular strength gains. There were no safety concerns noted.

Critique/Bottom Line: It would be beneficial to use LL-BFRT. Muscle strength gains were noted without increased pain. It would be appropriate to start with LL-BFRT and as the patient makes progress in strength, progress to heavier resistance without BFR.

Article #5 (Reference #20): Libardi C, Chacon-Mikahil M, Cavaglieri C, Tricoli V, Roschel H, Vechin F, Conceicao M, Ugrinowitsch. Effect of concurrent training with blood flow restriction in the elderly. *Int J Sports Med.* 2015; 36: 395-399. doi: 10.1055/s-0034-1390496.

Level of Evidence:

- **Oxford 1b**

Purpose: The purpose of this study was to assess the effects of blood flow restriction training with concurrent training and concurrent training on aerobic fitness, muscle mass, and muscle strength in older adults.

Methods: Participants were >60 years of age who were sedentary, were free of cardiovascular and neuromuscular disorders, and did not have a BMI that classified them as obese. The participants were ranked based on strength and CSA of the quads and were then randomly assigned to a concurrent training, concurrent training with moderate blood flow restriction, or a control group. There were two familiarization sessions then a leg press 1RM and VO_2max test was performed. The participants trained for 4 days a week for 12 weeks.

Results: Both training groups showed a statistically significant increase in training volumes throughout the training period. The both groups showed significantly increased VO_{2peak} from pre to post test but there was not a significant between group difference noted at the post test. Both groups demonstrated a significant increase in leg press 1RM from pre to post test but a between group difference was not noted at the post test. Both groups also had a statistically significant increase in their quadriceps cross sectional area between the pre and post test but a between group difference was not noted at the post test.

Critique/Bottom line: Based on the results of this study, it would be appropriate to utilize both an aerobic and strength training component in a patient's exercise prescription to maximize their outcomes.

Article #6 (Reference #15): Gaunder, C., Hawkinson, M., Tennent, D., Tubb, C. (2017). Occlusion training: Pilot study for postoperative lower extremity rehabilitation following primary total knee arthroplasty. *U.S Army Medical Department Journal*, 2-17:39-43
PMID: 28853118

Level of Evidence:
- **Oxford 4**

Purpose: The purpose of this study was to report on the outcomes of three patients, who had a primary diagnosis of knee OA, resulting in a TKA, and received BFRT exercises following their regular post-op rehabilitation.

Methods: The surgeon cleared and recommended subjects to participate in the study. In order to be cleared to participate, they had to complete postoperative rehab and regain adequate ROM, as determined by the surgeon. They participated in BFRT 3x/week for 8 weeks, during which they performed leg extension, leg press, and reverse press under occlusion conditions. Each exercise was performed to failure for 4 sets with a 30-sec rest between each. The occlusion pressure was set to 80% of limb occlusion pressure (100-150 mmHg).

Results: Case 1: 359.3% increase in knee extension peak torque and 17.8% increase in knee flexion peak torque at 90 degrees/second. Case 2: 57% increase in knee extension peak torque and 2.8% increase in knee flexion peak torque. Case 3: 84.1% increase in knee extension peak torque and 126.9% in knee flexion at 90 degrees/second

Critique/Bottom Line: Based on the findings of this case series, BFRT significantly improves knee extensor strength, even after traditional postoperative PT. However, the researchers did not use any functional outcomes or pain outcomes, so it cannot be determined if these findings are correlated to functional improvements and improvements in QOL. Also, the sample size was very small, a larger study is needed to confirm the findings of this study.

Article #7 (Reference #7): Vechin, F., Libardi, C., Conceicao, M., Damas, F., Lixandrao, M., Berton, R., Tricoli, V., Roschel, H., Cavaglieri, C., Chacon-Mikahil, M., Ugrinowitsch, C. (2015). Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. *Journal of Strength and Conditioning Research*, 29(4):1071-1076
DOI: 10.1519/JSC.0000000000000703

Level of Evidence:
- **Oxford 2b**

Purpose: The purpose of this study was to compare the effects of HL-RT and LL-BFRT on quadriceps muscle strength in an elderly population.

Methods: 14 men and 9 women were included (59-71 years old) who did not have CVD, HTN, DM, or any musculoskeletal conditions in the LEs. Leg press 1RM was determined for each group where subjects were required to go through 90 degrees of motion and achieve full concentric and eccentric motion. The quadriceps CSA was obtained by MRI; subjects supine with legs fully extended. BFR was 50% of maximal tibial arterial pressure (reassessed every week) with an 18-cm wide cuff. Training was 2x/week for 8 weeks.

Results: Significant increase in quadriceps CSA ($P<0.001$) and leg press 1RM ($P<0.001$; ES=1.50; 95% CI: 0.78-2.41) for HL-RT. LL-BFRT showed a significant increase in quadriceps CSA ($P<0.001$), but it did not show a significant increase in leg press 1RM ($P=0.067$; ES=0.59; 95% CI: 0.03-1.22), although it approached a statistically significant value. The control group showed no change in 1RM leg press ($P=0.998$); quadriceps CSA ($P<0.395$).

Critique/Bottom Line: These results are still clinically significant and can be considered in clinical practice as an effective way to increase quadriceps strength. This study's limitations including a small sample size, no report of attrition, and lack of blinding for the assessors and subjects; all of which may have impacted the study's outcomes.

Article #8 (Reference #16): Cook, S., LaRoche, D., Villa, M., Barile, H., Manini, T. (2017). Blood flow restricted resistance training in older adults at risk of mobility limitations. *Experimental Geronotology*, 99:138-145.
doi: 10.1016/j.exger.2017.10.004

Level of Evidence:
- **Oxford 1b**

Purpose: The purpose of this study is to evaluate the effects of a 12-week HL-RT program compared to a LL-BFRT program on LE strength, hypertrophy, physical function, and quality of life in older adults with muscle weakness who are at risk for mobility limitations.

Methods: Participants 65-75 years of age were placed into either LE HL-RT, LE LL-BFRT, or a control group which performed UE stretching and light resistance training. Supervised sessions were attended 2x/week for 12 weeks. Each exercise was performed to volitional failure for 3 sets with a 1 minute rest between each set and a 3 minute rest between each exercise. The cuffs were deflated for the 3 minute rests.

Results: HL showed significantly greater increases in leg extension, leg curl, and leg press 1RM and CSA compared to the control ($P<0.05$) and in leg extension 1RM compared to BFR group ($P=0.01$). BFR group showed significantly greater increases in CSA compared to the control ($P<0.01$). The 400-m walk speed improved an average of 4% across the sample ($P=0.007$) and chair rise ranking within SPPB improved from 2.72 to 3.11 ($P=0.011$). The 4-m walk time tended to improve from 3.8s to 3.6s ($P=0.05$). The overall SPPB did not improve in any group ($P=0.33$). There was no change in any of the QOL domains for all groups.

Critique/Bottom Line: It would be appropriate to initiate a patient, who has been screened, on a LL-BFRT program and progress to HL-RT without BFR. This will allow pain free strength gains and give them a foundation. It would be advantageous to include functional training along with strength training in order to maximize functional outcomes.

Table 1. Overview of articles included in analysis

#	Author(s)	Oxford Level	Pedro Score	Purpose	Outcome Measures	Results	Relevant to PICO?
1	Segal, N. et. al. (2015)	1b	7/10	The purpose of the study is to assess the effectiveness of LL-BFRT for increasing lower limb strength in men who are at risk of developing symptomatic knee OA.	Primary: Bilateral leg press isotonic strength Secondary: Isokinetic knee extensor strength Tolerance of intervention: Knee pain - KOOS	The results showed that there was not a statistically significant difference between the two groups for 1RM leg press however both improved significantly. Statistically significant improvements were observed in isokinetic knee extensor strength and KOOS scores for the control group but not in the treatment group. Although there was not a statistically significant improvement in the KOOS scores for the treatment group, their scores did not worsen.	Yes
2	Segal, N. et. al. (2015)	1b	7/10	The purpose of this study was to assess the efficacy of LL-BFRT, over 4 weeks, to improve knee extensor strength, quadriceps muscle volume, and LE muscle power in women who are at risk of developing symptomatic knee OA. Also to assess if the training program adversely impacted knee related pain, ADLs, or QOL.	Bilateral leg-press isotonic strength and power Quadriceps volume Maximum isokinetic strength Stair climbing muscle power Tolerance of intervention by assessing knee pain using the KOOS	8/24 control and 5/21 BFR participants had radiographic knee OA (*P* = .4819). Isokinetic knee strength was unchanged in the control group but increased in the BFRT group with a statistically significant intergroup difference (*P* =.0048). Statistically significant greater increase in the BFRT group compared to the control in 1RM isotonic leg press (*P* = .0385). Both groups improved significantly in stair climb power (control *P* <.0001; BFR *P* = .0163).	Yes
3	Bryk, F.F. et. al. (2016)	2b	6/10	The purpose of this study was to assess if women with knee OA would exhibit the same results in	Quadriceps strength Lequesne TUG	There was no significant group-by-time interaction for strength, function or pain. A significant time effect was present for strength (*P* = .001),	Yes

				quadriceps strength, pain relief, and functional improvement with LL-BFRT compared to HL-RT without BFR.	NPRS	function in Lequesne (*P* = .001), Tug (*P* = .006), and NPRS (*P* = .001) but there was not significant group effect. There was a significant between group difference observed for NPRS while performing the quad exercises – the occlusion group experienced less anterior knee discomfort (*P* = 0.01).	
4	Hughes, L. et. al. (2017)	2a	N/A	The purpose of this study was to conduct a meta-analysis to examine the efficacy of LL-BFRT in clinical rehabilitation of musculoskeletal disorders. It also aimed to perform a systematic analysis to examine the quality of studies and reporting, focusing on the safety and application of the BFR device.	Muscle strength Safety of blood flow restriction – hemodynamic distrubances, ischemic reprofusion injury, rhabdomyolosis	BFRT had a moderate effect on increasing muscle strength in those who had musculoskeletal weakness (Hedges's g=0.523, 95% CI 0.263-0.784, P<0.001). The I^2 statistic showed moderate heterogeneity at 49.8%. The meta-analysis also extracted data from 5 studies comparing LL-BFRT to HL-RT. The HL-RT had a moderate effect on increasing muscle strength compared to LL-BFRT (Hedge's g=0.674, 95% CI 0.296-1.052, P<0.001). Minimal heterogeneity was revealed by the I^2 statistic at 0%. A total Hedge's g=0.52 shows that LL-BFR, 69% of the population will experience greater muscular strength gains. There were no safety concerns noted.	Yes
5	Libardi, C. et. al. (2015)	1b	7/10	The purpose of this study was to assess the effects of blood flow restriction training with concurrent training and	Leg press 1RM Peak oxygen uptake (VO_{2peak}) Quadriceps cross sectional	Both training groups showed a statistically significant increase in training volumes throughout the training period. The both groups showed significantly	Yes

				concurrent training on aerobic fitness, muscle mass, and muscle strength in older adults	area Training volume	increased VO_{2peak} from pre to post test but there was not a significant between group difference noted at the post test. Both groups demonstrated a significant increase in leg press 1RM from pre to post test but a between group difference was not noted at the post test. Both groups also had a statistically significant increase in their quadriceps cross sectional area between the pre and post test but a between group difference was not noted at the post test.	
6	Gaunder, C., et. al. (2017)	4	N/A	The purpose of this study was to report on the outcomes of three patients, who had a primary diagnosis of knee OA, resulting in a TKA, and received BFRT exercises following their regular postoperative rehabilitation.	Knee extensor peak torque Knee flexion peak torque	Case 1: 359.3% increase in knee extension peak torque;17.8% increase in knee flexion peak torque at 90 degrees/second Case 2: 57% increase in knee extension peak torque;2.8% increase in knee flexion peak torque Case 3: 84.1% increase in knee extension peak torque;126.9% in knee flexion at 90 degrees/second	Yes
7	Vechin, F. et. al. (2015)	2b	4/10	The purpose of this study was to compare the effects of HL-RT and LL-BFRT on quadriceps muscle strength in an elderly population.	Quadriceps strength Quadriceps CSA	Significant increase in quadriceps CSA and leg press 1RM for the HL-RT. The LL-BFRT group showed a significant increase in quadriceps CSA, but it did not show a significant increase in leg press 1RM, although it approached a statistically significant value. The control group showed no change in the outcome measures.	Yes

8	Cook, S., et. al. (2017)	1b	7/10	The purpose of this study is to evaluate the effects of a 12 week HL-RT program compared to a LL-BFR training program on LE strength, hypertrophy, physical function, and quality of life in older adults with muscle weakness who are at risk for mobility limitations.	Knee extensor strength Quadriceps CSA Walking speed Short Physical Performance Battery (SPPB) Quality of life	HL: Significantly greater increases in LE, LC, and LP 1RM and CSA compared control ($P<0.05$); significantly greater increase in LE 1RM compared to BFR ($P=0.01$). BFR: Significantly greater increases in CSA compared to control ($P<0.01$). 400-m walk speed improved an average of 4% across the sample ($P=0.007$); chair rise ranking within SPPB improved from 2.72 to 3.11 ($P=0.011$). The 4-m walk time tended to improve from 3.8s to 3.6s ($P=0.05$). However, the overall SPPB did not improve in any group ($P=0.33$). No change in QOL.	Yes

Discussion:

Osteoarthritis is one of the most prevalent musculoskeletal disorders; affecting millions of individuals worldwide. It commonly affects the knee joint, and when it becomes symptomatic, it can be very debilitating and frequently leads to a total knee arthroplasty. Symptoms and the burden of symptoms experienced with knee OA varies but often includes joint pain, which increases with weight bearing or loaded activities, joint stiffness, swelling, deformity, altered biomechanics, and loss of function.

In 2014, the Osteoarthritis Research Society International published guidelines for non-surgical management of knee osteoarthritis based on a literature review, which stated that strength training and land based exercises were appropriate, including exercises for quadriceps strengthening[8] . However, consistent adherence to an exercise program is necessary for the program to be effective, which has proven difficult due to the exacerbation of pain during exercise, as demonstrated by dropout rates in clinical studies[9] ,[10]. Low load blood flow restriction training has recently become an area of interest in research as a possible alternative to increase strength without high loads that cause high compressive forces and pain in a pathologic joint. Recent clinical studies investigating the effectiveness of LL-BFRT on increasing quadriceps strength have yielded a low number of participants lost to follow-up due to pain, most have cited other reasons including illness or difficulty attending training sessions[13].

The literature reviewed on whether or not low-load blood flow restriction training is as effective as high load resistance training for strengthening the quadriceps muscles in individuals with knee osteoarthritis has shown mixed results. All have shown that there are definite increases in knee extensor strength with low-load blood flow restriction training, however, some of the results demonstrated only minimal increases in strength while others showed statistically

significant increases in strength; comparable to that seen in the high load resistance training groups. Although many randomized controlled trials (RCTs) are available on this topic, it is difficult to draw definitive conclusions from them due to the lack of standardization and confounding variables such as outside activity. There are many variables including: the type of occlusion device, pressure applied, location of occlusion device, progression of resistance training, and co-morbidities that need to be considered and controlled for in future studies in order to answer this question more definitively.

The current research available shows that the subjects who participated in low-load resistance training with concurrent blood flow restriction had increases in knee extensor strength and improvements in pain. An RCT by Bryk, F. et. al. produced results showing comparable values in all outcome measures, except there was a significant difference between groups in the numeric pain rating scale results while performing quadriceps exercises with the LL-BFRT group, who trained with pressures up to 200 mmHg, experiencing less anterior knee discomfort compared to the high-load resistance training group[13].

Current literature supports LL-BFRT being a viable option for knee extensor strengthening without eliciting significant pain in individuals with knee osteoarthritis. The literature reviewed also showed that the risks associated with the intervention were minimal. Most reported adverse effects included discomfort and minor bruising. However, all of the subjects were thoroughly screened prior to the initiation of the intervention, which may pose a threat to the external validity of those studies. Knee osteoarthritis is strongly associated with age and obesity, which are both associated with many co-morbidities[3] including cardiovascular related diseases such as hypertension. The associated co-morbidities may play a role in safety

implications surrounding blood flow restriction, therefore, high quality studies that investigate the safety of LL-BFRT are needed in populations with knee OA and associated co-morbidities.

The articles reviewed utilized different approaches in the application of blood flow restriction devices and the pressure provided. Many used pneumatic devices placed at the proximal thigh that were inflated to various pressures, up to 200 mmHg[2,12,13], while some used tourniquets. The pressures applied were determined in various ways. A few examples include (1) determining the systolic pressure at the tibial artery and using 50% of that for training[7,20], (2) determining the arterial occlusion pressure at the pedal pulse and using 60% of that for training[11], (3) choosing a high pressure of 200 mmHg and applying it to all participants throughout the duration of the study,[13] and (4) by choosing an initial application pressure of 30 mmHg and gradually increasing pressure throughout the training weeks and individual training sessions within the week until 200 mmHg was reached[2,12]. Previous studies have shown that pressures up to 200 mmHg do not fully occlude arterial flow[17,18], and higher levels of pressure are thought to be a factor in augmenting results with this method because the muscle will reach fatigue sooner, which is why some researchers may have chosen higher levels of pressure during their study. Although commonly reported adverse effects with this training method include discomfort and mild bruising at the site of cuff application, Bryk, F. et al make no mention of these and no participants were lost to follow up while utilizing a pressure of 200 mmHg[13].

The variability in devices used (pneumatic vs tourniquet and width), pressures applied, application time, and adjustment of pressure and training load over the training period are all factors that may explain the discrepancy in results. Further research is needed to determine recommendations for a protocol that addresses all of those factors to ensure safety and maximal results are attained.

Conclusion:

To conclude, the answer to the PICO question: Is low-load resistance training with concurrent blood flow restriction as effective as traditional resistance training at increasing knee extensor strength in patients with knee OA? cannot be definitively answered based on the articles analyzed as some showed that yes, LL-BFRT is as effective as high-load resistance training, while others showed only a minimal increase in strength with the intervention. Although further research is needed, in the meantime, LL-BFRT is an appropriate intervention for individuals with knee OA who are otherwise healthy. For instance, this intervention would be appropriate to use in patients who have developed knee OA secondary to a traumatic knee injury or overuse and not due to the associated risk factors/co-morbidities such as obesity.

This training method can easily be achieved by using a manual blood pressure cuff[19], which all physical therapy clinics should have, so a clinic would not have to purchase any specialized equipment. However, extra time will be required to determine the patient's maximal tibial arterial pressure or arterial occlusion pressure at the pedal pulse, which should be reassessed weekly to ensure the target pressure is being achieved. Extra time will also be needed to estimate and determine the patient's 1RM for the specific exercise such as unilateral or bilateral knee extension or leg press, and should also be reassessed regularly to ensure the target load is being applied.

The results from the articles analyzed are promising and indicate LL-BFRT may be a possible alternative to high-load resistance training for increasing knee extensor strength in individuals with knee OA. While the strength gains in some of the studies approached but did not reach a statistical significance, they may be clinically significant, and may serve as a starting point to attain strength gains while reducing pain until the patient reaches a point where they can

train with higher loads in order to manage their osteoarthritis. The clinical significance of these findings and the potential to translate into improved function and quality of life outweigh the extra time needed to implement this training method. However, further research is needed in patients with various co-morbidities and to determine device and pressure protocols in order to maximize results.

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Appendix A:

Article Analysis Sheets

Articles:

1. Segal, N. et. al. (2015)
2. Segal, N. et. al. (2015)
3. Bryk, F.F et. al. (2016)
4. Hughes, L. et. al. (2017)
5. Libardi, C. et. al. (2015)
6. Gaunder, C. et. al. (2017)
7. Vechin, F. et. al. (2015)
8. Cook, S. et. al. (2017)

Intervention – Evidence Appraisal Worksheet - #1

Citation: Segal, N., Davis, M., Mikesky, A. (2015). Efficacy of blood flow-restricted low-load resistance training for quadriceps strengthening in men at risk of symptomatic knee osteoarthritis. *Geriatric Orthopaedic Surgery & Rehabilitation,* 6(3), 160-167.

DOI: 10.1177/2151458515583088

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose was clearly stated. - The purpose of the current study is to determine if blood flow restriction training is effective in increasing the lower extremity strength in men at risk of developing knee OA
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. This study's need is justified by the Osteoarthritis Research Society International's statement that one method to slow the progression of knee OA may be strength training, however, based on ACSM's recommendations 60-70% 1RM is needed for strength gains and 70-85% 1RM for muscle hypertrophy. These recommendations are somewhat unrealistic for this population because the risk factors associated with knee OA reduce tolerance for high-load strength training. Thus, a program is needed where low-loads can be utilized.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing**	- Compensatory rivalry is possible. The control group may have figured out that they were in the control group and increased their activity.

➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***
– **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	– Yes, the investigators randomly assigned the subjects into treatment groups using a random number generator.
– **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	– Yes, the groups were similar at the start of the trial. The demographics of the participants were reported, and there was no statistically significant differences between the groups' characteristics or baseline measurements.
– **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	– No, the subjects were blinded. They were not given any information on which was the treatment group and which was the control group. The authors instructed the participants to not speak about their exercise experience to any other participants and they treatment times were staggered to reduce the risk of interaction between the two groups.
– **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	– No, the investigators did not know what would be assigned to each group prior to the allocation.
– **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, the groups were managed equally.
– **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– No, there is indication that the follow-up time was not sufficiently long to answer the research question. A potential consequence of this is the possibility of a type II error.
– **Did all the subjects originally enrolled complete the study?** **a. If not how many subjects were lost?** **b. What, if anything, did the authors do about this attrition?**	– No, not all the subjects originally enrolled in the study completed it. – 3 subjects were lost during the study. – The authors had planned ahead and estimated that they would need a total of 38 participants for the 2-treatment parallel study design. 44

c. **What are the implications of the attrition and the way it was handled with respect to the study's findings?**	participants were enrolled, 42 were randomized, and 41 were analyzed. The authors did not do anything about the attrition because it was within their estimated amount. There were not implications because it was planned for.
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?** a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	- No, there was one participant's data that was not analyzed after they were randomized. There was not an intention to treat analysis, and the data from this subject was not used. The excluded data did not pose any potential consequences to this study's results because it was planned for.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- A 2-sample t-test was used to compare characteristics of each intervention group. Wilcoxon rank sum test was used to analyze the differences in the number of visits because they were not normally distributed. Paired t-tests were used for each person based variable of interest. Intergroup difference for the main study were compared using 2-sample t-tests for percentage of change in the outcomes. Regression models were constructed to control for repeated limb as a repeated factor for the limb based outcome measure. The SAS 9.3 version was used for all analyses. The set p-value was not stated, so it is assumed to be 0.05. - These findings show that there was not a statistically significant difference between the number of training sessions attended or in the intergroup primary or secondary outcome measures. There was a statistically significant improvement made in leg press in both groups. The control group had statistically significant improvements in isokinetic knee extension strength and in the KOOS, but the treatment group did not. This may suggest that blood flow restriction training is not superior to traditional low load resistance training, which does not include added risk. However, these findings may be due to the short length of this study.
- **Do these findings exceed a minimally important difference?** a. **If not, will you still use this evidence?**	- There is not a set MCID for the outcome measures.

Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** **a. If not, how different? Can you use this intervention in spite of the differences?**	- Yes, the subjects in this study are similar to my client.
- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Given the results of this study, the potential benefits of this intervention do not outweigh any potential risk with my patient because the control group showed to have at least the same or better outcomes.
- **Does the intervention fit within your patient/client's stated values or expectations?** **a. If not, what will you do now?**	- Yes, the intervention fits within my patients stated values.
- **Are there any threats to external validity in this study?**	- The sample size was somewhat small. - Only men were included, which may limit generalizability.

What is the bottom line? What pedro score would you give this trial?:
(other comments about the article should be here)

- Pedro Score: 7/10
- The bottom line of this study is that the treatment group did not show statistically significant improvements compared to the control group, however the outcome of the study may have been a result of the inverention time not being long enough, there was no progression during the study, and activity level prior to beginning the study was not formally assessed. This intervention may be effective but this studied showed it was no better than traditional low-load resistance training, which does not carry increased risk.

Intervention – Evidence Appraisal Worksheet - #2

Citation: Segal, N., Williams, G., Davis, M., Wallace, R., Mikesky, A. (2015). Efficacy of blood flow-restricted, low-load resistance training in women with risk factors for symptomatic knee osteoarthritis. *PM&R: the journal of injury, function, and rehabilitation,* 7(4), 376-84.

doi: 10.1016/j.pmrj.2014.09.014

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose was clearly stated. - The purpose of this study was to assess the efficacy of a low-load resistance training program with blood flow restriction training, over four weeks, to improve knee extensor strength, quadriceps muscle volume, and lower extremity muscle power in women who are at risk of developing symptomatic knee OA. The secondary purpose of this study was to assess if the training program adversely impacted knee related pain, ADLs, or QOL.
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. The justification for this study came based on the results of an observational study that showed that higher knee extensor strength in women without knee OA may reduce the risk of developing symptomatic knee OA. It was also observed that higher knee extensor strength may reduce the risk for progression of joint narrowing. Based on these results, knee extensor strength may be a modifiable risk factor for knee OA, however, ACSM recommends a higher percentage of 1RM to achieve strength improvements. High load resistance training may not be tolerated by this population, so a low load training protocol is needed.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation**	- Compensatory rivalry is possible. The control group may have figured out that they were in the control group and increased their activity. - Statistical regression towards the mean is possible because there was a statistically significant difference between the groups

➢ **Maturation** ➢ **Testing** ➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	body size at the beginning of the study, but it was no longer statistically significant when the outcomes data was adjusted for BMI.

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***
– **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	– Yes, the investigators randomly assigned the subjects into treatment groups using a random number generator.
– **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	– Demographics of the study groups were reported. The only thing that was not similar at the start of the study was the body size between the two groups, but there was no statistically significant difference after BMI had been adjusted for. All other variables were similar.
– **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	– No, the subjects were blinded. They were not given any information on which was the treatment group and which was the control group. The authors instructed the participants to not speak about their exercise experience to any other participants and they treatment times were staggered to reduce the risk of interaction between the two groups.
– **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	– No, the investigators did not know what would be assigned to each group prior to the allocation.
– **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, the groups were managed equally.
– **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, there was sufficient follow-up time to answer the research question, however, a longer follow up time may have offered a more concrete answer.
– **Did all the subjects originally enrolled complete the study?**	– No, not all the subjects originally enrolled in the study completed it. – 5 subjects were lost during the study.

a. **If not how many subjects were lost?** b. **What, if anything, did the authors do about this attrition?** c. **What are the implications of the attrition and the way it was handled with respect to the study's findings?**	- The authors had planned ahead and estimated that they would need a total of 46 participants to be recruited, estimating that 20% would drop out of the study and this number would still allow them to achieve their desired power. 45 participants were enrolled and randomized and 40 were analyzed. The authors did not do anything about the attrition because it was within their estimated amount. There were not implications because it was planned for.
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?** a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	- No, there was one participant's data that was not analyzed after they were randomized. There was not an intention to treat analysis, and the data from this subject was not used. The excluded data did not pose any potential consequences to this study's results because it was planned for.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- An a priori sample size was estimated. 19 participants would be needed in each group with a 2-sided significance level of 0.025, SD in knee extensor strength response variable of 12.2 nm and a power of 0.80 to detect intergroup difference in means of 11.2 nm. The study design was a 2-treatment parallel design study. Baseline characteristics of each group were compared using 2-sample t tests. 8 of 24 control participants and 5 of 21 BFR participants had radiographic knee OA (P = .4819). The visits attended were not normally distributed, and therefore, analyzed using nonparametric methods with median (interquartile range of 12 (12, 12) sessions attended by control participants and 12 (11, 12) by BFR participants (P = .1682). Paired t tests were used for within group analysis for each person-based variable. Isokinetic knee strength was unchanged in the control group but increased in the BFR training group with a statistically significant intergroup difference (P = .0048). There was a statistically significant greater increase in the BFR training group compared to the control group in 1RM isotonic leg press (P = .0385). There were no other statistically significant intergroup differences, however, both groups improved significantly in stair climb power

	(control P <.0001; BFR P = .0163). Intergroup differences for person-based outcome variables were compared using linear regression, adjusting for BMI. Mixed models were constructed for limb based outcome variables to control for limb as repeated factor. - These outcomes support the use of BFT with low loads in this patient population. Based on these results, I would try this intervention with individuals in this patient population.
- **Do these findings exceed a minimally important difference?** **a. If not, will you still use this evidence?**	- There is no set minimally important difference
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** **a. If not, how different? Can you use this intervention in spite of the differences?**	- Yes, the subjects in this study are similar to my client.
- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Yes, the potential benefits of the this intervention outweigh the potential risks.
- **Does the intervention fit within your patient/client's stated values or expectations?** **a. If not, what will you do now?**	- Yes, the intervention fits within my patients stated values.
- **Are there any threats to external validity in this study?**	- The sample size was somewhat small. - Only women were included, which may limit generalizability

What is the bottom line? What pedro score would you give this trial?:
(other comments about the article should be here)

- Pedro Score: 7/10
- This intervention was shown to be more effective in this patient population compared to low-load resistance training on its own. The patient population would need to be screened to ensure the intervention is used safely without any contraindications. More research is needed on the ideal pressure and progression guidelines for the pressure.

Intervention – Evidence Appraisal Worksheet - #3

Citation: Bryk, F.F., dos Reis, A.C., Fingerhut, D., Araujo, T., Schutzer, M., Cury, R.P., Duarte, A., Fukuda, T.Y. (2016). Exercise with partial vascular occlusion in patients with knee osteoarthritis: a randomized clinical trial. *Knee surgery, sports traumatology, arthroscopy: official journal of the ESSK,* 24(5), 1580-6. DOI 10.1007/s00167-016-4064-7

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose was clearly stated. - The purpose of this study was to assess whether women with knee osteoarthritis would exhibit the same results in quadriceps strength, pain relief, and functional improvement with a low-load resistance training program with concurrent partial vascular occlusion compared to a high-load resistance training program without concurrent partial vascular occlusion.
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. The background information justifies the need for this study by stating that research has been performed in healthy individuals, and results suggest that low-load resistance training with concurrent partial vascular occlusion yields very similar results to those seen in high-load resistance training without concurrent partial vascular occlusion. There is however, a lack of clinical studies comparing these interventions in populations with degenerative knee injuries.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing**	- Compensatory rivalry is possible. The participants were not blinded to the groups they were placed into.

➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***
– **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	– Yes, the investigators randomly assigned the subjects into treatment groups. Opaque, sealed envelopes that contained the names of each group (conventional or occlusion) were used, and they were picked by an individual that was not involved in the study. The group assignment was performed after the initial evaluation but before the initial treatment session.
– **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	– Yes, the authors reported the demographics and baseline characteristics. The groups were all similar at the beginning of the trial.
– **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	– Yes, the subjects knew what treatment group they were in. A potential consequence includes compensatory rivalry which may have skewed the results of the study.
– **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	– No, the investigators did not know what would be assigned to each group prior to the allocation.
– **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, the groups were managed equally.
– **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, there was sufficient follow-up time to answer the research question.
– **Did all the subjects originally enrolled complete the study?** **a. If not how many subjects were lost?** **b. What, if anything, did the authors do about this attrition?**	– Yes, the subjects that were originally enrolled completed the study.

c. **What are the implications of the attrition and the way it was handled with respect to the study's findings?**	
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?** a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	- There was not an intention to treat analysis. No subjects were lost to follow up.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- There were no significant differences in the participants baseline characteristics or demographics. There was no significant group-by-time interaction for strength, function or pain. However, a significant time effect was present for strength (P = .001), function in Lequesne (P = .001), Tug (P = .006), and NPRS (P = .001) but there was not significant group effect. There was a significant between group difference observed for NPRS while performing the quad exercises – the occlusion group experienced less anterior knee discomfort (P = 0.01).
- **Do these findings exceed a minimally important difference?** a. **If not, will you still use this evidence?**	- The MCID for the NPRS is 2 and the findings did exceed this.
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** a. **If not, how different? Can you use this intervention in spite of the differences?**	- Yes, the subjects in this study are similar to my client.
- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Yes, the potential benefits of the this intervention outweigh the potential risks.

- **Does the intervention fit within your patient/client's stated values or expectations?** **a. If not, what will you do now?**	- Yes, the intervention fits within my patients stated values.
- **Are there any threats to external validity in this study?**	- The sample size was somewhat small. - Only women were included, which may limit generalizability

What is the bottom line? What pedro score would you give this trial?:
(other comments about the article should be here)

- Pedro Score: 6/10
- The outcomes for strength and function were similar between the two groups, however, the occlusion group experience less anterior knee pain during the exercises. The ability for patients to strength train at a lower %1RM with occlusion will benefit them by producing the same functional and strength outcomes without exposing them to more discomfort, which will aid in adherence to an exercise program.

Intervention – Evidence Appraisal Worksheet - #4

Citation: Hughes, L., Paton, B., Rosenblatt, B., Gissane, C., Paterson, S.D. (2017). Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. *British Journal of Sports Medicine,* 51(13), 1003-1011.

DOI 10.1136/bjsports-2016-097071

Does the design follow the Cochrane method?	
Appraisal Criterion	***Reader's Comments***
Step 1 – formulating the question • Do the authors identify the focus of the review • A clearly defined question should specify the types of: • people (participants), • interventions or exposures, • outcomes that are of interest • studies that are relevant to answering the question	-Yes, the focus of the review is clearly stated. -The focus of this review is to examine the efficacy of low-load blood flow restriction training in clinical rehabilitation of musculoskeletal disorders. It also aimed to perform a systematic analysis to examine the quality of studies and reporting, focusing on the safety and application of the blood flow restriction device.
Step 2 – locating studies • Should identify ALL relevant literature • Did they include multiple databases? • Was the search strategy defined and include: - Bibliographic databases used as well as hand searching - Terms (key words and index terms) - Citation searching: reference lists - Contact with 'experts' to identify 'grey' literature (body of materials that cannot be found easily through conventional channels such as publishers) - Sources for 'grey literature'	-The study used the following databases: SPORTDiscus, PubMed, and Science Direct. -Papers that were conducted between January 1, 1990 – March 1, 2016 were included. Search terms included were: 'blood flow restriction' OR 'vascular occlusion' OR 'kaatsu' AND 'strength training' OR 'resistance training' OR 'exercise training'.
Step 3 – Critical Appraisal/Criteria for Inclusion • Were criteria for selection specified? • Did more than one author assess the relevance of each report • Were decisions concerning relevance described; completed by non-experts, or both? • Did the people assessing the relevance of studies know the names of the authors, institutions, journal of publication and results when they apply the inclusion	-The inclusion criteria consisted of: exercise training studies that included subjects with a clinical musculoskeletal condition, published in English, and published in a scientific journal that is peer reviewed. -Two reviewers independently screened the articles. -It was not specified who made decisions regarding relevance. -It does not appear that the people assessing the studies knew the authors or any other information.

• criteria? Or is it blind?	
Step 3 – Critically appraise for bias: Selection – • Were the groups in the study selected differently? • Random? Concealed? Performance- • Did the groups in the study receive different treatment? • Was there blinding? Attrition – • Were the groups similar at the end of the study? • Account for drop-outs? Detection – • Did the study selectively report the results? • Is there missing data?	Selection: -The studies included in the meta-analysis were all RCTs but some included in the SR were not. Performance: -It was difficult to blind in these studies. Some provided a little different intervention protocol. Attrition: -No attrition rates were reported. Detection -There is no missing data.
Step 4 – Collection of the data • Was a collection data form used and is it included? • Are the studies coded and is the data coding easy to follow? • Were studies identified that were excluded & did they give reasons why (i.e., which criteria they failed).	-A collection data form was not used in the study, however, details were given on how studies were collected. -Studies that were not included were identified and given reasons to why they were not included.

Are the results of this SR valid?	
Appraisal Criterion	***Reader's Comments***
1. Is this a SR of randomized trials? Did they limit this to high quality studies at the top of the hierarchies a) If not, what types of studies were included? b) What are the potential consequences of including these studies for this review's results?	-RCTs were included, but they did not limit to high quality studies. Quasi experimental studies were included and controlled trials as well as a case report. a) All relevant studies were included. b) The potential consequence is that it lowers the level of evidence and is not as generalizable to the public
2. Did this study follow the Cochrane methods selection process and did it identify all relevant trials? If not, what are the consequences for this review's results?	-Yes.
3. Do the methods describe the processes and tools used to assess the quality of individual studies? If not, what are the consequences for this review's results?	-No. -A potential consequence is that the quality of the studies is lower and therefore this review is not as generalizable to the overall population.

4. What was the quality of the individual studies included? Were the results consistent from study to study? Did the investigators provide details about the research validity or quality of the studies included in review?	-Yes, the results were consistent from study to study. -Yes.
5. Did the investigators address publication bias?	-No.
Are the valid results of this SR important?	
Appraisal Criterion	***Reader's Comments***
6. Were the results homogenous from study to study? If not, what are the consequences for this review's results?	-There was slight heterogeneity which may limit generalizability
7. If the paper is a meta-analysis did they report the statistical results? Did they include a forest plat? What other statistics do they include? Are there CIs?	-Yes, this paper is also a meta-analysis. -Yes, they reported statistical results and included a forest plot. -They also included I^2 statistic and Hodge's g -CIs were reported
8. From the findings, is it apparent what the cumulative weight of the evidence is?	-The article states that it scored 7 out of 15 points but does not say what the overall weight is.
Can you apply this valid, important evidence from this SR in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
9. Is your patient different from those in this SR?	-My patient is similar to those in some of the studies but not all.
10. Is the treatment feasible in your setting? Do you have the facilities, skill set, time, 3rd party coverage to provide this treatment?	-Yes, this treatment is feasible. There are facilities and skill sets to provide this intervention.
11. Does the intervention fit within your patient/client's stated values or expectations? If not, what will you do now?	-Yes, this intervention fits with my patient's values and expectations.

What is the bottom line?	
Appraisal Criterion	***Reader's Comments***
Summarize your findings and relate this back to clinical significance.	-LL-BFRT was shown to be more effective at increasing strength compared to low load resistance training alone. However, its magnitude is smaller than that of high load resistance training. It would be appropriate to initiate a strength training program with LL-BFRT and progress to a high load resistance training program in order to maximize outcomes.

What is the bottom line? What pedro score would you give this trial?:

- There are greater strength gains with low load training when blood flow restriction is added. This study states that it is a good place to start when rehabilitating muscle weakness or trying to reduce joint pain associated with higher loads. The patients will potentially be able to progress to higher loads without the blood flow restriction.

Intervention – Evidence Appraisal Worksheet - #5
Citation: Libardi C, Chacon-Mikahil M, Cavaglieri C, Tricoli V, Roschel H, Vechin F, Conceicao M,

Ugrinowitsch. Effect of concurrent training with blood flow restriction in the elderly. *Int J Sports Med.*

2015; 36: 395-399. doi: 10.1055/s-0034-1390496.

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose was clearly stated. - The purpose of this study was to assess the effects of concurrent training with blood flow restriction and concurrent training on aerobic fitness, muscle mass, and muscle strength in older adults.
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. The authors presented current research showing that increases in muscle mass in elderly were not maximized due to lower loads being utilized and lack of hypertrophy when resistance training is alternated with endurance training. The authors demonstrated that there is a gap in current literature demonstrating increases in hypertrophy with lower loads and with endurance training. They are using blood flow restriction training to fill that gap.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing** ➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	- There were no internal threats to validity in this study.

Are the results of this therapeutic trial valid?

Appraisal Criterion	*Reader's Comments*
- **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	- Yes, the participants in this study were randomly assigned to groups. The participants were first ranked in quartiles based on quad CSA and muscle strength and then randomly allocated from the quartiles into either a concurrent with blood flow restriction training group, a concurrent endurance training group, or a control group.
- **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	- Demographics were reported in this study. The groups were similar at the start of the study in age and BMI.
- **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	- No, the participants did not know which group they were assigned to. They would have been able to figure it out if they were aware of what the other groups were.
- **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	- No, the investigators did not know who was being assigned to which group prior to allocation.
- **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- Yes, the groups were managed equally.
- **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- Yes, the training sessions took place over a 12 week period. However, there was not a follow up after the post-test so it is unclear what the long term effects of these training methods are.
- **Did all the subjects originally enrolled complete the study?** **a. If not how many subjects were lost?** **b. What, if anything, did the authors do about this attrition?** **c. What are the implications of the attrition and the way it was handled with respect to the study's findings?**	- The RCT makes no mention of any participants lost to follow up during the training period. - There is no mention of intention to treat analysis.
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?**	- The study makes no mention of participants dropping out of the study or an intention to treat analysis.

a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	– It is assumed that all participants completed the study and their data was analyzed in the original group they were assigned to.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
– **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** – **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	– Both training groups showed a statistically significant increase in training volumes throughout the training period. The both groups showed significantly increased VO_{2peak} from pre to post test but there was not a significant between group difference noted at the post test. Both groups demonstrated a significant increase in leg press 1RM from pre to post test but a between group difference was not noted at the post test. Both groups also had a statistically significant increase in their quadriceps cross sectional area between the pre and post test but a between group difference was not noted at the post test.
– **Do these findings exceed a minimally important difference?** a. **If not, will you still use this evidence?**	– I will still use this data although there was not a significant between group difference noted between the post tests because both groups still had statistically significant increases in all outcome measures, which is important clinically.
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
– **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	– Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
– **Are the study subjects similar to your patient/ client?** a. **If not, how different? Can you use this intervention in spite of the differences?**	– Yes, the participants are similar to my patient in age. However, they did not have a diagnosis of knee OA.
– **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	– Yes, the potential benefits of the intervention outweigh the potential risks.
– **Does the intervention fit within your patient/client's stated values or expectations?** a. **If not, what will you do now?**	– Yes, the intervention fits within my patients stated values.

- **Are there any threats to external validity in this study?**	- The only threat to external validity noted is that all the participants were screened and do not have any cardiovascular compromise. A significant number of adults this age have some sort of cardiovascular compromise.

What is the bottom line? What pedro score would you give this trial?:

- Pedro Score: 7/10
  The study suggests that increases in strength and quadriceps cross sectional area can be significantly increased with blood flow restriction training. The total volume used to train can also be significantly increased with this training method. This suggests that initial gains can be made with this training method and the patient can be trained to utilize and train with loads a higher 1RM percentage. This means that patients can potentially start with this training method and progress to loads where they are not using blood flow restriction concurrently.

Intervention – Evidence Appraisal Worksheet - #6

Citation: Gaunder, C., Hawkinson, M., Tennent, D., Tubb, C. (2017). Occlusion training: Pilot study for postoperative lower extremity rehabilitation following primary total knee arthroplasty. *U.S Army Medical Department Journal*, 2-17:39-43

PMID: 28853118

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- The purpose of this study was not clearly stated. - The purpose of this study was to report on three patients, who had a primary diagnosis of knee OA resulting in a TKA, and received BFR exercises in addition to normal physical therapy
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. The authors did not report any current gaps in knowledge, however, they reported on how the surgery affects quadriceps activation, which negatively impacts outcomes and function. They also presented current knowledge of the effects of muscle activation and strength from previous studies.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing** ➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	- This study included 3 case studies. The participants and assessors were not blind to the interventions, and there was not a control group, so those are potential threats to internal validity.

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***
– **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	– No, the participants were not randomly assigned to groups. The participants were given the opportunity to participate in the adjunct therapy at the recommendation of their surgeon once they had completed their postop rehab and regained adequate ROM, which was determined by their surgeon.
– **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	– The baseline characteristics were not compared at the start of the study because it is a case series, and the participants were not being compared to each other. The demographics of the participants included in the case series were not reported.
– **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	– Yes, the participants knew they would be receiving the intervention. Their knowledge may have potentially led the participants to work harder during the intervention time.
– **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	– Yes, the investigators knew who would be receiving the intervention because it is a case series.
– **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– The participants received the same treatment protocol and they were managed equally.
– **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	– Yes, the follow up time was 8 weeks, which was sufficiently long to answer the clinical question.
– **Did all the subjects originally enrolled complete the study?** **a. If not how many subjects were lost?** **b. What, if anything, did the authors do about this attrition?** **c. What are the implications of the attrition and the way it was handled with respect to the study's findings?**	– Yes, the subjects who agreed to participate in the case series all completed the intervention program.

- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?** **a. If not, what did the authors do with the data from these subjects?** **b. If the data were excluded, what are the potential consequences for this study's results?**	- The participants' data was analyzed and compared to their baseline data.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** **a. When appropriate use the calculation forms below to determine these values** **b. Include: tests of differences? With p-values and CI** **c. Include effect size with p-values and CI** **d. Include ARR/ABI and RRR/RBI with p-values and CI** **e. Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- Case 1: 359.3% increase in peak torque for knee extension and 17.8% increase in knee flexion peak torque at 90 degrees/second - Case 2: 57% increase in knee extension peak torque and 2.8% increase in knee flexion peak torque - Case 3: 84.1% increase in knee extension peak torque and 126.9% in knee flexion at 90 degrees/second
- **Do these findings exceed a minimally important difference?** **a. If not, will you still use this evidence?**	- There was a minimally important difference found for the VAS in the BFR training group over 8 weeks, but was not maintained at 6 months. Yes, I will still use this data because it still shows that pain can be reduced initially.
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** **a. If not, how different? Can you use this intervention in spite of the differences?**	- The patients are similar in age, functional limitations, and primary diagnosis. They differ in that my target client has not had a TKA as a result of their knee OA.
- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Yes, the potential benefits of the intervention outweigh the potential risks.
- **Does the intervention fit within your patient/client's stated values or expectations?** **a. If not, what will you do now?**	- Yes, the intervention fits within my patients stated values.

- **Are there any threats to external validity in this study?**	- The participants included were still very active in spite of their knee pain, which may be a threat to external validity because the general population will not continue to be as active if they are experiencing knee pain.

What is the bottom line? What pedro score would you give this trial?:

- Pedro Score:
  The case series shows that substantial gains in knee extensor torque can still be made, even after discharge from conventional postoperative physical therapy. However, the case series included a small sample size so it is difficult to determine if these effects will be attained in larger studies with a larger sample size.

Intervention – Evidence Appraisal Worksheet - #7

Citation: Vechin, F., Libardi, C., Conceicao, M., Damas, F., Lixandrao, M., Berton, R., Tricoli, V., Roschel, H., Cavaglieri, C., Chacon-Mikahil, M., Ugrinowitsch, C. (2015). Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. *Journal of Strength and Conditioning Research*, 29(4):1071-1076 doi: 10.1519/JSC.0000000000000703

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose of this study was clearly stated. - The purpose of this study was to compare the effects of high intensity resistance training and low intensity resistance training with blood flow restriction on quadriceps muscle strength in an elderly population.
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- Yes, relevant background information was presented. - The authors presented current knowledge that HRT is recommended to offset effects of aging, however, this may not be appropriate for elderly individuals who are frail, novice resistance trainers, or individuals with joint and/or cardiorespiratory impairments. - The authors state that research in the use of BFRT in elderly populations in scare, and the one study that investigated the effects of BFRT with low loads did not have a HRT group to compare results with. Thus, this study was needed.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing**	- Assignment: the assignment allocation was not concealed. The groups were randomly assigned, but the threat is still present because the sample size was small. - Compensatory equalization: the study does not indicate the assessors were blinded, so it is assumed they were not. This may lead to compensatory equalization during treatment

➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	sessions. This threat is slightly reduced because the treatment protocols were well outlined. - Compensatory rivalry: the study does not indicate the subjects were blinded, and they would be able to figure out which group they were in. This may have led to compensatory rivalry.

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***
- **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	- Yes, the participants were randomly assigned into treatment groups, but the allocation was not concealed. The randomization reduces the risk for differing baseline characteristics between the groups.
- **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	- The only demographics reported were age and number of males and females participating in the study. The 1RM for leg press was different between groups, which was adjust for in the statistics.
- **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	- The authors did not state whether the subjects were blinded in the study, so it is assumed that they were not. Also, if they were aware what the study was about, they would have been able to figure out which group they were in. This knowledge may have led to compensatory rivalry.
- **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	- The allocation into groups was not concealed, and the investigators were not blind to which groups were receiving which treatment. This may have led to compensatory equalization and skewed the study results.
- **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- The investigators were not blind, but the groups were managed equally apart form the treatment.
- **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- The follow up time was sufficiently long to see results, however, since the questions involved looking at muscle hypertrophy and strength the study could have had a longer follow up time to completely answer the question. This may have resulted in a type II error.
- **Did all the subjects originally enrolled complete the study?**	- The study does not state whether all of the participants originally enrolled in the study completed the study.

a. **If not how many subjects were lost?** b. **What, if anything, did the authors do about this attrition?** c. **What are the implications of the attrition and the way it was handled with respect to the study's findings?**	
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?** a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	- The study did not state there was an intention to treat analysis. The authors did not state if any subjects were lost during the study, or if they were what was done with their data.
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- HRT group: Significant increase in leg press 1 RM (P<0.001; ES=1.50; 95% CI: 0.78-2.41). Significant increase in quadriceps CSA (P<0.001) - LRT-BFR group: Leg press 1RM trended towards significant increase (P=0.067; ES=0.59; 95% CI: 0.03-1.22). Significant increase in quadriceps CSA (P<0.001). - CG: No difference in 1RM leg press (P=0.998). No changes in quadriceps CSA (P<0.395).
- **Do these findings exceed a minimally important difference?** a. **If not, will you still use this evidence?**	- Although the quadriceps strength increase in the LRT-BFR group was not statistically significant, it is still clinically significant and can still be used.
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** a. **If not, how different? Can you use this intervention in spite of the differences?**	- The patients are similar in age, however, to be included in the study they could not have had any musculoskeletal conditions in the LEs, which differed from my patient. The intervention can still be used in spite of this difference.

- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Yes, the potential benefits of the intervention outweigh the potential risks.
- **Does the intervention fit within your patient/client's stated values or expectations?** **a. If not, what will you do now?**	- Yes, the intervention fits within my patients stated values.
- **Are there any threats to external validity in this study?**	- The participants did not have any other comorbidities, which may be a threat to external validity because individuals at that age usually have comorbidities.

What is the bottom line? What pedro score would you give this trial?:

- Pedro Score: 4/10
- The findings were clinically significant, even if they were not statistically significant. The findings in this study can be used to make decisions in clinic.

Intervention – Evidence Appraisal Worksheet - #8

Citation: Cook, S., LaRoche, D., Villa, M., Barile, H., Manini, T. (2017). Blood flow restricted resistance training in older adults at risk of mobility limitations. *Experimental Geronotology*, 99:138-145.

doi: 10.1016/j.exger.2017.10.004

Is the purpose and background information sufficient?	
Appraisal Criterion	***Reader's Comments***
Study Purpose Stated clearly? Usually stated briefly in abstract and in greater detail in introduction. May be phrased as a question or hypothesis. A clear statement helps you determine if topic is important, relevant and of interest to you. Consider how the study can be applied to PT and/or your own situation. What is the purpose of this study?	- Yes, the purpose of this study was clearly stated. - The purpose of this study is to evaluate the effects of a 12 week high load resistance training program compared to a low load BFR training program on LE strength, hypertrophy, physical function, and quality of life in older adults with muscle weakness who are at risk for mobility limitations. - Yes, relevant background information was presented.
Literature Relevant background presented? A review of the literature should provide background for the study by synthesizing relevant information such as previous research and gaps in current knowledge, along with the clinical importance of the topic. Describe the justification of the need for this study	- The authors state that the current gap in knowledge revolves around the fact that previous studies on this topic did not include subject with existing muscle weakness. Also, the findings surrounding the transfer of strength gain to improved physical function is inconsistent.

Does the research design have internal validity?	
Appraisal Criterion	***Reader's Comments***
➢ **Discuss possible threats to internal validty in the research design. Include:** ➢ **Assignment** ➢ **Attrition** ➢ **History** ➢ **Instrumentation** ➢ **Maturation** ➢ **Testing** ➢ **Compensatory Equalization of treatments** ➢ **Compensatory rivalry** ➢ **Statistical Regression**	- Compensatory equalization: The therapists overseeing the sessions were not blinded, so there is a possibility for compensatory equalization. - Compensatory rivalry: the participants would have easily been able to distinguish which group they were in if they knew the purpose of the study.

Are the results of this therapeutic trial valid?	
Appraisal Criterion	***Reader's Comments***

- **Did the investigators randomly assign subjects to treatment groups?** **a. If no, describe what was done** **b. What are the potential consequences of this assignment process for the study's results?**	- Yes, the participants were randomly assigned into treatment groups using a stratified randomization approach.
- **Were the groups similar at the start of the trial? Did they report the demographics of the study groups?** **a. If they were not similar – what differences existed?**	- The demographics were reported. At the start of the study there was no difference between groups in anthropometric, physical function and strength measurements. However, the HL group rated their QOL higher than the BFR group.
- **Did the subjects know to which treatment group they were assign?** **a. If yes, what are the potential consequences of the subjects' knowledge for this study's results**	- The authors did not state whether the subjects were blinded in the study, so it is assumed that they were not. Also, if they were aware what the study was about, they would have been able to figure out which group they were in. This knowledge may have led to compensatory rivalry.
- **Did the investigators know who was being assigned to which group prior to the allocation?** **a. If they were not blind, what are the potential consequences of this knowledge for the study's results?**	- The allocation into groups was not concealed, and the investigators were not blind to which groups were receiving which treatment. This may have led to compensatory equalization and skewed the study results.
- **Were the groups managed equally, apart from the actual experimental treatment?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- The investigators were not blind, but the groups were managed equally apart from the treatment.
- **Was the subject follow-up time sufficiently long to answer the question(s) posed by the research?** **a. If not, what are the potential consequences of this knowledge for the study's results?**	- The follow up time was sufficiently long to see results.
- **Did all the subjects originally enrolled complete the study?** **a. If not how many subjects were lost?** **b. What, if anything, did the authors do about this attrition?** **c. What are the implications of the attrition and the way it was handled with respect to the study's findings?**	- No, one subject was lost in HL group and two subjects were lost in the BFR group. All of the participants randomized into the control group completed the study in that group. - The authors collected post testing prior to the study completion for the participants that dropped out. This may have slightly skewed the results and possible led to a type II error.
- **Were all patients analyzed in the groups to which they were randomized (i.e. was there an intention to treat analysis)?**	- Yes, all subjects were analyzed in the groups they were originally assigned to and there was an intention to treat.

a. **If not, what did the authors do with the data from these subjects?** b. **If the data were excluded, what are the potential consequences for this study's results?**	
Are the valid results of this RCT important?	
Appraisal Criterion	***Reader's Comments***
- **What were the statistical findings of this study?** a. **When appropriate use the calculation forms below to determine these values** b. **Include: tests of differences? With p-values and CI** c. **Include effect size with p-values and CI** d. **Include ARR/ABI and RRR/RBI with p-values and CI** e. **Include NNT and CI** - **What is the meaning of these statistical findings for your patient/client's case? What does this mean to your practice?**	- HL group showed significantly greater increases in leg extension, leg curl, and leg press 1RM and CSA compared to the control (P<0.05). It showed significantly greater increase in leg extension 1RM compared to BFR group (P=0.01). - BFR group showed significantly greater increases in CSA compared to the control (P<0.01). - The 400-m walk speed improved an average of 4% across the sample (P=0.007) and chair rise ranking within SPPB improved from 2.72 to 3.11 (P=0.011). The 4-m walk time tended to improve from 3.8s to 3.6s (P=0.05). However, the overall SPPB did not improve in any group (P=0.33). - There was no change noted in any of the QOL domains for all groups over the course of the study.
- **Do these findings exceed a minimally important difference?** a. **If not, will you still use this evidence?**	- The BFR training group still improved more than the control group, so it is clinically significant and this data can be used if there are contraindications to HL training.
Can you apply this valid, important evidence about an intervention in caring for your patient/client? What is the external validity?	
Appraisal Criterion	***Reader's Comments***
- **Does this intervention sound appropriate for use (available, affordable) in your clinical setting?**	- Yes, this intervention does sound appropriate for use in the clinical setting as long as the patients are screened for precautions/contraindications.
- **Are the study subjects similar to your patient/ client?** a. **If not, how different? Can you use this intervention in spite of the differences?**	- Yes the participants are similar to my client.
- **Do the potential benefits outweigh the potential risks using this intervention with your patient/client?**	- Yes, the potential benefits of the intervention outweigh the potential risks.
- **Does the intervention fit within your patient/client's stated values or expectations?**	- Yes, the intervention fits within my patients stated values.

a. If not, what will you do now?	
- **Are there any threats to external validity in this study?**	- The participants in the study were thoroughly screened and otherwise healthy which may be a threat to external validity for the generalized public of that age group.

What is the bottom line? What pedro score would you give this trial?:

- Pedro Score: 7/10
  The findings were clinically significant in the BFR group. It would be appropriate to initiate an individual, who has been screened, on a low load BFR training program and then switch them to a higher load training program without the BFR. This will allow them to make strength gains, pain free, and give them a foundation to work off of for higher load resistance training.