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UNC DPT Capstone Final Project

Evidence Table: Use of Blood Flow Restriction Therapy in the Geriatric Population

Title/Author/Year	***Study Details***
The blood flow restriction training effect in knee osteoarthritis people: a systematic review and meta-analysis[1] Ferlito et al. (2020)	Study Design: Systematic review and meta-analysis of randomized control trials (RCTs) with the aim of assessing the available evidence on using blood flow restriction (BFR) in individuals with knee osteoarthritis compared to using high load training (HLT) or low load training (LLT). Subjects: This systematic review included a total of 5 articles that were all RCTs. PEDro scores were classified as "good" for each RCT (> or = 6/11). The number of participants in each study ranged from 27 to 48. The mean age of participants in each study ranged from 55.4 to 68.2 years old. One study included both sexes as participants, one study included only male participants, and three studies included only female participants. For this systematic review, a total of 190 participants were assessed across the RCTs with a mean age of 59.89 years old (+/- 7.47 years) that was largely composed of females. Tests/Measures: Strength, pain, and function were measured in each of the five studies, but the outcome measures used to assess such varied across studies. – Functional measures: Timed Up and Go, Timed Position Test, Stair Climb Power, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Lequesne, Late Life Function and Disability Index, Short Physical Performance Battery, gait speed – Pain: WOMAC Pain Subscale, KOOS pain, Numeric Pain Rating Scale – Strength: Bilateral isotonic leg press, isokinetic knee extensor, 1RM of seated leg press, 40% of 1RM of seated leg press, isometric voluntary contraction, 1RM of knee extension – Muscle size (assessed in 2 of 5 studies): Muscle CSA

	Interventions: The comparison group for each study was either low load (20-30% 1RM) or high load (60-80% 1RM) strength training without the application of BFR. All studies assessed the use of BFR in combination with low load strength training (20-30% 1RM) administered by a trained physiotherapist. The duration of intervention ranged from 4 to 12 weeks. The exercise frequency ranged from 2-3x/week. Only 3 of the 5 studies reported the type and size of the inflator device/cuff used. Inflated pressure of the cuff during exercise ranged from 100-200 mmHg. Exercise protocols were reported for 4 of the 5 studies. Types of exercises were different for each study, although the leg press was included in 4 of the 5 studies. Other exercises included seated knee extension, calf raises, hamstring curl, isometric bridging, and sensory-motor training. Results: The meta-analysis of the effects of BFR versus high load resistance training on knee strength demonstrated no significant different between BFR versus high load training (n=124, SMD=0.00, 95% CI, -0.54-0.54, I^2 =0%, *P*=1.00). The meta-analysis of the effects of BFR versus high load resistance training on knee function demonstrated higher significant increases in knee function with high load training (n=245, SMD=-0.20, 95% CI, -0.45-0.06, I^2=0%, *P*=0.13). Descriptive analysis shows significant positive effects from BFR compared to high load training, found with the measurements of quadriceps strength and pain during exercise. The studies that used knee pain as an outcome measure had high levels of heterogeneity (I^2>80%), so the results of such were only descriptively reported. There was no significant difference in knee pain between BFR and low load training (n=81, MD=-1.70, 95% CI, -8.65-5.24, I^2=13%, *P*=0.63). Two of the five studies assessed knee function and increases were found for both BFR and low load training (n=116, SMD=0.01, 95% CI, -0.42-0.44, I^2=25%, *P*=0.95). There was not a meta-analysis performed on the data from the three studies that assessed muscle strength from BFR versus low load training due to lack of homogeneity (I^2>90%). Descriptive analysis showed significant positive effects from BFR compared to low load training with the measurements of 1RM of knee extension, 1 RM of leg press, 40% 1RM of leg press, isokinetic knee extensor torque, and quadriceps volume. One of the five studies assessed muscle volume and found a significant effect of BFR compared to low load training (n=40, MD=1.66, 95% CI, 0.93-2.38, *P*<0.00001). Conclusion & Clinical Implications: The authors do recommend the use of BFR training in patients with knee osteoarthritis due to its ability to produce responses that compare to high load resistance training for the outcomes of muscle strength, muscle volume, knee pain, and knee function. Additionally, using BFR training

	resulted in more of an increase in muscle volume and strength compared to using low load training alone. This is beneficial because low load training alone is not as effective in increasing muscle volume compared to BFR. Meta-analysis heterogeneity is likely explained by the "diversity in the BFR application and used exercise protocols,"[1] such as differences in cuff size and pressure used. The overarching clinical implication gathered from this review is that BFR training can produce strength and functional gains in people with knee OA without a large increase in pain and is thus a viable option to consider when creating a treatment plan for this population.
Blood-flow restriction resistance exercise for older adults with knee osteoarthritis: a pilot randomized clinical trial[2] Harper et al. (2019)	<u>Study Design:</u> This is a two-arm randomized, single-masked pilot RCT aiming to assess both the safety and efficacy of using BFR in the older adults with knee OA population, in addition to determining the the feasibility of completing a fully-powered RCT for comparing the effects of BFR to moderate-intensity resistance training (MIRT) in the population of older adults with knee OA. <u>Subjects:</u> 35 participants all equal to over the age of 60 with a diagnosis of knee OA participated in the trial. Recruitment consisted of mailing, newspaper advertisement, and various techniques used in the community. Eligibility criteria included "(1) ≥60 years of age, (2) objective functional limitations, (3) no participation in regular resistance training, and (4) symptomatic knee OA"[2]. Those that had a peripheral vascular disease, systolic BP of > 160 or < 100 mmHg, resting diastolic BP of > 100 mmHg, other contraindications to use of a tourniquet, or other medical conditions that presented contraindications to exercise training were excluded from participation. The sample was randomized into either the BFR intervention group (n=16) or the MIRT intervention group (n=19). At baseline, key characteristics of these groups were similar including age, sex, race, ethnicity, BMI, BP, gait speed, WOMAC pain subscale, peak torque extension, leg press 1RM, leg extension 1RM, leg curl 1RM, and calf flexion 1RM. However, there was a significantly higher self-reported knee pain using the visual analog scale at baseline in the MIRT group. There were 2 participants that dropped out of the study, one from each intervention group. Additionally, 3 participants in each group stopped participating in the intervention but stayed in the trial. Overall adherence to the interventions were 81.4% for the BFR group and 83.0% for the MIRT group. <u>Tests/Measures:</u> Assessments were administered by an investigator separate to the investigator administering the interventions.

- Unilateral isokinetic strength of the knee extensors of the limb with knee OA assessed via a dynamometer (if both knees exhibit OA, then the knee with a higher self-report pain was tested).
- Unilateral knee extensor peak torque (Nm) at 60, 90, and 120 degrees/second.
- Walking speed assessed via 10 laps of 40 meters (400 meters total) walking at the participant's usual pace.
- Pain after assessment of walking speed via the visual analog scale (1-10, with 10 being the worst pain).
- Lower-extremity function assessed via the Short Physical Performance Battery (SPPB). This assessment includes ability to stand side-by-side, semi-tandem, and tandem; fastest 3- or 4-meter walk; and timed 5x sit-to-stand. Scores range from 0-12, with 12 being highest lower extremity function.
- Self-assessed physical function via the Late Life Function and Disability Instrument (LLFDI). This includes a self-assessment of ability to complete a wide range of tasks, as well as the frequency able to complete and any associated limitations. Scores from the 16 tasks are scored from 0-100 – a higher score is indicative a higher self-perceived level of function.
- Knee-related pain assessed via the WOMAC. This measure has established validity and sensitivity specific to the effects of treatment in those with lower limb OA and associated pain. The participants self-assess their knee pain and its influence on completing an activity with a rating of difficulty from 0-4 (0 = none; 1 = mild, 2 = moderate, 3 = severe, 4 = extreme).
- Serum concentrations of N-terminal peptide of procollagen type III, tumor necrosis-like inducer of apoptosis, and insulin-like growth factor assessed via an enzyme-linked immunosorbent assays kit.

Interventions:

Control: Supervised lower-body resistance training 3x/week that consists of a warm-up, strength training, stretching, and balance exercises. Resistance was provided with standard isotonic equipment from Life Fitness. 1RM was calculated at baseline to determine appropriate weights for the leg press, leg extension, calf flexion, and leg curl and this was reassessed at week 3, 6, 9, and 12. The Borg scale was used to assess RPE during each exercise session. The exercise protocol for the MIRT group was aligned with the recommendations for older adults with OA and included performing the leg press, leg extension, leg curl, and calf flexion at 60% 1RM. Blood tests were used for safety reasons to monitor adverse effects at baseline, as well as at week 6 and 12.

	Experimental: Supervised lower-body resistance training 3x/week that consists of a warm-up, strength training, stretching, and balance exercises. Resistance was provided with standard isotonic equipment from Life Fitness. 1RM was calculated at baseline to determine appropriate weights for the leg press, leg extension, calf flexion, and leg curl and this was reassessed at week 3, 6, 9, and 12. The Borg scale was used to assess RPE during each exercise session. The low-load BFR group performed the leg press, leg extension, leg curl, and calf flexion at 20% 1RM with compression from the cuffs provided at both proximal thighs throughout the lower extremity strengthening exercises. In between exercises, the cuff was deflated before being inflated again before the next exercise. The following equation was used to determine appropriate cuff inflation: [pressure mm Hg = 0.5 (SBP) + 2(thigh circumference) + 5] (p.4). All exercises were performed to fatigue. Blood tests were used for safety reasons to monitor adverse effects at baseline, as well as at week 6 and 12. <u>Results:</u> Exercise training volume and 1RM: "Overall, pre- to post-training changes in 1RM for the four training exercises were as follows (mean and 95% CI): leg press 72.29 (40.47, 105.11) lbs, leg extension 41.34 (27.50, 55.19) lbs, calf flexion 75.16 (45.64, 104.68) lbs, and leg curl 17.67 (7.61, 27.72) lbs. Differences in post-training changes in 1RM between groups were as follows (BFR relative to MIRT): leg press −50.81 (−117.22, 15.60) lbs, leg extension −26.60 (−54.94, 1.74) lbs, calf flexion −30.66 (−91.05, 29.73) lbs, and leg curl −16.46 (−36.05, 3.13) lbs"[2] Intent-to-treat analysis (according to week 12 for all measures): – Knee extensor peak torque: Pre- to post-training change was 9.96 (5,76, 14,16) Nm across both groups. Between groups mean, BFR relative to MIRT was –1.87 (-10.96, 7.23) Nm. – Knee extensor strength: Positive effects for both groups at 60, 90, and 120 degrees/second. – 400m walk gait speed: Mean change was −0.03 (−0.08, 0.01) m/s. Between groups change was −0.01 (−0.11, 0.09) m/s. – SPPB: Across both groups, change was 0.47 (−0.03, 0.97) points. Between groups, mean change was −0.66 (−1.74, 0.42) points. – LLFDI: For Frequency Total, both groups change from pre to post training was −0.14 (−2.23, 1.94) points and between groups change was −0.79 (−6.76, 5.17) points. For Limitation Total, both groups change from pre to post training was 4.36 (0.06, 8.72) points and between group change was 6.60 (−18.99, 5.79) points.

	– WOMAC: Across groups, the pain subscale change was −0.81 (−2.04, 0.42) points and between group change was 0.24 (−2.51, 2.98) points. – Total lean mass and total body fat: Change from pre to post training for total lean mass was 0.40 (−0.61, 1.40) kg and between groups change was −1.10 (−3.44, 1.24) kg. Changes from pre to post training for total body fat percentage was −1.02 (−0.13, −1.91) % and between groups was 1.12 (-0.90, 3.14) %. Change from pre to post training for lower body lean mass specifically was 0.71 (1.07, 0.36) kg and between groups change was -0.44 (−1.26, 0.39) kg. – Biomarkers: Across groups, the mean change for serum P3NP was −0.63 (−1.28, 0.02) mg/dL and between groups change was 0.98 (−2.39, 0.44) mg/dL. Across groups, the mean change for serum TWEAK was 21.70 (−90.16, 133.56) mg/dL and between groups was −92.70 (−306.14, 120.74) mg/dL. Across groups, the mean change for serum IGF-1 was 92.70 (−306.14, 120.74) mg/dL and between groups was 0.04 (−0.19, 0.11) mg/dL. Conclusion & Clinical Implications: The authors concluded that overall, BFR is a safe and feasible approach to strength training in older adults with knee OA and may be associated with less increases in knee pain when compared to MIRT. Preliminary results of this pilot study show that the BFR intervention may be a less painful yet still effective strength training option for this population and a fully-powered RCT should assess the effects of BFR versus MIRT in order to draw adequate conclusions.
Exercises with partial vascular occlusion in patients with knee osteoarthritis: a randomized clinical trial[3] Bryk et al. (2016)	Study Design: This study is an RCT aiming to determine if women with knee osteoarthritis (OA) demonstrate similar changes in quadriceps strength, pain, and function when participating in low-load exercises with BFR compared to women participating in high-load exercises without BFR. Subjects: 34 females with a mean age of 61 years old with a clinical and radiological diagnosis of knee osteoarthritis established by the American College of Rheumatology, as well as a score of 2 or 3 on the Kellgren and Lawrence scale. Patients that had a history of surgery or previous physical therapy on the affected knee, or had a change in medication in the last 3 months were excluded. Additional exclusions included those that had a debilitating disease, neurological disorder, heart or vascular condition, or tumor. All subjects were randomly assigned to the control or experimental group.

	<u>Tests/Measures:</u> The examiner was blind to the group assignment of all participants and did not participate in the interventions. The following measures were used to evaluate all participants at baseline and at the end of the 6 weeks of intervention: – Numerical Pain Rating Scale (NPRS) – also completed during treatment sessions – Lequesne Questionnaire – assesses pain, discomfort, and function – Timed Up and Go (TUG) – assesses physical mobility and balance – Muscle strength via hand-held dynamometer <u>Interventions:</u> Treatment sessions for both the control and BFR groups were provided 3x/week for 6 weeks for a total of 18 sessions and included the same exercise routine as follows: – Hamstring stretch, 3 bouts of 30 seconds – Bridge with isometric transversus abdominis contraction, 3 bouts of 30 seconds – Sidelying hip abduction with weights (70% of repetition maximum (RM)), 3 sets of 10 repetitions – Calf raises, 3 sets of 10 repetitions – Sidelying clamshells with elastic band (max resistance that enables 10 repetitions), 3 sets of 10 repetitions – Sensorimotor training in standing on mini-trampoline, 3 bouts of 30 seconds – Seated knee extension machine 0-90 deg of knee flexion (70% of 1RM for control group and 30% 1 RM plus use of occlusion for BFR group), 3 sets of 10 repetitions The difference in interventions between the 2 groups is indicated by the intensity used for the seated knee extension exercise noted above. In the BFR group, the occlusion cuff was applied to the upper third of the thigh and inflated to 200 mmHg. <u>Results:</u> There was no significant difference for demographics (age, height, body mass, body mass index) or outcome measure results between groups. Participants from both the control and experimental groups demonstrated improvements in function (via Lesquene questionnaire and TUG), decreased pain (via NPRS), and increased quadriceps strength after 6 weeks of intervention (all $p < 0.05$). The between-group analysis showed no differences for outcomes posttreatment. Patients in the BFR group did report less pain (via NPRS) during treatment sessions than those in the control group ($p < 0.05$).

	<u>Conclusion & Clinical Implications:</u> The results of this RCT show that participating in low-load strength training in combination with BFR produces the same improvements in function, pain, and strength as participating in high-load strength training without BFR in patients with knee OA. Since the patients in the BFR group demonstrated less anterior knee pain during exercise than those in the control group, BFR can be a viable option for those with degenerative diseases such as OA to increase strength without simultaneously increasing pain.
Benefits of resistance training with blood flow restriction in knee osteoarthritis[4] Ferraz et al. (2018)	<u>Study Design:</u> This study is an RCT aiming to determine the clinical effects of using BFR in combination with low intensity resistance training (LI-RT) specifically in females with knee OA. <u>Subjects:</u> Participants were all females between ages 50-65 that that been diagnosed with knee OA using the American College of Rheumatology criteria. Those excluded included having been participating in exercise training in the past year, disease that prohibited exercise participation, Kellgren-Lawrence radiograph grade of 1 or 4, knee pain of less than 1 or greater than 8 using the Visual Analog scoring, use of non-steroidal anti-inflammatory drugs in the past 3 months, or use of intra-articular hyaluronic acid and corticosteroids in the past 6 months. Patients were randomized into either the high-intensity resistance training (HI-RT), LI-RT, or LI-RT with BFR groups. <u>Tests/Measures:</u> All measures were assessed at baseline and after 12 weeks of training. – 1 RM leg press – 1 RM knee extension – Timed-stands test (TST) = determines number of times the patient can stand from a standard armless chair in 30 seconds – TUG – Quadriceps cross-sectional area via computed tomography imaging (CT) – Short Form Health Survey (SF-36) = measures functional health and well-being status – WOMAC = self-report of pain, stiffness, and physical function (scored as 0/none - 4/extreme) <u>Interventions:</u> All interventions for all 3 groups were completed 2x/week for 12 weeks.

- HI-RT: Week 1 included 4 sets of 10 repetitions at 50% 1RM (1 minute rest between sets) for the leg press and knee extension machine exercises. Week 2 and beyond included increasing the intensity to 80% 1 RM. Week 5 and beyond included increasing to 5 sets of 10 repetitions.
- LI-RT: Week 1 included 4 sets of 15 repetitions at 20% 1RM (1 minute rest between sets) for the leg press and knee extension machine exercises. Week 2 and beyond included increasing the intensity to 30% 1 RM. Week 5 and beyond included increasing to 5 sets of 10 repetitions.
- LI-RT + BFR: Week 1 included 4 sets of 15 repetitions at 20% 1RM (1 minute rest between sets) for the leg press and knee extension machine exercises, with the blood pressure cuff placed at the inguinal fold inflated to 70% of pressure necessary to restrict blood flow. Initially, the blood pressure cuff was inflated until auscultatory pulse was absent, and training protocol was determined to be 70% of this pressure. This pressure was sustained throughout the duration of the treatment session. Week 2 and beyond included increasing the intensity to 30% 1 RM. Week 5 and beyond included increasing to 5 sets of 10 repetitions.

Results: For the LI-RT + BFR and HI-RT groups, comparable within-group increases were determined for leg press 1RM (26% and 33% respectively; all $P<0.0001$), knee extension 1RM (23% and 22% respectively; all $P<0.0001$), and quadriceps cross-sectional area (7% and 8% respectively; all $P<0.0001$). These results were significantly greater (all $P<0.05$) than those of the solely LI-RT group. For the LI-RT + BFR and HI-RT groups, there were comparable improvements in the timed-stands test (7% and 14% respectively), with the HI-RT group showing larger increases than the LI-RT group. TUG scores were not significantly different within or between the groups. ; all $P<0.05$), and improvements in the WOMAC pain scores were demonstrated in the LI-RT + BFR and LI-RT groups (-45% and -39% respectively; all $P<0.05$). Four patients (of 16) were excluded during the 12-week intervention period due to exercise-induced knee pain in the HI-RT group.

Conclusion & Clinical Implications: Results show that participating in LI-RT with BFR produces comparable outcomes in increasing strength, muscle mass, and function in patients with knee OA when compared to participating in HI-RT. Additionally, participating in the LI-RT with BFR is an alternative for producing these effects while simultaneously minimizing pain and reducing joint stress. Therefore, this treatment approach is a feasible option for improving overall function in OA patients.

Does blood flow restriction therapy in patients older than age 50 result in muscle hypertrophy, increased strength, or greater physical function? A systematic review[5] Baker et al. (2020)	Study Design: This study is a systematic review aiming to assess the effects of BFR in adults over 50 years old, specifically muscle hypertrophy, strength, and physical function. Subjects: 30 articles were used with a range of 6 to 56 participants across the studies. Articles ranged from publication dates of 1990 to 2019. The Risk of Bias in Nonrandomized Studies of Interventions and the Cochrane's Collaboration's tool were used to assess risk of bias in the included studies. Two thirds of the studies were determined to be at moderate or high risk of bias. Tests/Measures: – Muscle hypertrophy – quantified by either cross-sectional area, volume, thickness, circumference, or mass – Muscle strength – quantified as either max voluntary contraction force, max voluntary isometric contraction force, torque, muscle activation, or one repetition maximum – Functional performance – quantified as either the 30 second sit-to-stand, 8 feet TUG, or muscle strength Interventions: Interventions of studies used in the review ranged from lasting 16 weeks to a cross-sectional design. Interventions used in the various studies include passive mobilization, electrical stimulation, walking, resistance training using machines, resistance training using free weights, resistance training using body weight, resistance training using elastic bands, and water-based activities. Results: BFR used in combination with a variety of exercises did display an increase in muscle hypertrophy (average effect size of 0.75 calculated for 16 of the 30 papers) and an increase in functional performance (average effect size of 1.15 calculated for 21 of the 30 papers). Conclusion & Clinical Implications: BFR therapy used as a treatment intervention adjunct does demonstrate improvements in muscle hypertrophy, strength, and physical function in adults over 50 years old and thus may be a viable and safe option for combating muscle atrophy for those that are unable to perform high-intensity resistance training. However, due to the high bias present in a large amount of the studies, further research is indicated using larger sample sizes, appropriate randomization, and adequate follow-up.

The effects of low-intensity resistance training with vascular restriction on leg muscle strength in older men[6] Karabulut et al. (2010)	<u>Study Design:</u> This study is an RCT aimed to determine the strength effects of different types of resistance training programs in older males. <u>Subjects:</u> 37 males from ages 50-64 (mean age of 56.8 years old) that were described as physically active but not participating a formal exercise program. Exclusion criteria for participants included those with a Body Mass Index (BMI) greater than 40 kg/m^2, unable to participate in strength training, or had participated in a resistance training program in the last 4 months. <u>Tests/Measures:</u> 1RM testing performed for each exercise at baseline, every 2 weeks, and final session. <u>Interventions:</u> There were 3 groups that participants were randomly assigned to that included high intensity resistance training defined as 80% 1RM (Group RT80), low intensity resistance training defined as 20% 1RM in combination with BFR (Group VR-RT20), or a control group that performed no exercise (Group CON). The study lasted 8 weeks, with 6 of those weeks consisting of resistance training interventions. Both exercise groups performed the same interventions with their parameters according to their assigned group. Each session started with a warm-up of 5 minutes on a cycle ergometer or treadmill. RT80 Group: 3 upper body exercises (lat pull down, shoulder press, and bicep curl), 2 lower body exercises (leg press and leg extension) for 3 sets of 8 repetitions at 80% 1RM VR-RT20 Group: 3 upper body exercises (lat pull down, shoulder press, and bicep curl) for 3 sets of 8 repetitions at 80% 1 RM, 2 lower body exercises (leg press and leg extension) for 1 set of 30 repetitions and 2 sets of 15 repetitions all at 20% 1RM with BFR. Cuffs were placed on the thigh and pressure was maintained throughout completion of lower extremity exercises. The pressure of the cuff was initially inflated to 160 mmHg and adjusted at the next session according to the patient's reported perceived rate of exertion (RPE) after each set at the previous session. Pressure was increased by 20 mmHg if RPE was below 16 and kept thte same if RPE was between 16-19. Mean pressure used was 205.4 +/- 4.3 mmHg and mean RPE reported was 16.5 +/- 0.5.

	<u>Results:</u> Increases in leg press strength were comparable between the RT80 and VR-RT20 groups (p>0.05), although the RT80 group displayed significantly greater strength gains for leg extension specifically (p>0.05). No improvements seen in the control group. <u>Conclusion & Clinical Implications:</u> Lower extremity strength can improve with low intensity exercises performed in combination with BFR in older men, and is almost as effective in the amount of strength gains compared to high intensity training without BFR. This is a viable treatment option that allows for lower extremity strengthening with less risk of injury compared to high resistance training for older men.
Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly[7] Vechin et al. (2015)	<u>Study Design:</u> This is an RCT with an aim to compare outcomes from low intensity resistance training with BFR (LRT-BFR) and high intensity resistance training (HRT) in the elderly population, specifically assessing quadriceps muscle strength and mass. <u>Subjects:</u> There were 23 participants (14 male, 9 female) with a mean age of 64 years old. Participants were randomly assigned to one of 3 groups discussed below. Participants were excluded if they had cardiac disease, arterial hypertension, diabetes mellitus, or any lower extremity musculoskeletal condition. Participants were also excluded if they had participated in a resistance training program in the past 6 months prior to the study. <u>Tests/Measures:</u> – Strength via leg press 1RM. Assessed at baseline, 6 weeks, and 12 weeks. – Quadriceps CSA via MRI. Assessed at baseline and 12 weeks. <u>Interventions:</u> Interventions for all groups were delivered 2x/week for 12 weeks. – Control group – HRT group = 4 sets of 10 repetitions at 70-80% 1RM of the leg press machine – LRT-BFR group = 1 set of 30 repetitions and 3 sets of 15 repetitions at 20-30% 1RM of the leg press machine, with occlusion pressure set at 50% of the maximum tibial arterial pressure sustained throughout. Average cuff pressure was 71 +/- 9 mmHg.

	<u>Results:</u> Both the HRT and LRT-BFR groups demonstrated improvements in leg press 1RM (HRT: 54% increase, $p<0.001$; LRT-BFR: 17% increase, $p = 0.067$) and quadriceps CSA (HRT: 7.9% increase, $p<0.001$; LRT-BFR: 6.6% increase, $p<0.001$), with greater strength improvements seen in the HRT group compared to the LRT-BFR group. No improvements seen in the control group. <u>Conclusion & Clinical Implications:</u> While HRT may lead to greater strength improvements, LRT with BFR can still demonstrate strength gains and is thus an appropriate option for the elderly population that cannot participate in HRT. Improving strength in the elderly population can lead to improved function that is necessary for maintaining a healthy quality of life.
The efficacy and validity of blood flow restriction training in clinical and post-surgical populations[8] Serrano et al. (2019)	<u>Study Design:</u> This study is a literature review aiming to assess the validity and efficacy of using BFR with low load resistance training (LL-BFR) compared to low load training without BFR as well as high load training without BFR, specifically in the post-surgical and clinical population. <u>Subjects:</u> Inclusion criteria for articles reviewed included publication date in the last 20 years, ranked as a level 3 or higher evidence according to the Oxford Center for Evidence-Based Medicine, and written in English. Exclusion criteria included a score of less than 3 according to the Oxford Center for Evidence-Based Medicine, a score of 13 or less on the PEDr scale, written in a language other than English, interventions included bio-enhancement modalities, or the patient population included neurological and vascular patients (stroke, intermittent claudication, cerebral palsy). Studies included had to have patients that had a clinical condition such as osteoarthritis or are post-surgical (ACL reconstruction, total knee arthroplasty, knee arthroscopy, etc.). Out of the 171 articles screened, 17 were used in the review. <u>Tests/Measures:</u> Varied across different studies but 1 RM for the leg press was included in all of them as an outcome to measure changes in strength. Some studies also assessed cross sectional area as a measure of muscle mass. <u>Interventions:</u> Intervention time frames varied across studies but ranged from 4 weeks of exercises to 12 weeks of exercises. The intensity used for the low load resistance in combination with BFR ranged from 10-35% 1RM.

	Results: LL-BFR demonstrates more improvements in strength compared to low load training without BFR ($p<0.05$), demonstrated by higher 1RM, greater muscle cross sectional area, greater muscle mass, or greater muscle volume. LL-BFR does not lead to more strength gains than high load training without BFR ($p<0.03$). Conclusion & Clinical Implications: Due to high prevalence of contraindications in the clinical population for participating in high load training (joint instability, joint degeneration, pain, surgical restrictions), LL-BFR can lead to similar strength improvements while keeping the patient safe. This is especially pertinent to consider for the geriatric post-surgical and arthralgia populations due to the increased risk of muscle atrophy.
Effects of blood flow restriction training on muscular strength and hypertrophy in older individuals: a systematic review and meta-analysis[9] Centner et al. (2019)	Study Design: This is a systematic review and meta-analysis aiming to assess the effects of low-load BFR training (LL-BFR) compared to conventional resistance training, specifically measuring muscle mass and strength in older adults. It also assessed the effects of walking with and without BFR. Subjects: Electronic databases that were searched include PubMed, Web of Science, Scopus, CINAHL, SPORTDiscus, and CENTRAL that yielded 2658 studies to screen with 11 being included. Total population across the 11 studies was 238 subjects. Inclusion criteria included subjects that were health adults over the age of 50, a study design that compared resistance training with and without BFR (with a high load parameter of >70% RM and a low load parameter of <50% 1RM), and assessment of muscle mass and/or strength before and after the intervention delivered. Exclusion criteria included if the subjects had received a substance that produces muscle gains, if the literature was written in a language other than English, and a PEDro score of <4. Tests/Measures: Measures for strength included the 1RM of a leg extension, leg curl, leg press, plantar flexion, rowing, chest press, or shoulder press. Muscle mass was measured via an MRI, ultrasound, or DEXA of the muscle group being utilized during the primary exercise. For the studies that assessed BFR with walking, strength was measured via a 30 second sit-to-stand test, knee extension, or knee flexion. Interventions: Interventions aligned with the exercise that was being measured for a 1RM. Duration of interventions ranged from 4 to 12 weeks and frequency ranged from 2 days/week to 3 days/week. Protocol for the LL-BFR 1RM percentage ranged from 10% to 50% and the high resistance 1RM percentage ranged from 70% to 90%.

	For the studies that assessed BFR with walking, interventions included walking for 20 minutes at either 45% of their heart rate reserve or at a speed of 4 km/h for 4 days/week for 6 to 10 weeks. Muscle mass was measured via an MRI. Results: This review concluded that both LL-BFR and walking with BFR yield significantly larger improvements in strength than without with pooled effect sizes of 2.16 (95% CI 1.61 to 2.70) for LL-BFR and 3.09 (95% CI 2.04 to 4.14) for walking with BFR. Additionally, muscle mass was found to have increased in walking with BFR [ES 1.82 (95% CI 1.32 to 2.32)]. LL-BFR was found to produce similar increases in muscle size compared to high-load training [ES 0.21 (95% CI − 0.14 to 0.56)] but not as much of an increase in strength compared to high-load resistance training [ES − 0.42 (95% CI − 0.70 to − 0.14)]. Conclusion & Clinical Implications: The results demonstrated in this review show that LL-BFR and walking with BFR can be effective treatment approaches for producing increases in muscle size and strength in older adults. This is an important conclusion because it provides a safe alternative for increasing strength for those who are unable to participate in high resistance training due to pain from too much mechanical stress on the joints. Further research is recommended to determine the most effective and appropriate parameters for cuff pressure and training volume/frequency in the older adult population specifically.
Effects of blood flow restricted exercise training on muscular strength and blood flow in older adults[10] Kim et al. (2017)	Study Design: This is an experimental study aimed to assess the effects of BFR on strength and blood flow to muscles between younger and older patients as well as between older patients performing BFR training and older patients performing high intensity resistance exercise. Subjects: The older adults were classified as 60-80 years old and consisted of 23 participants (13 in the BFR group and 10 in the high intensity group). The younger adults were classified as 19-25 years old and consisted of 15 participants. Participants could not be smokers or taking anticoagulants or antihypertensives. Participants could not have a diagnosis of cardiovascular disease, peripheral vascular disease, diabetes, hypertension, or arthritis in their hands. They could not currently be participating in a resistance training program. Tests/Measures: All measures were taken at baseline and after 4 weeks of interventions.

- Maximum voluntary contraction (MVC) of handgrip strength assessed bilaterally using a Jamar-type handgrip dynamometer
- Forearm girth measured at 1/3rd the distance from the olecranon process to the ulnar styloid
- Peak forearm blood flow (FBF) via venous occlusion strain gauge plethysmography
- Forearm vascular conductance (FVC) = FBF divided by the mean arterial pressure

Interventions: The participants were randomly assigned to one of three groups:

- Older adults participating in BFR exercise (O-BFRE): BFR exercise of forearm musculature, 3 sets of repetitions to fatigue, 3x/week at 20% MVC
- Younger adults participating in BFR exercise (Y-BFRE): BFR exercise of forearm musculature, 3 sets of repetitions to fatigue, 3x/week at 20% MVC
- Older adults participating in high intensity resistance training (O-HI): high intensity training of forearm musculature at 75% MVC, 3 sets of repetitions to fatigue, 3x/week

For those in the BFR groups, the cuff was inflated to 30% above their resting systolid blood pressure.

Results:

- MVC increased in all 3 groups (O-BFRE: 33.4 ± 4.7 to 36.3 ± 4.7 kg; Y-BFR:, 37.2 ± 4.9 to 43.0 ± 5.0 kg; O-HI: 34.0 ± 4.4 to 39.8 ± 4.4 kg; all $p < 0.05$)
- Forearm girth only increased in the O-BFRE group (26.3 ± 1.1 to 26.7 ± 1.1 cm; $p < 0.05$) and the Y-BFRE group (23.9 ± 0.9 to 25.1 ± 1.5 cm; $p < 0.05$) and not in the O-HI group (25.9 ± 1.0 to 26.1 ± 1.0 cm; $p = 0.26$).
- Peak FVC increased only in the Y-BFRE group (0.190 ± 0.016 to 0.311 ± 0.031 units; $p = 0.01$), and not in the O-BFRE group (0.157 ± 0.024 to 0.193 ± 0.029 units; $p = 0.48$) or in the O-HI group (0.188 ± 0.035 to 0.227 ± 0.035 units; $p = 0.18$).

Conclusion & Clinical Implications: The results of this study show that BFR training can in fact be an effective approach to help increase strength, muscle size, and vascularity in younger adults. In older adults, BFR training can be effective for aiming to increase strength and muscle size, but not necessarily vascularity. BFR training can demonstrate more strength gains in older adults than older adults performing high intensity resistance exercise, demonstrated by increased forearm girth in this study.

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