

**OPTIMIZATION OF BLOOD FLOW
RESTRICTION WITHIN THE
REHABILITATION AND
PERFORMANCE SETTING**

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DPT, OCS, FAAOMPT, CSCS

ABOUT ME

Dr. Brandon Paulus, DPT, OCS, FAAOMPT, CSCS, earned his Doctorate in Physical Therapy (DPT) from Radford University. He is board-certified in orthopedics, a Fellow of the American Academy of Orthopaedic Manual Physical Therapists, and a certified strength and conditioning specialist. He is also certified in dry needling, spinal manipulation, and blood flow restriction training.

Brandon enjoys treating individuals with a holistic approach, focusing on health and wellness, athletic performance, and pain management. He specializes in treating tactical athletes, including military personnel, law enforcement officers, and firefighters, as well as recreational athletes, such as CrossFitters and powerlifters.

Brandon works primarily with Direct Performance Physical Therapy, serves as an adjunct professor with the Virginia Commonwealth University DPT program, and as an Injury Prevention Specialist with O2X. He currently mentors entry-level DPTs, residents, and fellows-in-training.





OBJECTIVES

01

TO UNDERSTAND THE CONCEPT OF BLOOD FLOW RESTRICTION (BFR) TRAINING:

A. PARTICIPANTS WILL LEARN THE DEFINITION AND HISTORICAL CONTEXT OF BFR TRAINING, AS WELL AS ITS DEVELOPMENT WITHIN THE FIELD OF ALLIED HEALTH, ENABLING THEM TO GRASP THE FUNDAMENTAL PRINCIPLES UNDERLYING THIS TRAINING METHOD.

02

TO IDENTIFY AND EVALUATE THE BENEFITS OF BFR TRAINING:

A. PARTICIPANTS WILL EXPLORE THE VARIOUS BENEFITS OF BFR TRAINING IN CLINICAL SETTINGS AND RECOGNIZE SAFETY CONCERNS, PRECAUTIONS, AND CONTRAINDICATIONS ASSOCIATED WITH ITS PRACTICE, EMPOWERING THEM TO MAKE INFORMED DECISIONS REGARDING ITS APPLICATION.



OBJECTIVES

03

TO COMPREHEND THE PHYSIOLOGY BEHIND BFR TRAINING:

A. PARTICIPANTS WILL GAIN AN UNDERSTANDING OF VASCULAR PHYSIOLOGY, OCCLUSION MECHANISMS, AND THE EFFECTS OF BFR TRAINING ON MUSCLE GROWTH AND STRENGTH GAINS, ENABLING THEM TO EXPLAIN THE PHYSIOLOGICAL BASIS OF BFR TRAINING TO PATIENTS AND COLLEAGUES.

04

TO ANALYZE CURRENT RESEARCH ON BFR TRAINING:

A. PARTICIPANTS WILL REVIEW CURRENT RESEARCH ON BFR TRAINING, INCLUDING ITS EFFICACY COMPARED TO TRADITIONAL HIGH-LOAD TRAINING METHODS, FOSTERING CRITICAL THINKING SKILLS AND EVIDENCE-BASED PRACTICE IN THE APPLICATION OF BFR TRAINING.



OBJECTIVES

05

TO DETERMINE APPROPRIATE INDICATIONS AND PATIENT POPULATIONS FOR BFR TRAINING:

A. PARTICIPANTS WILL LEARN TO IDENTIFY APPROPRIATE INDICATIONS AND PATIENT POPULATIONS FOR BFR TRAINING, INTEGRATING BFR PROTOCOLS INTO REHABILITATION PROGRAMS EFFECTIVELY AND TAILORING TREATMENT PLANS TO INDIVIDUAL PATIENT NEEDS AND GOALS.

06

TO DEMONSTRATE PROFICIENCY IN APPLYING BFR DEVICES:

A. PARTICIPANTS WILL LEARN TO CORRECTLY APPLY DIFFERENT TYPES OF BFR DEVICES, SUCH AS BANDS AND CUFFS, AND DEMONSTRATE PROFICIENCY IN ENSURING PROPER FIT AND PLACEMENT, ESSENTIAL FOR SAFE AND EFFECTIVE BFR TRAINING.



OBJECTIVES

07

TO UNDERSTAND AND ASSESS ARTERIAL OCCLUSION PRESSURE (AOP):
A. PARTICIPANTS WILL GAIN AN UNDERSTANDING OF THE CONCEPT OF ARTERIAL OCCLUSION PRESSURE AND ITS SIGNIFICANCE IN BFR TRAINING. THEY WILL ALSO DEVELOP THE SKILL TO ASSESS AOP USING VARIOUS METHODS, ENSURING A PERSONALIZED AND SAFE APPROACH TO BFR FOR EACH INDIVIDUAL.

08

TO IMPLEMENT BFR EXERCISE PROTOCOLS SAFELY AND EFFECTIVELY:
A. PARTICIPANTS WILL LEARN TO PERFORM A RANGE OF EXERCISES USING BLOOD FLOW RESTRICTION, INCLUDING RESISTANCE AND AEROBIC EXERCISES. THEY WILL PRACTICE MODIFYING THESE EXERCISES AND THEIR INTENSITY LEVELS TO CATER TO DIFFERENT TRAINING NEEDS AND GOALS.



OBJECTIVES

09

TO DEVELOP AND PLAN INDIVIDUALIZED BFR TRAINING PROGRAMS:

A. PARTICIPANTS WILL BE EQUIPPED WITH THE KNOWLEDGE TO DESIGN AND DEVELOP INDIVIDUALIZED BFR TRAINING PROGRAMS. THIS INCLUDES UNDERSTANDING HOW TO PROGRESS AND ADAPT THESE PROGRAMS OVER TIME, CATERING TO THE SPECIFIC NEEDS AND GOALS OF DIFFERENT INDIVIDUALS.

10

TO IDENTIFY AND MANAGE RISKS ASSOCIATED WITH BFR TRAINING:

A. PARTICIPANTS WILL LEARN TO IDENTIFY POTENTIAL RISKS AND COMPLICATIONS ASSOCIATED WITH BFR TRAINING. THEY WILL BE TRAINED IN MONITORING TECHNIQUES AND EMERGENCY PROCEDURES TO MANAGE AND RESPOND TO ADVERSE EVENTS EFFECTIVELY, ENSURING A HIGH STANDARD OF SAFETY IN BFR PRACTICE.

**30,000 FT VIEW OF
BLOOD FLOW
RESTRICTION (BFR)**

Blood flow restriction (BFR) training involves applying a cuff or tourniquet to limit blood flow, allowing for increased muscle stress and physiological changes at lower resistance.

BFR training is popular for achieving muscle hypertrophy and strength changes with lower resistance, benefiting injury recovery and limited equipment access.



Surgical Trauma

- During surgery, manipulation can involve stretching, cutting, or retraction of the muscle, tendon, and other tissues which physically impacts the tissue involved.
- The direct trauma initiates a cascade of inflammatory responses, leading to local edema and cellular breakdown. This acute muscle trauma can result in immediate strength loss and starts the process of muscle protein degradation, which if prolonged, leads to muscle atrophy.



<https://www.jonathanshultsmd.com/blog/what-to-expect-before-during-and-after-knee-arthroscopy>

Swelling and Pain

- Caused by fluid accumulation and inflammatory responses as the body begins to heal. Pain is a direct result of surgical trauma and the inflammatory processes affecting nerve endings.
- Both swelling and pain can significantly restrict voluntary muscle activation. Swelling physically impedes the contraction mechanics of muscle fibers and pain discourages active movement. The resultant reduced muscle activity leads to a decline in muscle protein synthesis and an increase in muscle protein breakdown, enhancing atrophy.



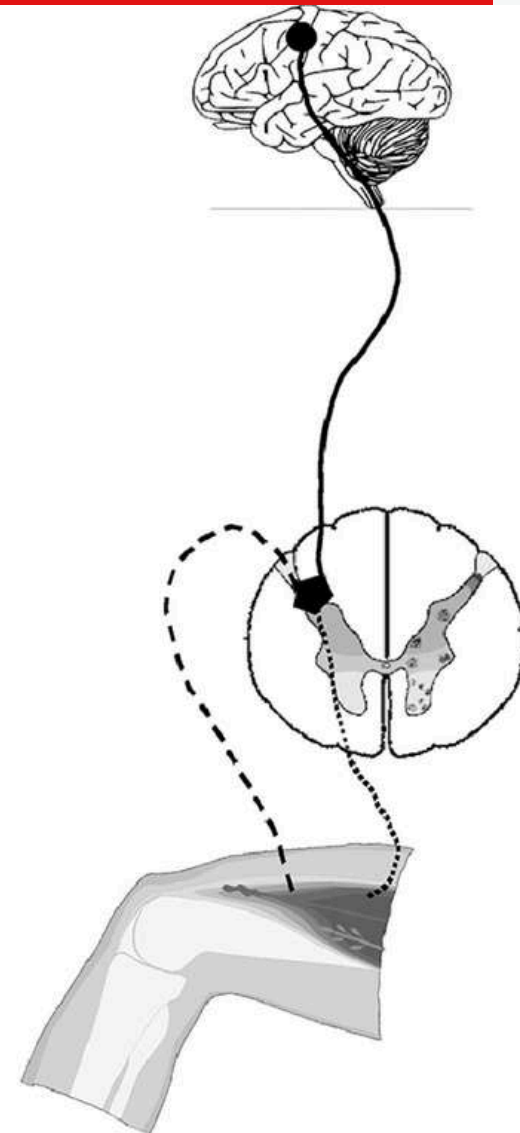
Eidolem. ACL surgery for Climbers Part 2: The surgery and first week.
Patchwork&Pebbles. Published March 5, 2020.
<https://www.patchworkandpebbles.com/acl-surgery-part-2/>

Reduced Motor Neuron Excitability

- Surgery can impact the nerves that innervate the muscle, either through direct trauma, swelling compressing nerve pathways, or altered biofeedback from the joint to the spinal cord and brain. This results in decreased excitability of motor neurons, which are less able to transmit signals effectively.
- When motor neurons are less excitable, the electrical impulses that trigger muscle contraction are diminished. This leads to incomplete and inefficient muscle activation. Over time, inadequate stimulation of muscle fibers results in their atrophy due to non-use and a lack of required tension to maintain muscle mass.

ACL-reconstructed individuals demonstrate bilateral

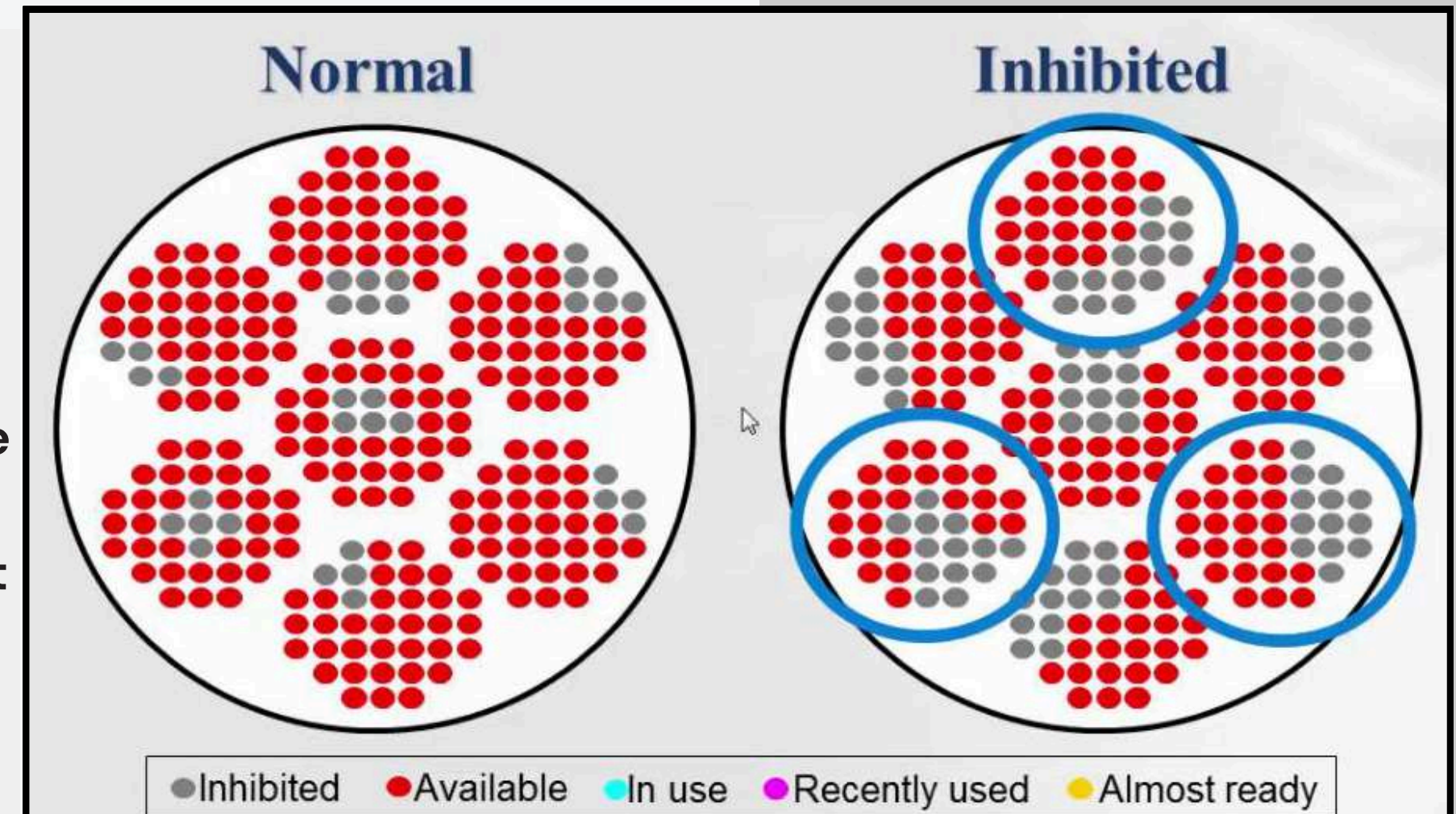
- ↑ in spinal-reflex excitability
- ↓ in corticospinal excitability
- ↓ in quadriceps strength
- ↓ in voluntary activation



Rodriguez KM, Palmieri-Smith RM, Krishnan C. How does anterior cruciate ligament reconstruction affect the functioning of the brain and spinal cord? A systematic review with meta-analysis. *Journal of Sport and Health Science/Journal of Sport and Health Science*. 2021;10(2):172-181. doi:10.1016/j.jshs.2020.07.005

Arthrogenic Muscle Inhibition (AMI)

- Condition where the body automatically inhibits the contraction of muscles surrounding a joint after injury or surgery. It is theorized that this is a protective mechanism triggered by pain, swelling, and joint damage, which are interpreted by the nervous system as signals to minimize movement and facilitate healing.
- Can lead to a sustained inability to fully activate the muscle fibers. This reduced neural drive means that despite a patient's effort to contract the muscle, only a portion of the muscle fibers are activated, which leads to underuse atrophy. Over time, the lack of full muscle engagement diminishes the muscle's size and strength, complicating rehabilitation.



Disuse Atrophy

- Following surgery, patients often experience a phase of enforced immobility or reduced mobility to allow healing. This leads to a significant decrease in the regular use of muscle groups, particularly the quadriceps, which are critical for knee extension and weight-bearing activities.
- Muscle fibers adapt to the decreased demand by reducing their size and metabolic activity, a process known as disuse atrophy. Prolonged periods of reduced activity not only decrease muscle size but also alter the muscle's metabolic properties, making it less efficient and more prone to fatigue upon reactivation.



Physical therapists should be aware of BFR as a useful tool in rehabilitation programs, enabling tailored exercises and better outcomes.

Safety and effectiveness of BFR training rely on proper techniques and pressures.



HISTORY OF BFR UTILIZATION

HISTORICAL CONTEXT

01

1970–1990

Dr. Yoshiaki Sato's
Kaatsu resistance
training technique

02

1990–2000

First study published
by Takarada et al.,
which showed its
potential for muscle
growth and strength
with low-intensity
resistance training

03

2000–2010

Original research on
the KAATSU-Master
device used restrictive
pressures based on
upper body systolic
blood pressure (SBP) or
arbitrary pressures
around 200mmHg.
Everyone recieved the
same pressure, no
indiividualization

04

2010–PRESENT

Traditional BFR exercise uses
individualized restrictive
pressures based on total
occlusion pressure measured
via Doppler ultrasound or
predicted equations. Pressures
typically range from 40% to
60% of the total occlusion
pressure, leading to
adaptations ranging from 40%
to 90%.

01

HISTORICAL CONTEXT

01

1970–1990

Dr. Yoshiaki Sato's
Kaatsu resistance
training technique



This is KAATSU. KAATSU Singapore. <https://kaatsu.com.sg/pages/about>

Dr. Yoshiaki Sato employed small rubberized bands as tourniquets on his upper arms and legs while engaging in limited exercises during his injury recovery. He believed that by restricting blood flow, he could effectively stimulate his muscles, thereby not only preventing muscle loss but also accelerating his recovery.

01

HISTORICAL CONTEXT

02

1990–2000

First study published by Takarada et al., which showed its potential for muscle growth and strength with low-intensity resistance training

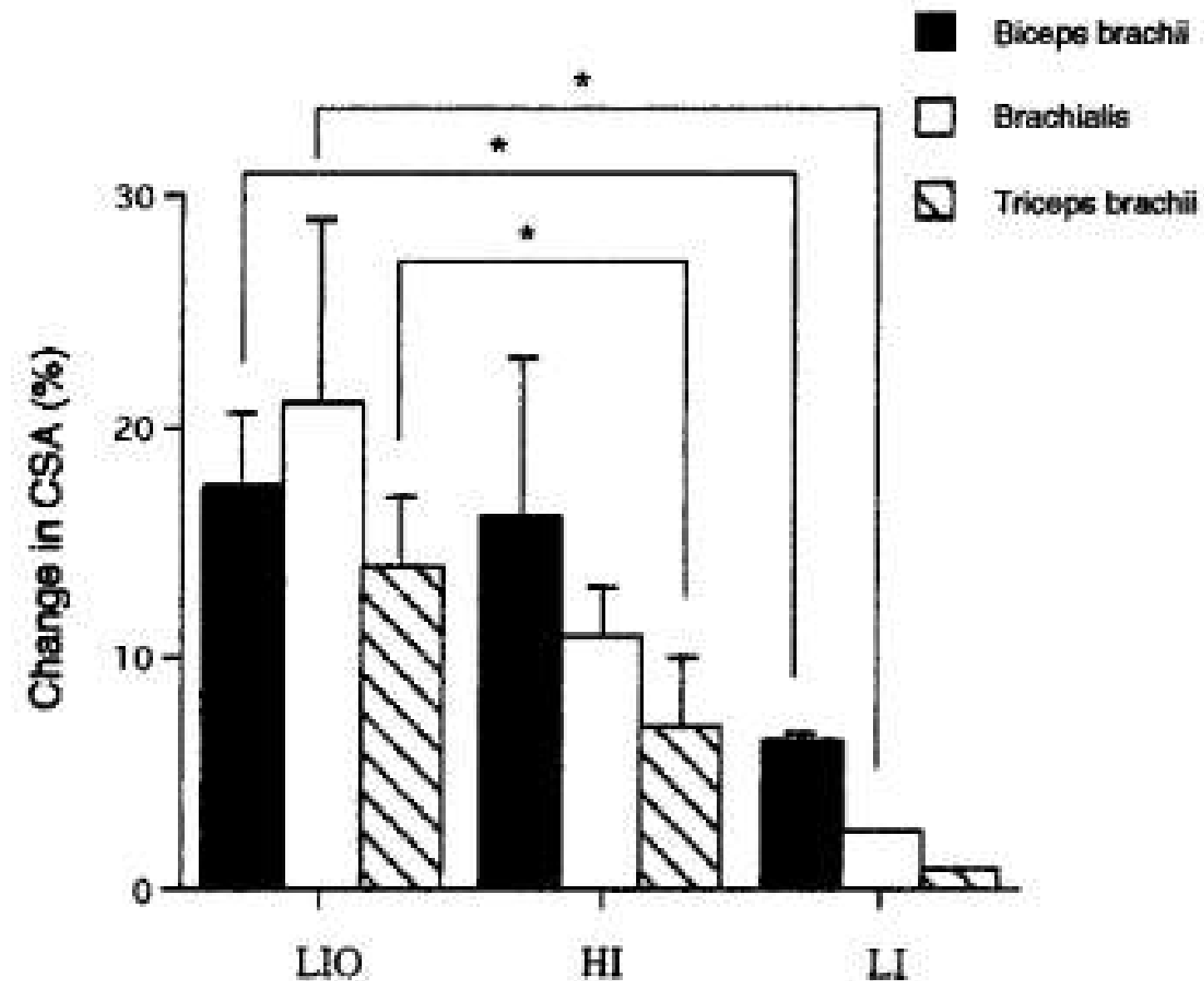


Fig. 6. Percent changes in muscle cross-sectional area (CSA) after exercise training at low intensity with occlusion (LIO), low intensity without occlusion (LI), and high intensity (HI), shown as means $\pm$ SE ($n = 19$). * Statistically significant differences ($P < 0.05$).

Takarada Y, Takazawa H, Sato Y, Takebayashi S, Tanaka Y, Ishii N. Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. *Journal of Applied Physiology*. 2000;88(6):2097–2106. doi:10.1152/jappl.2000.88.6.2097

01

HISTORICAL CONTEXT

03

2000–2010

Original research on the KAATSU-Master device used restrictive pressures based on upper body systolic blood pressure (SBP) or arbitrary pressures around 200mmHg. Everyone recieved the same pressure, no indiividualization



Getting Started with KAATSU BFR & Blood Flow Restriction Training. KAATSU.
<https://kaatsu.com/pages/getting-started-with-kaatsu>

HISTORICAL CONTEXT

04



Physical Therapy Portland - MechanoTherapy. Blood Flow Restriction Training Portland, OR - MechanoTherapy. Physical Therapy Portland - MechanoTherapy. Published December 11, 2019. <https://mechanotherapy.physio/physical-therapy-treatments/blood-flow-restriction-training/>

2010-PRESENT

Traditional BFR exercise uses individualized restrictive pressures based on total occlusion pressure measured via Doppler ultrasound or predicted equations. Pressures typically range from 40% to 80% of the total occlusion pressure, leading to adaptations ranging from 40% to 90%.



MADUP - Moving Forward Physical Therapy PC. Moving Forward Physical Therapy PC. Published February 12, 2021. <https://movingforwardpt.nyc/madup-tmfc/>

BENEFITS OF BFR

BENEFITS

Cross-Sectional Area



- BFR training and high-intensity resistance training at different percentages of 1RM lead to similar increases in muscle cross-sectional area (CSA).

- BFR training at 30–50% 1RM produces comparable muscle hypertrophy and strength gains as high-intensity resistance training at 70–80% 1RM.
- In studies assessing muscle strength using various tests, 90% reported improvements with BFR training compared to control groups of only low-load resistance training.

Strength



MSc ES. What is a Strength-Based approach? (Incl. examples & tools). PositivePsychology.com. Published April 25, 2024. <https://positivepsychology.com/strengths-based-interventions/>

Safford DW, Shah KM, Breidenbach F, McClure PW. Effects of Low-Load Blood Flow Restriction Training on rotator cuff strength and Hypertrophy: Case Series. International Journal of Sports Physical Therapy. 2024;19(6). doi:10.26603/001c.118143

BENEFITS

Torque

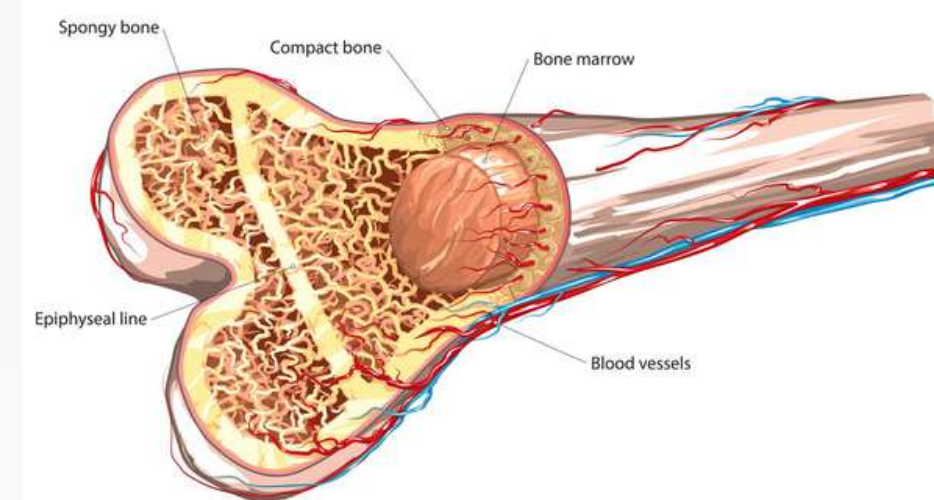


Basic Biomechanics:
Moment arm & torque.
<https://www.aaronswansonpt.com/basic-biomechanics-moment-arm-torque/>

- Studies showed improvements in squat, bench press, and knee extension torque with BFR training compared to control groups of low-load resistance training.

- Serum concentrations of bone formation and bone resorption improved in heavy resistance training and low intensity resistance training with vascular occlusion, suggesting increased bone turnover with a balance favoring bone formation.

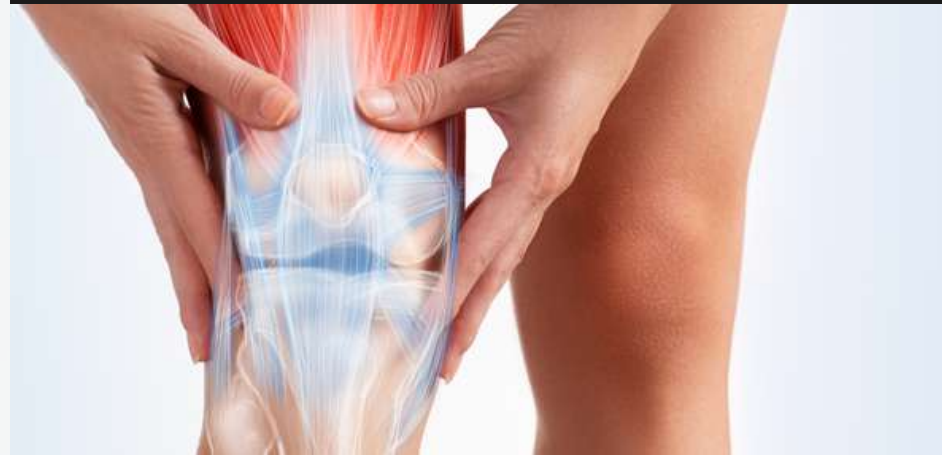
Bone Health



Scheve T. How many bones are in the human body and other skeletal facts. HowStuffWorks. Published February 3, 2023. <https://health.howstuffworks.com/human-body/systems/musculoskeletal/bone.htm>

BENEFITS

Pain



- In patients with PFP, a significantly greater reduction in pain with daily activities in the BFR training group relative to the standardised quadriceps strengthening programme.

- Supplementary sprint-interval training (SIT) with BFR increased pulmonary maximal oxygen uptake ($\dot{V}O_{2\max}$) by 5%–6% with a simultaneous trend toward a greater maximal aerobic power output (3%–4%).

Aerobic Capacity



SAFETY WITH BFR

PRE-SCREENING FOR BFR UTILIZATION



- Consider the following questions prior to BFR:
 - a. Is my patient like the participants in the studies with BFR?
 - b. Does BFR have a clinically relevant benefit (e.g., improved function or hypertrophy) that outweighs the potential risks of application?
 - c. Is another treatment or method available that could provide similar results with less risk than BFR?

TABLE 3

Modified IMPROVE risk score.

Patient's Name: _____

Age: _____

Sex: _____

DVT risk assessment	DVT risk score
Previous VTE	3
Known thrombophilia ^a	2
Current lower leg paralysis or paresis ^b	2
Prior cancer ^c	2
ICU/CCU stay	1
Complete immobilization ≥ 1 day ^d	1
Age ≥ 60 years	1

ICU, intensive care unit; CCU, cardiac care unit; VTE, venous thromboembolism. ^aA congenital or acquired condition leading to excess risk of thrombosis (e.g., factor V Leiden, lupus anticoagulant, factor C or factor S deficiency). ^bLeg falls to bed by 5 s, but has some effort against gravity or presence hemiparesis, hemiplegia, paraplegia, and quadriplegia. ^cCancer (excluding non-melanoma skin cancer) present at any time in the last 5 years (cancer must be in remission to meet eligibility criteria). ^dConfined to bed or chair with or without bathroom privileges. Adapted from previous studies ([Spyropoulos et al., 2011](#); [Mahan et al., 2014](#); [Rosenberg et al., 2014](#); [Raskob et al., 2016](#)).

SAFETY CONCERNS

- BFR has been extensively studied and is considered a safe treatment with minimal reported complications
- The most common risks associated with BFR
 - Temporary bruising at the tourniquet site (13% of cases)
 - Transient numbness in the extremity after tourniquet deflation (1.2% of cases)
 - Dull pain or discomfort due to the tourniquet (up to 9% of cases)
- Rare side effects(<1% of cases)
 - Lightheadedness
 - Temporary cold sensation in the extremity
 - Venous thrombus
 - Pulmonary embolism



Anderson KD, Rask DMG, Bates TJ, Nuelle J a V.
Overall Safety and Risks Associated with Blood Flow
Restriction Therapy: A Literature Review. Military
Medicine. 2022;187(9-10):1059-1064.
doi:10.1093/milmed/usac055

SAFETY CONCERNS

- Proper tourniquet safety guidelines, such as using wider cuffs with a variable contoured fit to reduce pressure gradients and employing tourniquet systems with personalized limb occlusion pressure, can significantly minimize the risk of complications
- No increase risk of DVT or vascular injury compared to other forms of exercise
- Clotting factor measurements have demonstrated no increase after BFR, while fibrinolytic factors like TPA antigen have been found to increase after tourniquet use and BFR exercise.
- The FDA mandates the use of listed medical devices for tourniquet-based blood flow occlusion, with the Delfi PTS for BFR being the only FDA-listed BFR system. Achieving the desired occlusion pressure in BFR requires attention to factors such as the patient's systolic blood pressure, limb circumference, density, cuff width, and location. While there is currently no formula to determine individual limb occlusion pressure, using a Doppler system is considered the gold standard.

PRECAUTIONS



Shining or scaly skin
Brittle, dry nails
Extremity hair loss
Capillary filling time
Presence of varicose
veins

INTEGUMENTARY

CIRCULATION



Arterial calcification
Abnormal clotting times
Hypertension
Anti-hypertensive
medication
Atherosclerotic vessels

CARDIOVASCULAR

ISCHEMIA



Sickle Cell Trait

HEMATOLOGICAL

PAIN

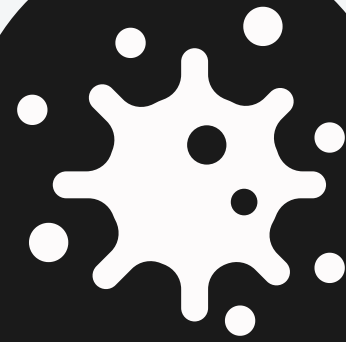
PRECAUTIONS



Tumor

ONCOLOGICAL

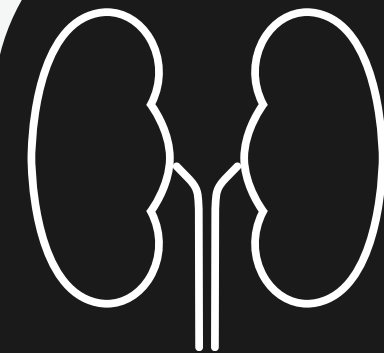
HEMORRHAGE



General infection
COVID-19

INFECTIOUS

EXACERBATION

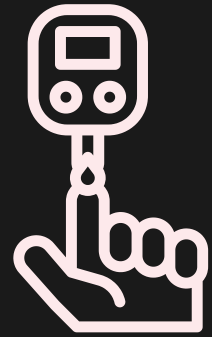


Renal compromise

RENAL

STRAIN

PRECAUTIONS



Diabetes

METABOLIC/ENDOCRINE

CIRCULATION



Pregnancy

REPRODUCTIVE

CLOTTING



CONTRAINDICATIONS



Extremity infection
Skin grafts

INTEGUMENTARY

EXACERBATION



Venous thromboembolism
Impaired circulation or
peripheral vascular
compromise
Increased intracranial pressure
Severe hypertension
Vascular grafting
Factor V Leiden

CARDIOVASCULAR

CIRCULATION



Sickle cell Anemia

Medications and
supplements known to
increase clotting risk

HEMATOLOGICAL

PAIN

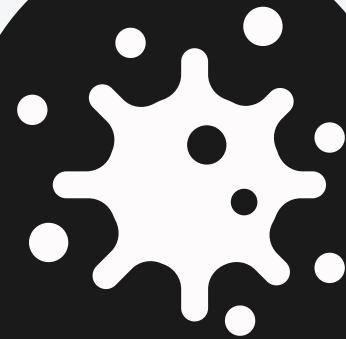
CONTRAINDICATIONS



Active Cancer
Lympechtomy

ONCOLOGICAL

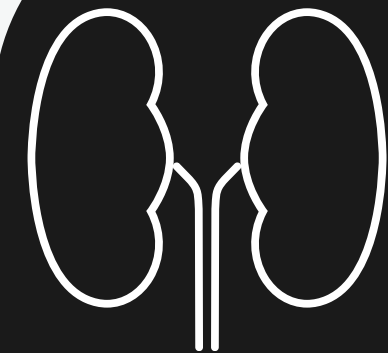
**METASTISIS
FLOW**



Local Active
Infection

INFECTIOUS

EXACERBATION

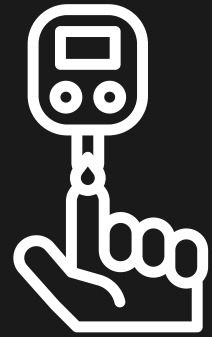


Acidosis

RENAL

COMPROMISED

CONTRAINDICATIONS



Diabetes

METABOLIC/ENDOCRINE

CIRCULATION

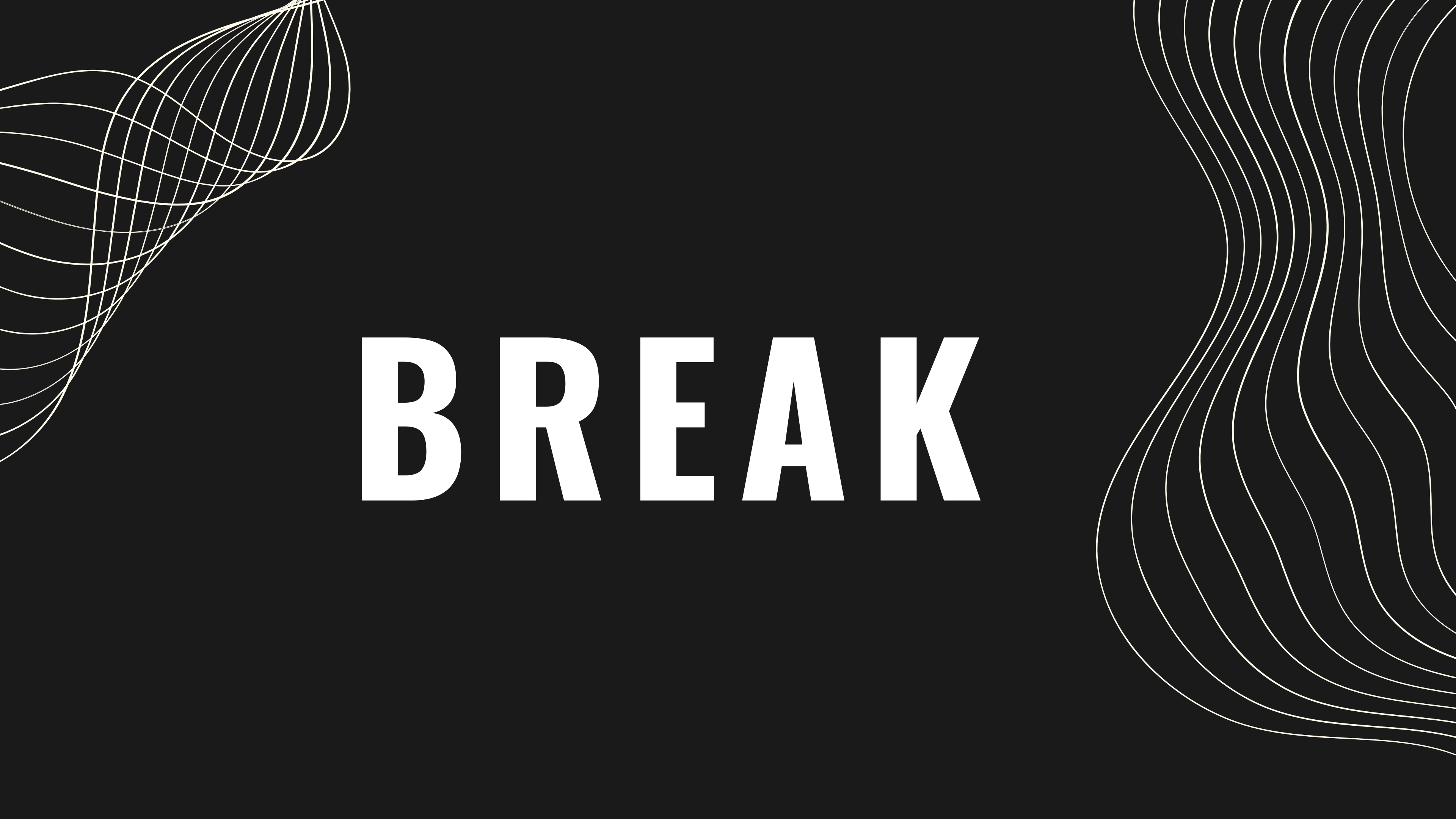


Extremities with dialysis access
Previous revascularization
Open fracture
Open soft tissue injuries
Recent hand reconstructions
Severe crushing injuries
Recent Elbow surgery

MUSCULOSKELETAL

**CIRCULATION
PAIN**





BREAK



PHYSIOLOGICAL MECHANISMS BEHIND BFR

1. Mechanical Tension

Mechanism:

- **Muscle Loading with BFR:** During BFR exercise, external cuffs or wraps are applied to partially restrict arterial blood flow and fully restrict venous outflow in the working muscles.
- **Enhanced Mechanical Tension:** Despite using lower loads (intensity of exercise), BFR increases the mechanical tension on muscle fibers during contraction.
- **Activation of Muscle Fibers:** The combination of muscle contraction and external pressure leads to enhanced activation of both slow-twitch and fast-twitch muscle fibers.
- **Mechanotransduction:** Mechanical tension during BFR exercise stimulates mechanotransduction pathways within muscle cells.
 - **Mechanotransduction Pathways:** These pathways convert mechanical signals (tension and stretch) into biochemical signals that regulate cellular responses.
 - **Activation of Signaling Pathways:** Mechanotransduction pathways include the activation of mammalian target of rapamycin (mTOR) pathway and mitogen-activated protein kinase (MAPK) pathways, which are critical for protein synthesis, muscle growth, and adaptation.
 - **Reactive Oxygen Species (ROS) Production:** Mechanical tension also contributes to the production of ROS, which further enhance signaling cascades involved in muscle hypertrophy.

Role in Muscle Hypertrophy:

- **Recruitment of Muscle Fibers:** BFR allows for recruitment of both slow-twitch and fast-twitch muscle fibers at lower exercise intensities compared to traditional high-load resistance training.
- **Fiber Adaptation:** The mechanical tension applied during BFR exercise induces adaptive responses in muscle fibers, promoting growth, repair, and remodeling.
- **Synergistic Effects with Metabolic Stress:** Mechanical tension acts synergistically with metabolic stress (e.g., hypoxia, metabolite accumulation) to maximize muscle hypertrophy and strength gains.
- **Adaptations in Muscle Architecture:** Over time, consistent application of BFR can lead to changes in muscle architecture, including increases in muscle fiber cross-sectional area and overall muscle mass.

2. Cellular Swelling

Mechanism:

- **Pressure Gradient Creation:** During BFR exercise, the partial restriction of arterial inflow and complete restriction of venous outflow lead to the accumulation of metabolites within the muscles, including lactate, hydrogen ions, and phosphate.
- **Fluid Shift:** Metabolite accumulation creates a gradient that causes fluid to shift from the plasma into the intracellular space of muscle fibers.
- **Cellular Swelling:** This fluid shift results in cellular swelling, where muscle cells expand due to increased fluid volume within the intracellular space.

Effects:

- **Activation of Intracellular Pathways:** Cellular swelling activates mechanosensitive ion channels, particularly stretch-activated channels (SACs), within muscle cells.
- **Signaling Pathways:** Activation of the volume sensor triggers intracellular signaling pathways, including the mammalian target of rapamycin (mTOR) pathway and mitogen-activated protein kinase (MAPK) pathways.
 - **mTOR Pathway:** Activation of mTOR pathway enhances protein synthesis and reduces protein breakdown, promoting muscle hypertrophy and adaptation.
 - **MAPK Pathways:** MAPK pathways are involved in cellular responses to mechanical stress and growth signals, contributing to muscle fiber growth and adaptation.

Contribution to Muscle Hypertrophy:

- **Protein Synthesis:** Cellular swelling-induced activation of mTOR and MAPK pathways stimulates protein synthesis, leading to increased muscle fiber cross-sectional area and hypertrophy.
- **Proteolysis Inhibition:** The activation of these pathways also inhibits proteolysis, the breakdown of muscle proteins, further supporting muscle growth and maintenance.
- **Integration with Metabolic Stress:** Cellular swelling acts synergistically with metabolic stress (e.g., hypoxia, ROS production) and mechanical tension to optimize muscle adaptation during BFR exercise.

3. Metabolic Stress and Hypoxia

Mechanism:

- **Arterial and Venous Occlusion:** During BFR exercise, there is partial restriction of arterial blood flow and complete restriction of venous outflow within the muscles undergoing contraction.
- **Hypoxic Environment:** This partial occlusion leads to a reduction in oxygen delivery to the muscles, creating a localized hypoxic (low oxygen) environment despite increased blood flow compared to resting conditions.
- **Metabolite Accumulation:** The restriction of venous outflow causes metabolites (such as lactate, hydrogen ions, and others) to accumulate in the muscles.

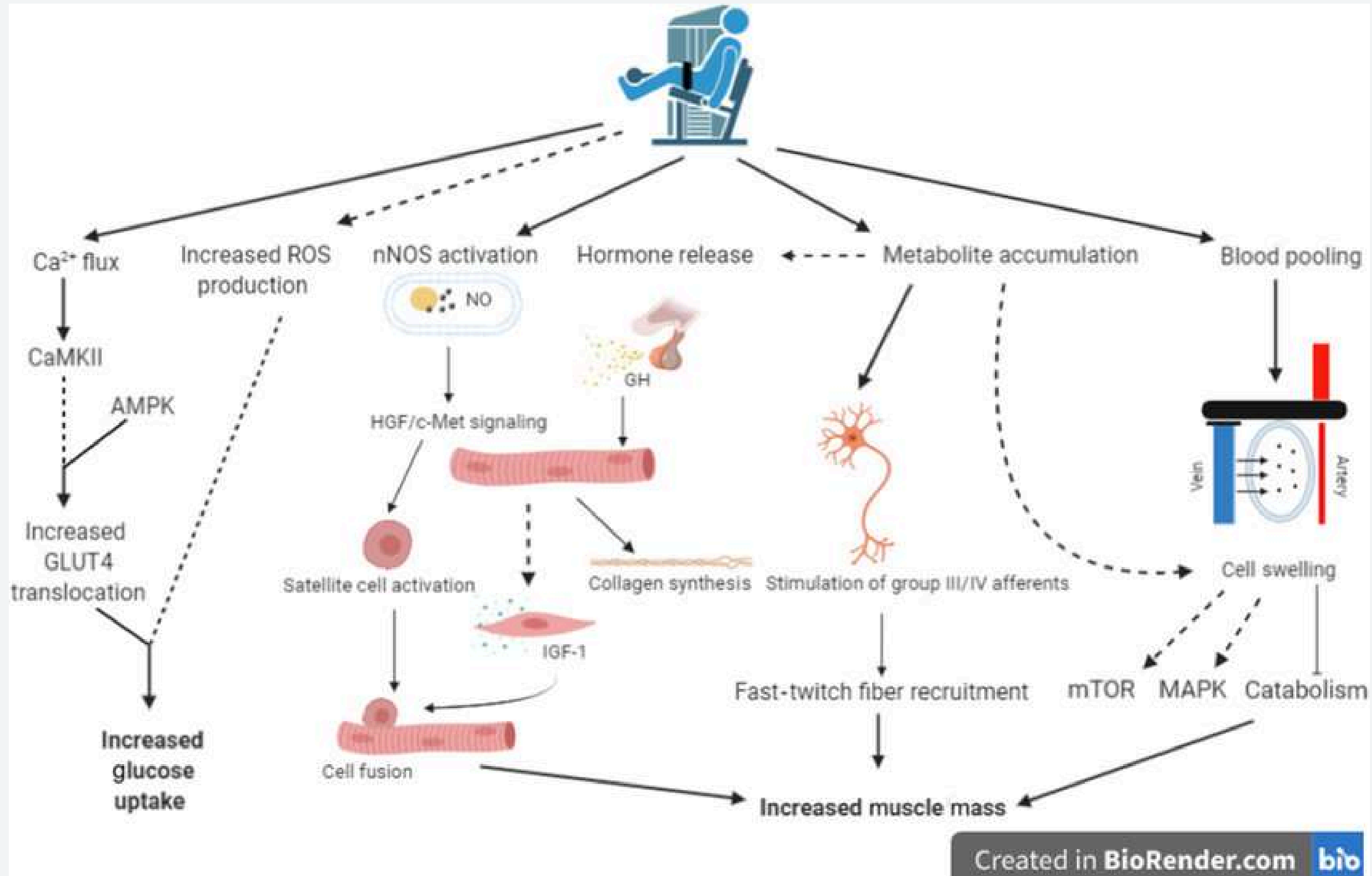
Effects:

- **Stimulation of Muscle Protein Synthesis:** The hypoxic environment and metabolite accumulation stimulate pathways involved in muscle protein synthesis. This includes activation of mechanistic target of rapamycin (mTOR) and other signaling pathways crucial for muscle growth and repair.
- **Gene Regulation of Muscle Satellite Cells:** Hypoxia and metabolite accumulation alter gene expression related to muscle satellite cells, which are important for muscle regeneration and growth.
- **Muscle Fiber Recruitment:** The combination of hypoxia and metabolite accumulation can recruit a broader spectrum of muscle fibers, including both slow-twitch and fast-twitch fibers, compared to traditional exercise without BFR.
- **Improvement in Muscular Endurance:** The adaptive responses to hypoxia and metabolite accumulation contribute to enhanced muscular endurance over time.

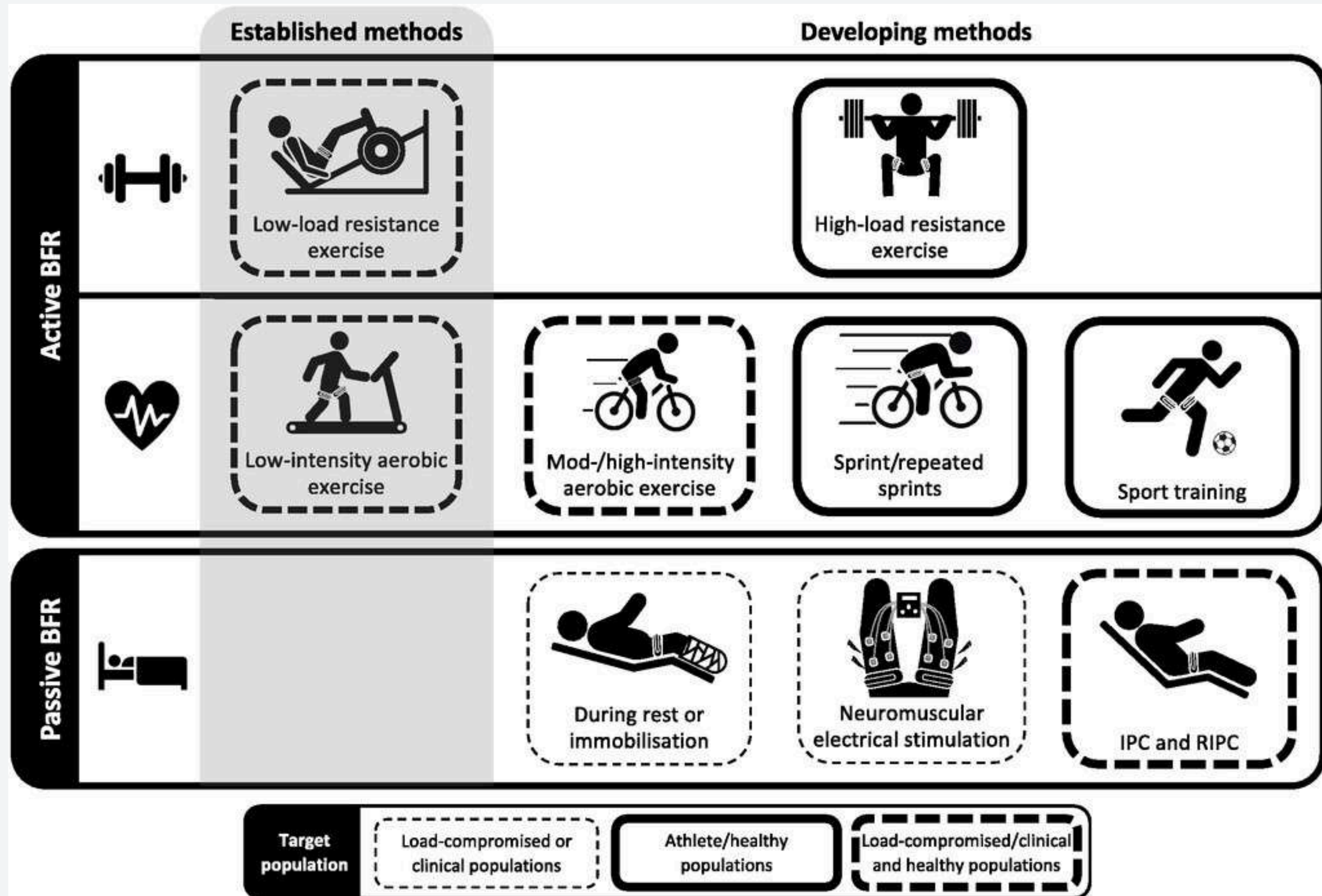
Factors:

- **Acidic Environment (pH Decrease):** The accumulation of hydrogen ions (resulting in increased acidity) contributes to the acidic environment within the muscle, which is known to stimulate muscle adaptation.
- **Endocrine Responses:** The hypoxic environment and metabolic stress also trigger the release of hormones such as growth hormone (GH) and insulin-like growth factor-1 (IGF-1), which are associated with muscle hypertrophy and adaptation.

PHYSIOLOGICAL MECHANISMS



BFR RESEARCH DEEP DIVE





Differences between low-load blood flow restriction training and traditional high-load training



Low-load blood BFR training and traditional high-load training are two different approaches to resistance training that can elicit similar physiological responses and adaptations in the body.

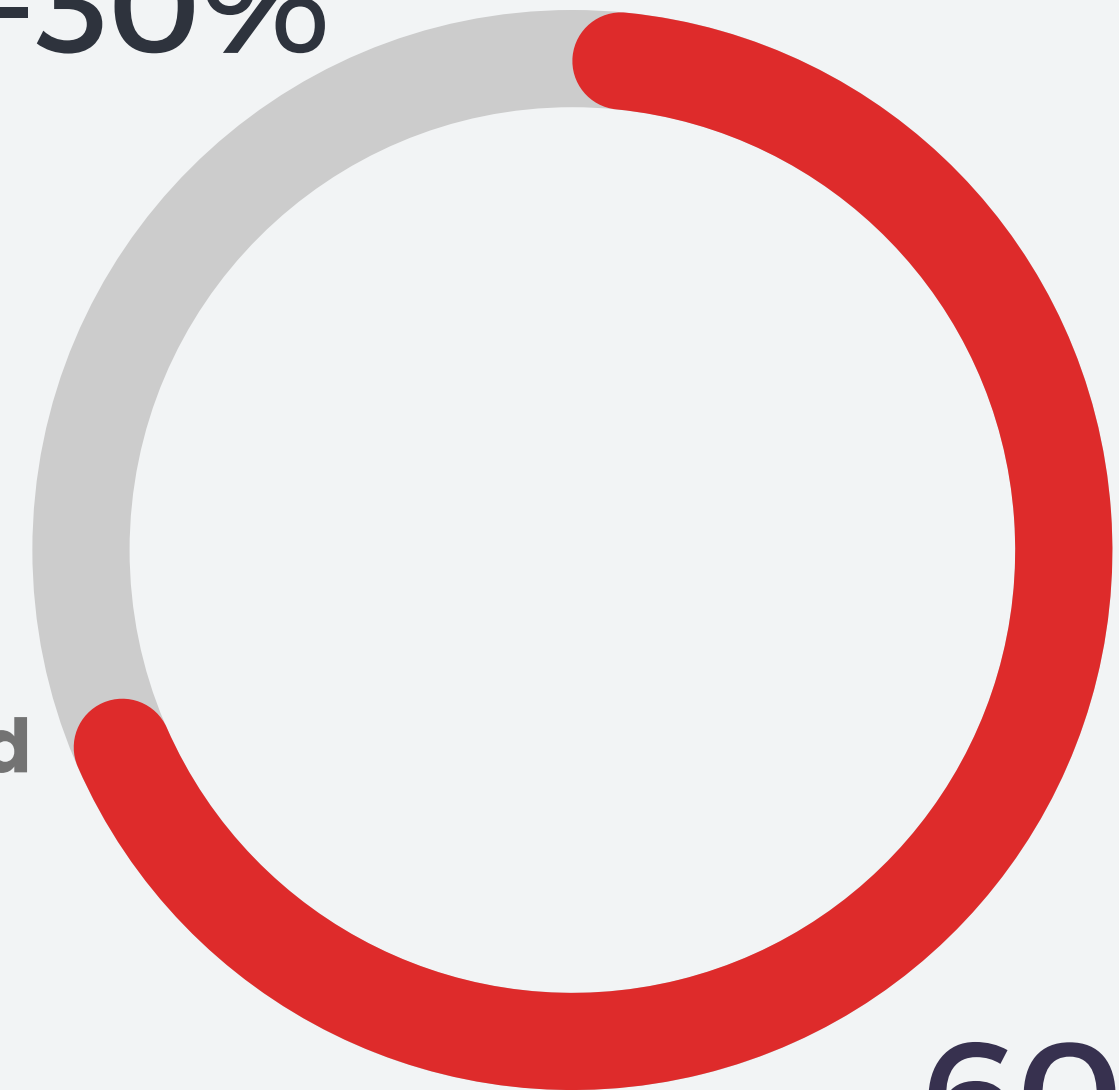


04

Low Load vs Heavy Load

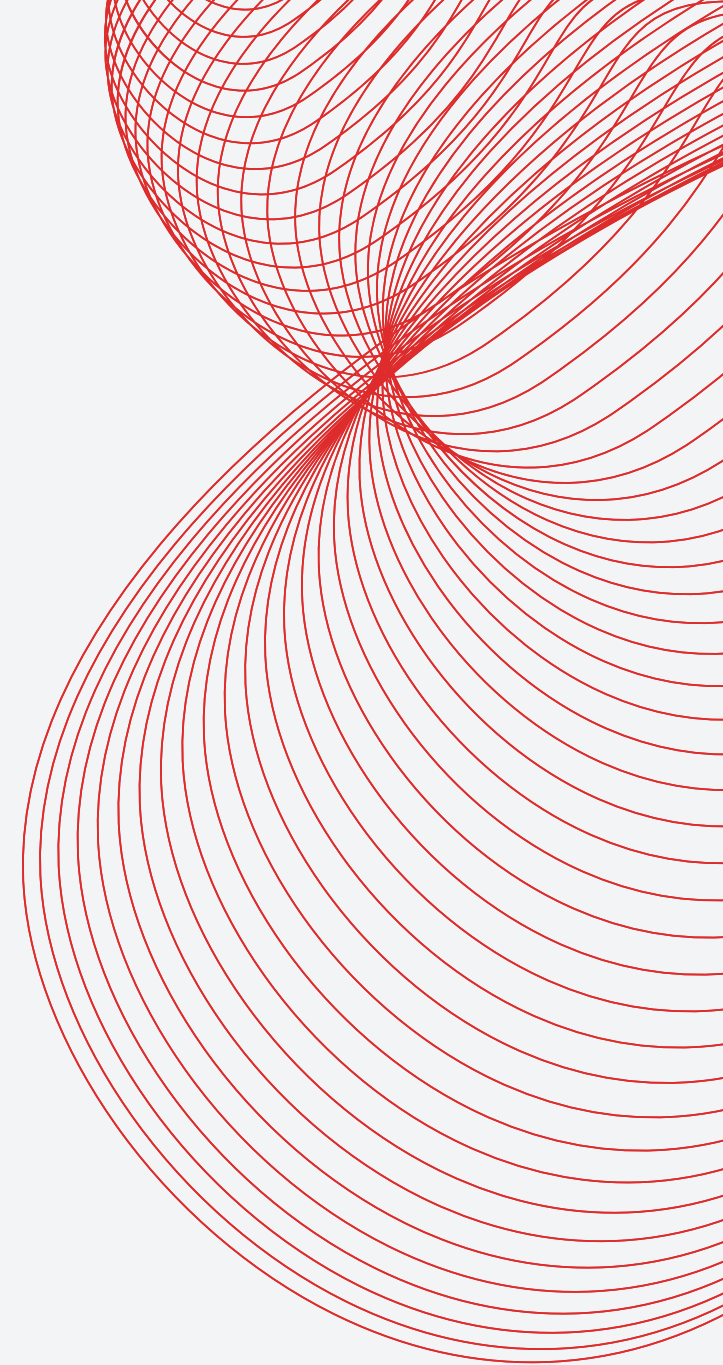
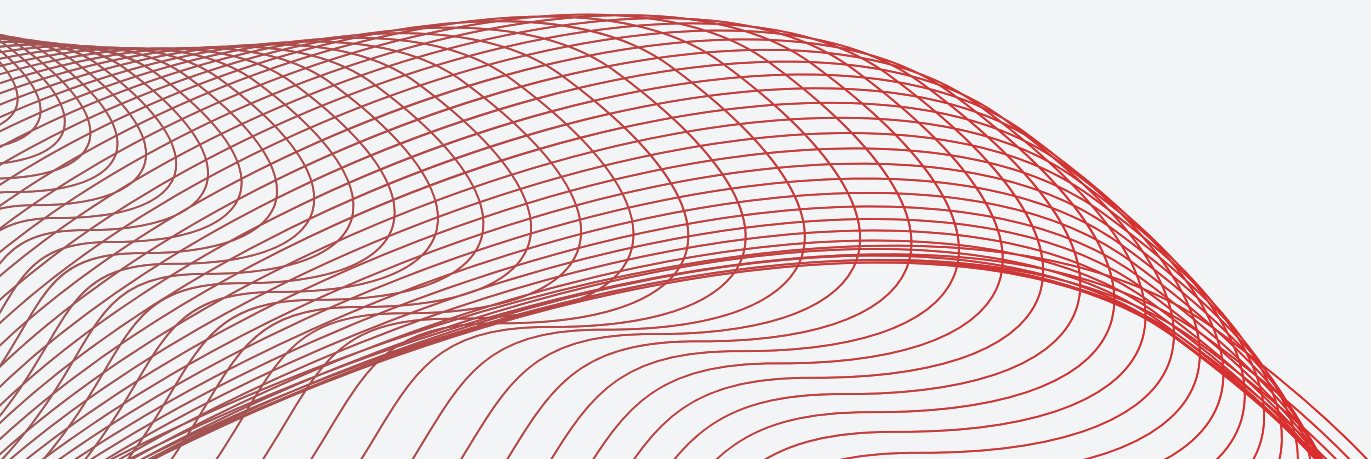
Low-load BFR training involves using relatively light weights (typically 20–30% of 1RM) and restricting blood flow whereas standard resistance training aims to be greater than 60% of 1RM to elicit changes in muscular hypertrophy and strength.

20-30%

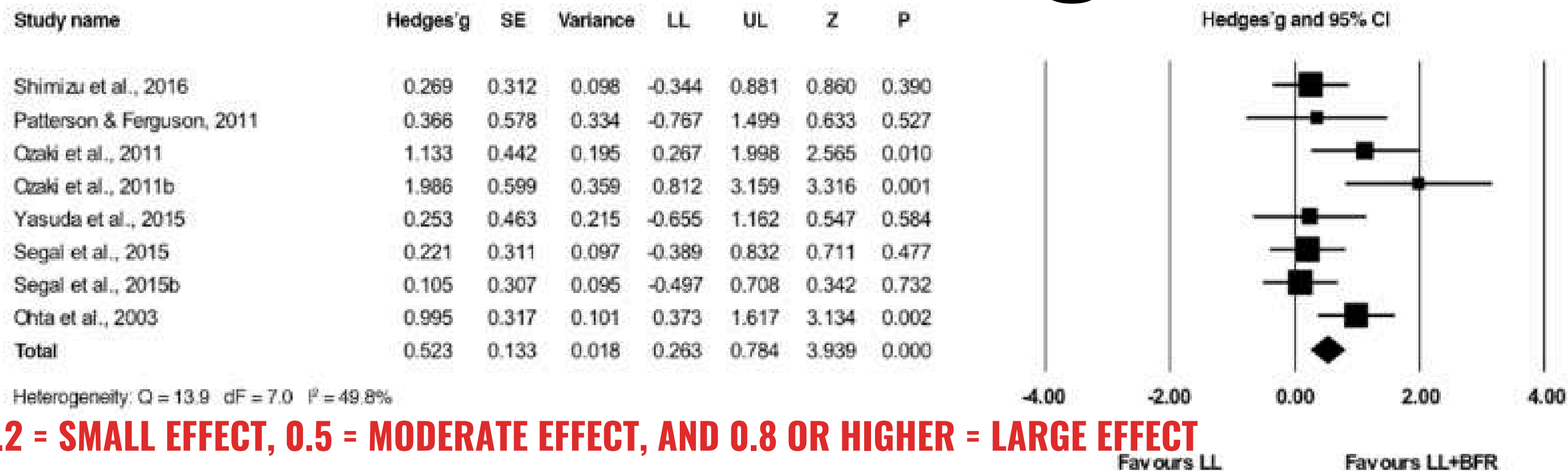


60%+

MUSCULAR STRENGTH

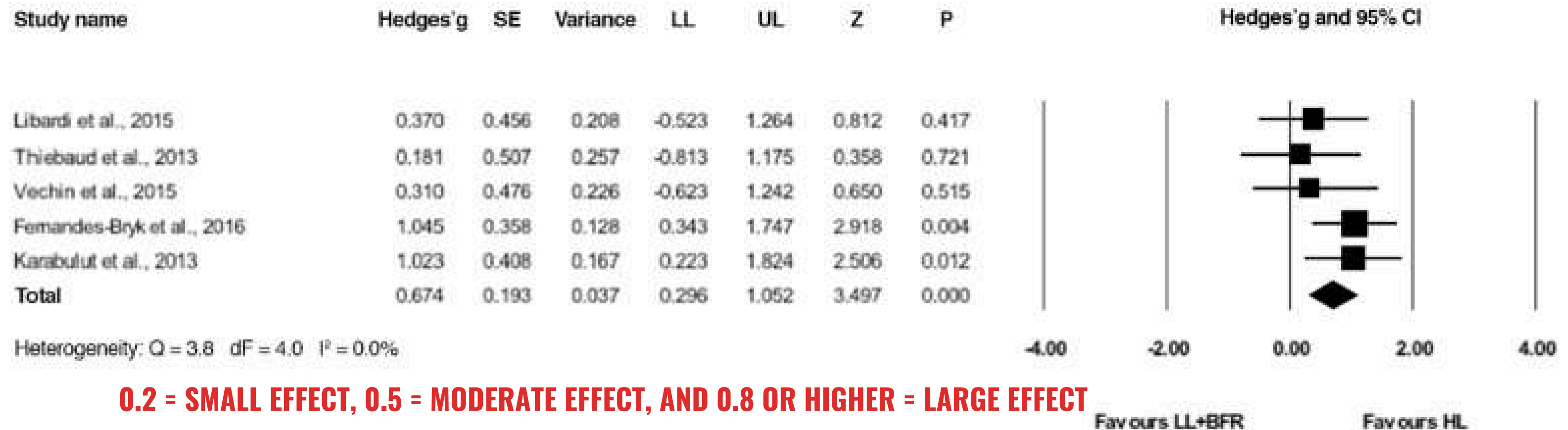


Low Load vs Low Load + BFR on Muscular Strength Gains



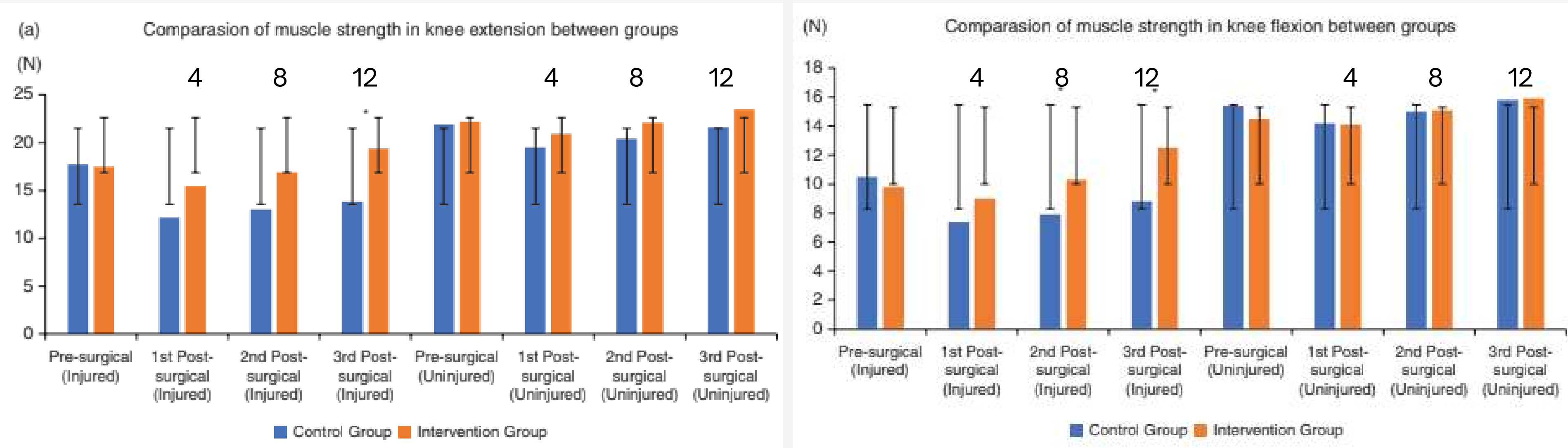
FOREST PLOT ILLUSTRATING THE COMPARISON OF LOW-LOAD TRAINING WITH BLOOD FLOW RESTRICTION (BFR) TO LOW-LOAD TRAINING ALONE. SQUARES INDICATE INDIVIDUAL STUDY HEDGES' G AND THE LINES REPRESENT 95% CIs. THE SIZE OF THE SQUARE CORRESPONDS TO THE WEIGHT OF THE STUDY. THE DIAMOND REPRESENTS THE OVERALL HEDGES' G, WITH ITS WIDTH REPRESENTING THE 95% CIs. LL AND UL REPRESENT THE LOWER AND UPPER LIMIT OF 95% CIs, RESPECTIVELY. DF, DEGREES OF FREEDOM.

Low Load + BFR vs High Load on Muscular Strength Gains



FOREST PLOT ILLUSTRATING THE COMPARISON OF LOW-LOAD TRAINING WITH BFR, BLOOD FLOW RESTRICTION (BFR) TO HEAVY-LOAD TRAINING. SQUARES INDICATE INDIVIDUAL STUDY HEDGES' G AND THE LINES REPRESENT 95% CIs. THE SIZE OF THE SQUARE CORRESPONDS TO THE WEIGHT OF THE STUDY. THE DIAMOND REPRESENTS THE OVERALL HEDGES' G, WITH ITS WIDTH REPRESENTING THE 95% CIs. LL AND UL REPRESENT THE LOWER AND UPPER LIMIT OF 95% CIs, RESPECTIVELY. DF, DEGREES OF FREEDOM.

Low Load vs Low Load + BFR on Muscular Strength Gains



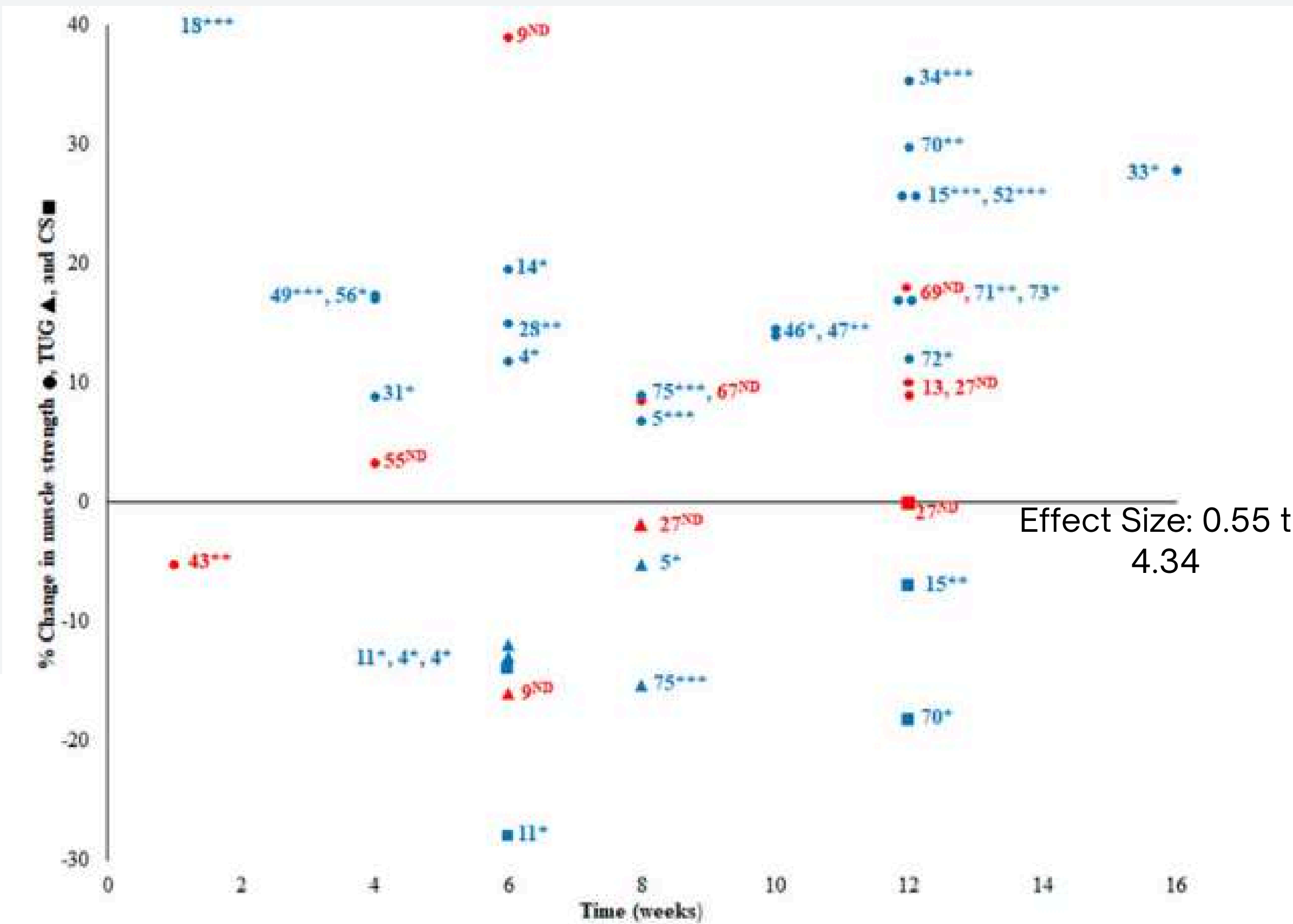
S/P ACL RUPTURE, LEG PRESS AND SEATED LEG CURL FOR 30-15-15-15 REPS COMPARED TO 70% 1RM 3 X 10 REPS, 2 X WEEK FOR 12 WEEKS

$1RM = \frac{\text{submaximal load}}{1 - (0.02 \times \text{number of repetitions})}$

04

Does Blood Flow Restriction Therapy in Patients Older Than Age 50 Result in Muscle Hypertrophy, Increased Strength, or Greater Physical Function? A Systematic Review

Fig. 3 Twenty-five studies reported changes in muscle strength ●, four reported changes in chair-stand performance ■, and five reported changes in timed-up-and-go performance ▲. Each study is plotted according to the magnitude of change in response to BFR therapy and the duration of the intervention. Data in blue represent studies with findings that report substantial positive effects of BFR on skeletal muscle strength or performance, while data in red represent no-difference (ND) or unsupportive findings of the second aim of our study. For the chair-stand and timed-up-and-go tasks, negative values indicate a reduction in time to completion and an improvement in performance. *p < 0.05; **p < 0.01, ***p < 0.001; TUG = timed-up and-go; CS= chair-stand.



Summary of Benefits on Muscular Strength Gains

Load Low < Low Load + BFR < High Load

69% of the population benefits	76% of the population benefits
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MUSCLE

CROSS-SECTIONAL AREA & THICKNESS

The Effects of Blood Flow Restriction on Upper-Body Musculature Located Distal and Proximal to Applied Pressure

Table 2 All study protocols included in qualitative analysis

Study	<i>n</i>	Sessions	%1RM	Cuff width (cm)	Highest cuff pressure (mmHg)	Final protocol	Method of muscle size measurement
Burgomaster et al. [31]	8	16	50	12	100	5 sets of 10, 6th set to failure	
Credeur et al. [32]	12	12	60	NA	80	300 contractions	Circumference
Counts et al. [33]	7	22	30	5	40/90 % arterial occlusion	1 set of 30 followed by 3 sets of 15	Ultrasound
Farup et al. [34]	10	18	40	8	100	4 sets to failure	MRI
Hunt et al. [35]	9	12	40	13	80	3 sets to failure	Water displacement
Luebbbers et al. [36]	15	14	20	7.6	NA	1 set of 30 followed by 3 sets of 20	Circumference
Lowery et al. [37]	21	16	30	7.6	NA	3 sets of 30	Ultrasound
Moore et al. [38]	8	24	50	7	100	2 sets of 10, 3rd set to failure	
Ozaki et al. [39]	10	18	30	3	160	1 set of 30 followed by 3 sets of 15	MRI
Sakamaki et al. [40]	13	6	30	3	100	1 set of 30 followed by 3 sets of 15	MRI
Takarada et al. [41]	11	32	50	2.5	100	3 sets to failure	MRI
Thiebaud et al. [42]	6	24	10–30	3.3	120	1 set of 30 followed by 3 sets of 15	Ultrasound
Weatherholt et al. [43]	20	24	20	3	180	3 sets of 15	pQCT scan
Yamanaka et al. [44]	16	12	20	5	NA	1 set of 30 followed by 3 sets of 20	Circumference
Yasuda et al. [45]	10	18	30	NA	160	1 set of 30 followed by 3 sets of 15	MRI
Yasuda et al. [46]	9	24	30	3	270	1 set of 30 followed by 3 sets of 15	MRI
Yasuda et al. [47]	5	24	30	NA	160	1 set of 30 followed by 3 sets of 15	Ultrasound
Yasuda et al. [48]	10	18	30	NA	160	1 set of 30 followed by 3 sets of 15	MRI
Yasuda et al. [49]	10	18	30	3	160	1 set of 30 followed by 3 sets of 15	MRI

MRI magnetic resonance imaging, NA data not reported, pQCT peripheral quantitative computed tomography, RM repetition maximum

Table 3 Muscle adaptations occurring in all included studies

References	Muscle size	% Δ per session	% Total Δ	Effect size	Muscle strength	% Δ per session	% Total Δ	Effect size
Burgomaster et al. [31]	NA				Isokinetic 60°/sec	0.69	11.0	1.48
	NA				Biceps 1RM	1.40	22.5	4.13
Credeur et al. [32]	NA				Handgrip MVC	1.34	16.1	6.7
Counts et al. [33]	Biceps upper MTH	0.56	12.5	0.56	Biceps 1RM	0.80	17.9	0.37
	Biceps 10cm MTH	0.45	10	0.45	Isokinetic 60°/sec	0.51	11.2	0.23
Farup et al. [34]	Biceps CSA	0.64	11.5	0.54	Biceps 3RM	1.08	19.4	0.60
					Biceps MVC	−0.29	−5.2 ^a	−0.14
Hunt et al. [35]	Forearm volume	0.14	1.7 ^a	0.16	Handgrip 1RM	1.00	11.9	0.59
Luebbbers et al. [36]	NA				Bench press 1RM	0.16	2.3 ^a	0.20
Lowery et al. [37]	Biceps MTH	0.69	11.1	3.90	NA			
Moore et al. [38]	NA				Elbow flex 1RM	0.90	21.7	6.63
					Elbow flex MVC	0.32	7.7	0.95
Ozaki et al. [39]	Chest CSA	0.38	6.8	1.00	Bench press 1RM	0.49	8.7	1.54
Sakamaki et al. [40]	Biceps volume	0.88	5.3	0.39	Biceps MVC	1.1	6.6	0.33
Takarada et al. [41]	Biceps brachii CSA	0.63	20.3	NA	Biceps isokinetic 60°/sec	0.58	18.4	NA
	Biceps brachialis CSA	0.56	17.8		Biceps MVC	0.52	16.5	
Thiebaud et al. [42]	Biceps MTH	0.13	3.0 ^a	0.21	Bench press 1RM	0.43	10.4	0.44
	Triceps MTH	0.27	6.5 ^a	0.32	Back row 1RM	0.29	7.0	0.31
	Deltoid MTH	0.16	3.8 ^a	0.22	Shoulder press 1RM	0.22	5.3	0.49
	Chest MTH	0.73	17.4	1.02				
Weatherholt et al. [43]	Arm CSA	0.15	3.6	0.47	Biceps 1RM	0.56	13.5	1.35
					Triceps 1RM	0.64	15.4	1.57
Yamanaka et al. [44]	NA				Bench press 1RM	0.60	7.2	0.55
Yasuda et al. [45]	Triceps CSA	0.26	4.7	0.24	Bench press 1RM	0.48	8.7	0.46
	Chest CSA	0.47	8.5	0.47				
Yasuda et al. [46]	Biceps CSA	0.73	17.7	0.62	Elbow flex MVC	0.35	8.5	0.22
	Triceps CSA	0.68	16.3	0.50	Elbow ext MVC	0.68	16.3	0.50
Yasuda et al. [47]	Chest MTH	0.75	17.9	0.22	Bench press 1RM	0.26	6.2	0.63
	Triceps MTH	0.31	7.5	0.07				
Yasuda et al. [48]	Chest CSA	0.47	8.4	0.46	Bench press 1RM	0.51	9.1	0.49
	Triceps CSA	0.26	4.6	0.23	Tricep MVC	−0.01	−0.2 ^a	−0.01
Yasuda et al. [49]	Biceps volume	0.69	12.3	1.64	Biceps MVC	0.44	8.0	0.79
	Biceps mid-upper CSA	0.56	10.1	1.2				
	Biceps 10 cm CSA	0.64	11.6	1.42				

CSA cross-sectional area, ext extension, flex flexion, MTH muscle thickness, MVC maximal voluntary isometric contraction, NA data not measured or, in the case of effect sizes, no standard deviations were reported, RM repetition maximum

^a Insignificant change

Dankel SJ, Jessee MB, Abe T, Loenneke JP. The effects of blood flow restriction on Upper-Body musculature located distal and proximal to applied pressure. Sports Medicine. 2015;46(1):23-33. doi:10.1007/s40279-015-0407-7

Low Load vs Low Load + BFR on Muscle Cross-Sectional Area

PARTICIPANTS: 23 SEDENTARY MEN AND WOMEN, AGED 57 TO 76 YEARS

PROTOCOL: BOTH GROUPS PERFORMED 20-MINUTE TREADMILL WALKING AT AN EXERCISE INTENSITY OF 45% OF HEART RATE RESERVE (HRR), 4 DAYS PER WEEK FOR 10 WEEKS

INTERVENTION: BFR-W GROUP WORE PRESSURE CUFFS ON BOTH LEGS DURING TRAINING SESSIONS, WITH CUFF PRESSURES GRADUALLY INCREASED FROM 140 MM HG TO APPROXIMATELY 200 MM HG OVER THE TRAINING PERIOD

RESULTS: THE BFR-W GROUP SHOWED SIGNIFICANT IMPROVEMENTS IN MAXIMUM ISOKINETIC KNEE EXTENSION AND FLEXION TORQUES AND THIGH MUSCLE CSA, WHEREAS THE CON-W GROUP DID NOT.

Table 1. Changes in Anthropometric Variables, Skeletal Muscle Size, and Strength Following 10-Weeks Walk Training With (BFR-W) and Without (CON-W) Blood Flow Reduction^a

	BFR-W			CON-W		
	PRE	POST	%	PRE	POST	%
Anthropometric variables						
Age (yr)	66 (1)			68 (1)		
Standing height (m)	1.56 (0.01)			1.54 (0.02)		
Body mass (kg)	55.9 (1.5)	55.3 (1.4) ^b	-0.9	55.9 (2.8)	55.6 (2.8) ^b	-0.7
BMI (kg/m ²)	23.0 (0.7)	22.8 (0.7) ^c	-0.9	23.5 (1.0)	23.3 (1.0) ^c	-0.7
Thigh muscle CSA and strength						
CSA (cm ²)	104 (5)	107 (5) ^c	3.2 ^d	100 (5)	99 (5)	-0.2
Knee extension (Nm)	110 (5)	120 (6) ^c	8.7	104 (6)	108 (9)	2.7
Knee flexion (Nm)	55 (4)	62 (3) ^c	15.0 ^d	50 (5)	50 (6)	-0.3

Abbreviations: BMI, body mass index; CSA, cross sectional area.

^a Data are mean ± SE.

^b $P < .05$, PRE versus POST.

^c $P < .01$.

^d $P < .01$, BFR-W versus CON-W.

BFR in Addition to High Load/Sprinting on Muscle Cross-Sectional Area

PARTICIPANTS

- 15 MALE TRACK AND FIELD COLLEGE ATHLETES (SPRINTERS AND JUMPERS)
- THEY TRAINED REGULARLY 5 DAYS PER WEEK IN BOTH SPRINTING/JUMPING AND RESISTIVE EXERCISE TRAINING PROGRAMS
- RANDOMLY DIVIDED INTO TWO GROUPS: KAATSU-TRAINING GROUP & CONTROL GROUP

PROTOCOL AND INTERVENTION

- KAATSU-TRAINING GROUP:
 - TRAINED TWICE PER DAY (7:00-8:00 AND 17:00-18:00) FOR 8 CONSECUTIVE DAYS.
 - PERFORMED 3 SETS OF 15 REPETITIONS OF SQUAT AND LEG CURL EXERCISES AT AN INTENSITY OF 20% OF ONE REPETITION MAXIMUM (1-RM).
 - RESTED FOR 30 SECONDS BETWEEN SETS AND EXERCISES.
 - WORE CUFF AROUND PROXIMAL PORTION OF BOTH LEGS DURING EXERCISE SESSIONS
 - PRESSURE STARTED AT 160 MMHG ON DAY 1 AND INCREASED BY 20 MMHG EACH DAY UNTIL REACHING 240 MMHG ON DAY 5
 - THE RESTRICTION WAS MAINTAINED FOR THE ENTIRE EXERCISE SESSION AND RELEASED IMMEDIATELY UPON COMPLETION.
- CONTROL GROUP:
 - DID NOT PERFORM ANY RESISTIVE EXERCISES DURING THE STUDY.
 - BOTH KAATSU AND CONTROL GROUPS CONTINUED THEIR REGULAR SPRINT/JUMP TRAINING DURING THE STUDY PERIOD.

MEASUREMENTS

MUSCLE SIZE MEASUREMENTS

- MUSCLE-BONE CROSS-SECTIONAL AREA (CSA):
 - ESTIMATED USING ANTHROPOMETRY, WHICH INCLUDES MEASUREMENTS OF MID-THIGH GIRTH AND ULTRASOUND-MEASURED ANTERIOR AND POSTERIOR THIGH ADIPOSE TISSUE THICKNESS
- MUSCLE THICKNESS (MTH):
 - MEASURED USING B-MODE ULTRASOUND WITH A 5 MHZ SCANNING HEAD FOR THE ANTERIOR AND POSTERIOR MID-THIGH

BFR in Addition to High Load/Sprinting on Muscle Cross-Sectional Area

Performance Tests

- Maximum Strength Measurements:
 - Evaluated using an isotonic leg press machine for 1-RM before and after the training period.

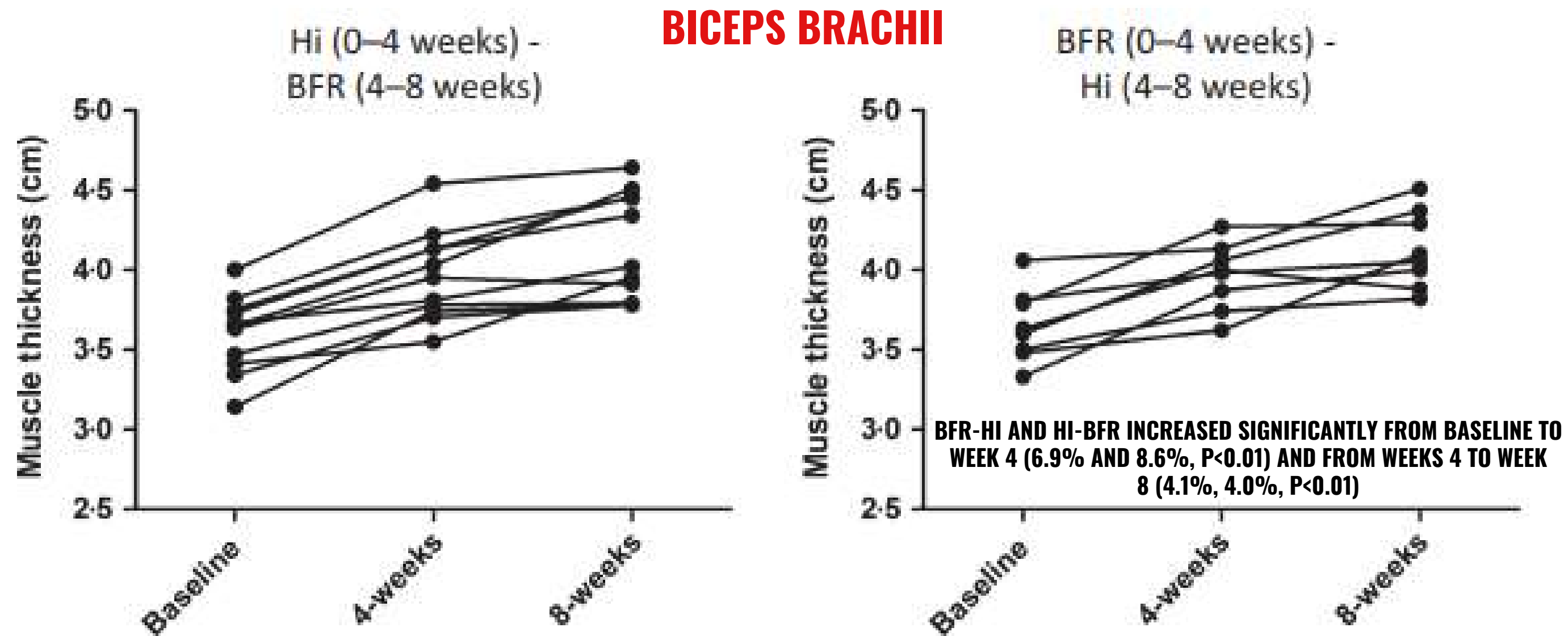
Sprint and Jump Performance Tests:

- Conducted on an outdoor track.
 - Included a 30-m dash (with timing systems) and three different jump tests (standing jump, standing triple jump, and standing 5-step jump). for either group.

Results

- Changes in Skeletal Muscle Size
 - Muscle-Bone CSA:
 - Increased by 4.5% ($p < 0.01$) in the KAATSU-training group.
 - Decreased by 1% ($p > 0.05$) in the control group.
 - Quadriceps and Hamstrings MTH:
 - Increased by 5.9% and 4.5%, respectively ($p < 0.01$) in the KAATSU-training group.
 - No change in the control group.
 - Changes in 1-RM Strength and Sprint/Jump Performance
 - Leg Press Strength:
 - Increased by 9.6% ($p < 0.01$) in the KAATSU-training group.
 - Increased by 4.8% ($p > 0.05$) in the control group.
 - Sprint Performance:
 - Overall 30-m dash time improved ($p < 0.05$) in the KAATSU-training group, particularly in the initial acceleration phase (0-10m, $p < 0.01$).
 - No improvement in jump performance for either group.

High Load and BFR on Muscle Thickness (Ultrasound)



For non-pBFR weeks, subjects performed three sets of curls at one-half the repetitions and twice the load of their pBFR weeks.
During pBFR weeks, subjects performed three sets of thirty repetitions with 30% of their calculated 1-RM.

Low Load vs Low Load + BFR on Muscle Girth

TABLE 2. Thigh Girth (cm) Proximal to Superior Patellar Pole (cm)†					
	Initial Uninvolved	Initial Involved	Final Involved	Change Involved	P
6-cm proximal					
Occlusion	46.50 (43-53.25)	44.50 (42.3-50.5)	47.25 (45.5-53.6)	1.75 (1 to 4.6)	0.0111*
Control	50.00 (44-52)	49.00 (45.5-51)	50.00 (45.5-50.5)	0 (-1 to 0.5)	1
16-cm proximal					
Occlusion	58.00 (51.4-63.3)	54.50 (50.3-61.4)	57.50 (51.6-64)	2.25 (0.75 to 3)	0.0001*
Control	59.50 (53-62)	60.00 (54-61)	60.00 (54-61)	0.50 (0 to 1.5)	0.1453

*Significance set at $P < 0.05$.
†Data shown as median (interquartile ranges).

Both groups followed the same supervised accelerated physical therapy protocol for nonreconstructive knee arthroscopy as per our facility's guidelines consisting of immediate weight bearing, immediate formal physical therapy, and unrestricted range of motion.

NON-RECONSTRUCTIVE KNEE ARTHROSCOPY
2 X WEEK FOR 12 WEEKS
3 EXERCISES IN ADDITION TO STANDARD PROGRAM
30/15/15/15 REPS @ 80% LOP
LEG PRESS, SEATED LEG EXTENSION, STANDING HIP EXTENSION



Does Blood Flow Restriction Therapy in Patients Older Than Age 50 Result in Muscle Hypertrophy, Increased Strength, or Greater Physical Function? A Systematic Review

% Change
in Muscle
Size

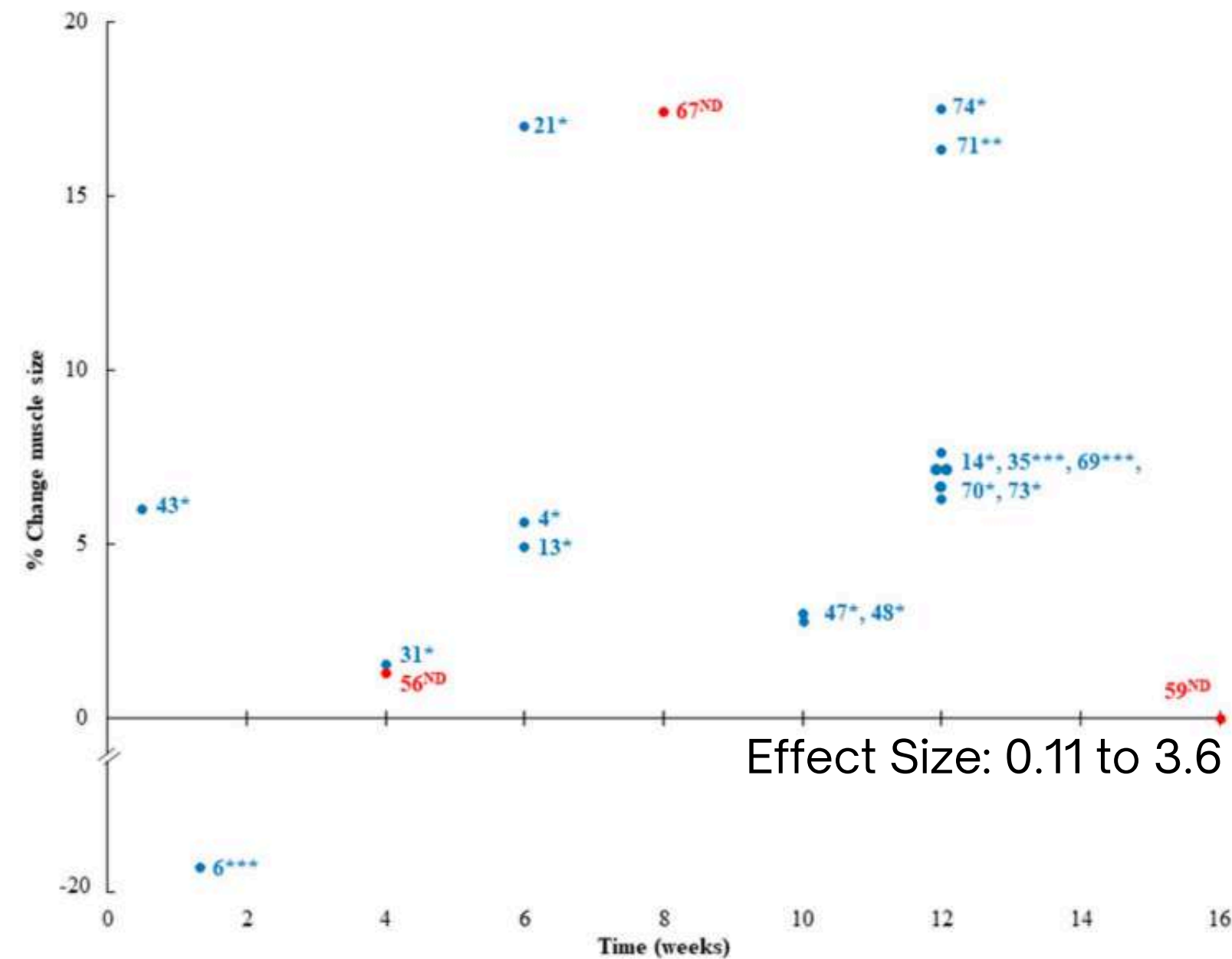


Fig. 2 Twenty studies examining muscle size were separated by the magnitude of the effect of BFR on change in muscle size and the duration of the intervention. Data in blue represent studies with findings that report substantial positive effects of BFR on skeletal muscle size, while data in red represent no-difference (ND) or unsupportive findings of the first aim of our study; * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$.

Aerobic Capacity

Low-intensity cycle exercise training with and without blood flow restriction (BFR) on muscle size and maximum oxygen uptake (VO₂max)

BFR-Training Group:

- Training was conducted 3 days per week for 8 weeks.
- Participants performed cycling exercises on an electrically braked bicycle ergometer at 40% of their VO₂max for 15 minutes per session.
- Blood flow restriction was applied using pressure belts (Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan) on both legs.
- The belt pressure was progressively increased from 160 mmHg on the first day to a maximum of 210 mmHg by the final week.
- Blood flow was restricted for a total of approximately 18 minutes per session, including 3 minutes of preparation and 15 minutes of cycling.

CON-Training Group:

- Participants performed the same cycling exercises at 40% of their VO₂max but for a duration of 45 minutes per session without blood flow restriction.

Low-intensity cycle exercise training with and without blood flow restriction (BFR) on muscle size and maximum oxygen uptake (VO₂max)

Table 1. Changes in anthropometric variables and thigh muscle cross-sectional area and muscle volume. Values are mean(SD).

	BFR-Training Group			CON-Training Group		
	Pre	Post	%Δ	Pre	Post	%Δ
Anthropometric variables						
Height, m	1.72 (.07)			1.71 (.04)		
Weight, kg	61.1 (8.4)	62.0 (9.0)	1.4	61.7 (6.3)	61.4 (6.1)	-.4
BMI, kg·m ⁻²	21.2 (2.5)	21.5 (2.5)	1.4	21.0 (2.4)	20.9 (2.3)	-.4
Thigh girth, cm	49.7 (3.1)	50.5 (3.0) ^a	1.7 ^b	50.0 (3.9)	49.7 (3.6)	-.6
Muscle cross-sectional area, cm²						
Thigh at 50%	142.3 (8.7)	147.1 (9.2) ^c	3.4 ^d	144.0 (17.6)	144.1 (15.0)	.1
Quadriceps at 50%	69.5 (5.4)	72.6 (5.3) ^c	4.6 ^b	70.7 (7.3)	71.0 (6.5)	.6
Muscle volume, cm³						
Thigh	3508 (283)	3641 (320) ^c	3.8 ^b	3696 (447)	3689 (418)	-.1
Quadriceps	1575 (153)	1655 (132) ^c	5.1 ^b	1730 (190)	1731 (180)	-.1

BMI, body mass index. Significant differences between BFR-training and CON-training: ^a $p < 0.05$, ^b $p < 0.01$. Significant differences between pre- and posttraining: ^c $p < 0.05$, ^d $p < 0.01$.

Table 2. Changes in isometric knee extension and flexion strength and specific tension. Values are mean (SD).

	BFR-Training Group			CON-Training Group		
	Pre	Post	%Δ	Pre	Post	%Δ
Isometric muscle strength, Nm						
Knee extension	194 (80)	209 (73)	7.7 ^a	216 (47)	219 (45)	1.4
Knee flexion	77 (26)	79 (27)	3.3	87 (23)	84 (16)	-3.4
Specific tension, Nm/cm²						
Knee extension/qCSA	2.79 (1.08)	2.86 (.90)	2.5	3.05 (0.51)	3.09 (0.54)	1.3

qCSA, quadriceps muscle cross-sectional area (at 50%). Significant differences between BFR-training and CON-training: ^a $p < 0.10$.

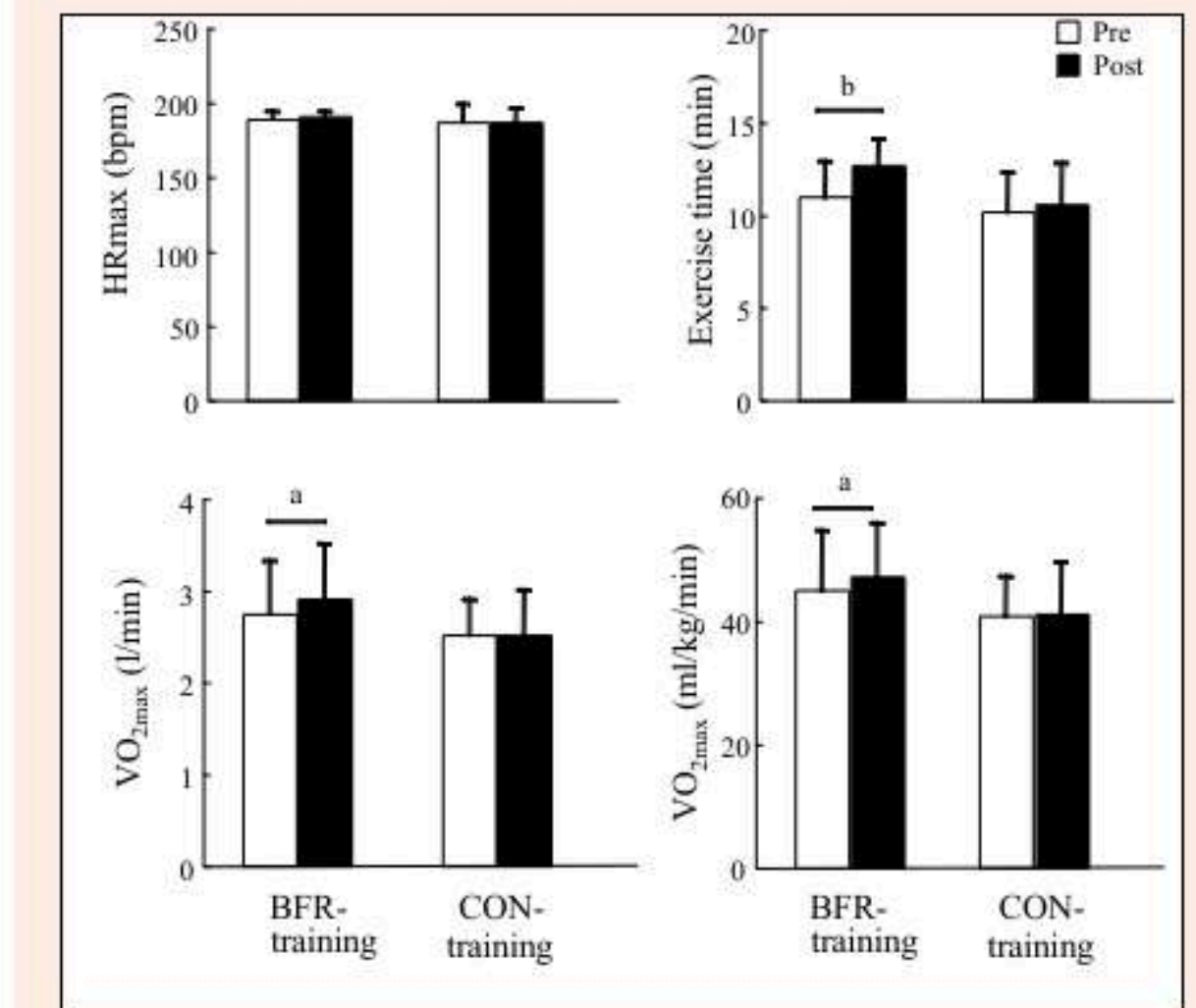
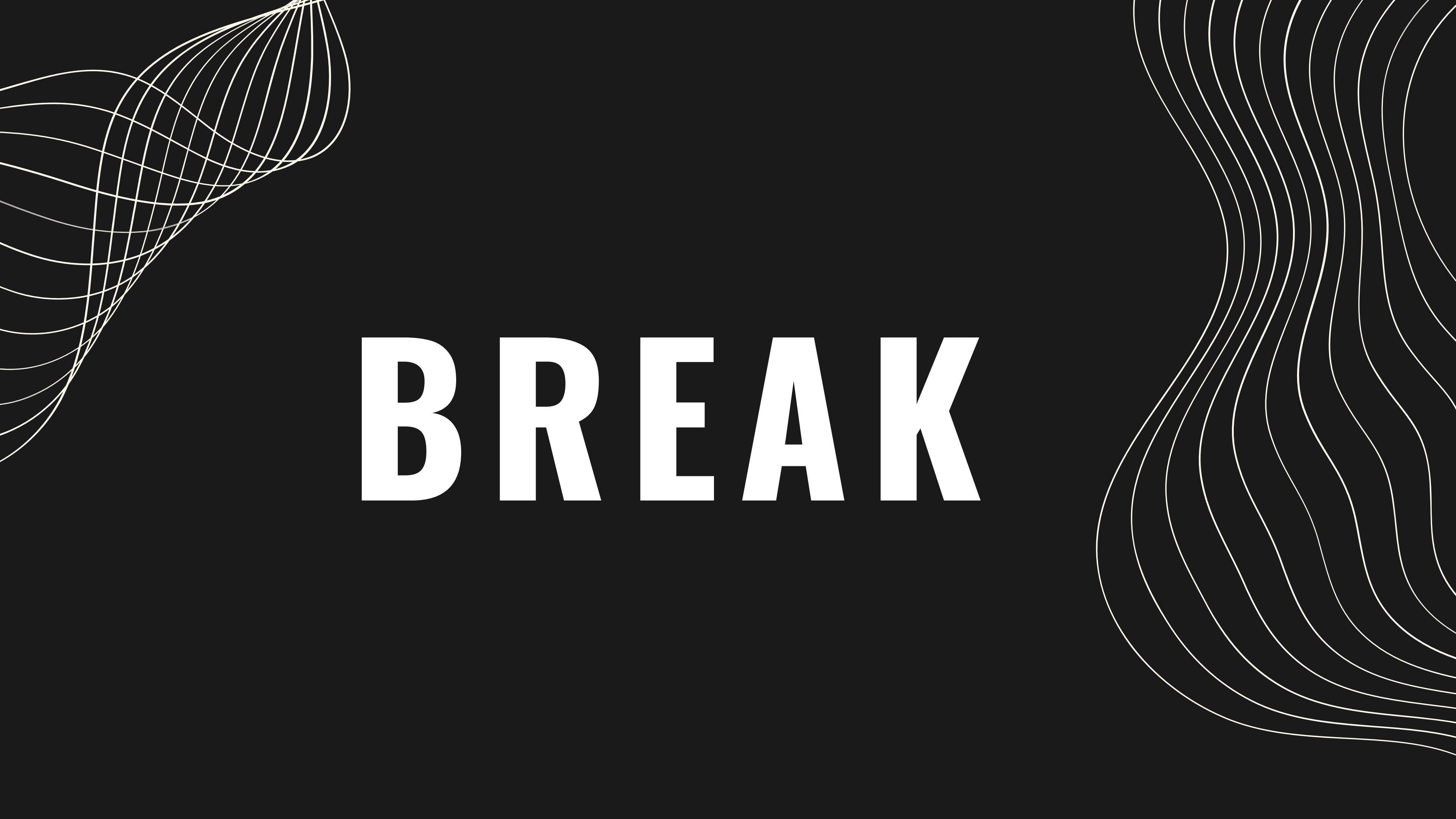


Figure 2. Changes in absolute and relative VO₂max and exercise time. Significant differences between pre- and post-training: ^a $p < 0.05$, ^b $p < 0.01$.

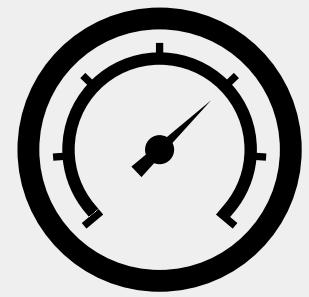


BREAK

INDICATIONS AND PATIENT POPULATIONS



Rehabilitation

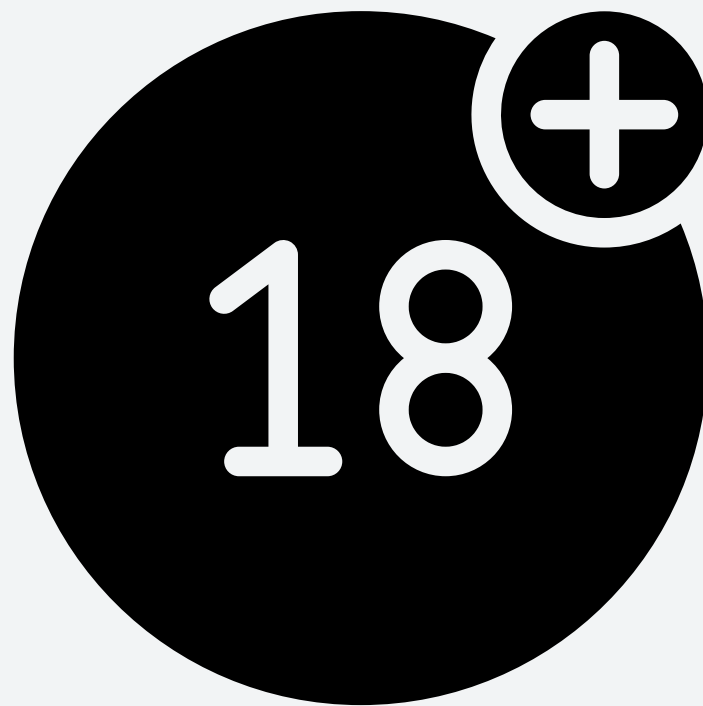


Performance



REHABILITATION

Ages



Utilized clinically with
teenagers

Diagnoses

Post-operative extremity-based
procedures (i.e. shoulder to
hand & hip to ankle)

Osteoarthritis

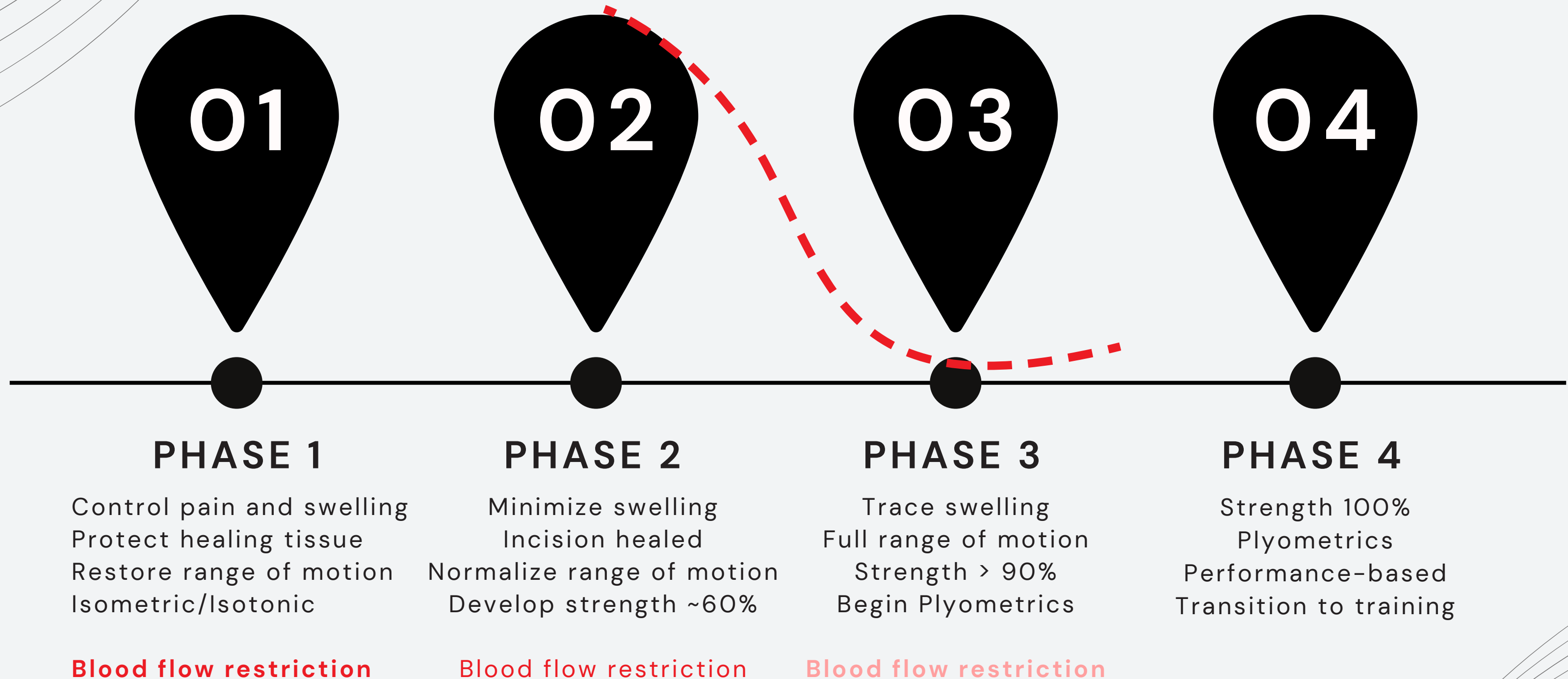
Rheumatoid Arthritis

Multiple Sclerosis

Sarcopenia

Chronic Pain

POSTOPERATIVE TIMELINE



ACUTE PAIN STATE

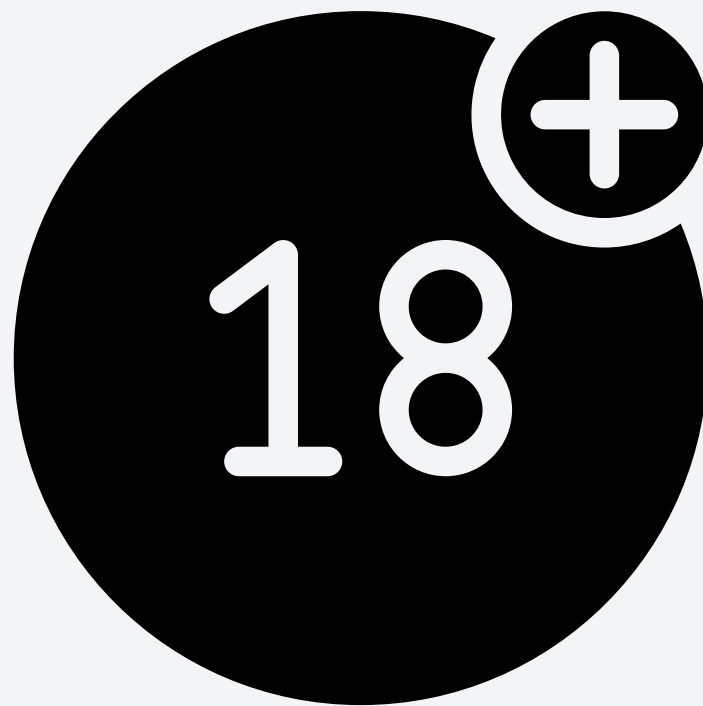
- The same concept applies to acute injuries or individuals who are having a recent increase in pain with current levels of training.
- BFR can be utilized to continue to drive changes or maintenance in hypertrophy and strength of tissue while reducing external load.

0-4 WEEKS



PERFORMANCE

Ages



Aim

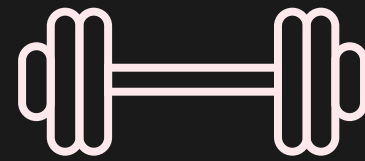
Hypertrophy
Strength
Force Production
Aerobic Capacity
Bone Health

PERFORMANCE



Can be used in conjunction with current training program to increase total volume/hypertrophy

ACCESSORY WORK



Can be used in-season/during competition training to mitigate high intensity loading while still driving positive tissue changes and adaptations

IN-SEASON



Can be used in the aging population to mitigate muscular loss and improve strength, endurance, and muscular size

DISUSE

BFR APPLICATION

TYPES OF BFR

MAD-UP

Delfi

SmartCuffs



AUTOMATIC

KAATSU

B Strong

Voodoo Bands



MANUAL

COST OF BFR

AUTOMATIC

MAD-UP



\$9-10k

Delfi



\$4,995

SmartCuffs



\$499-\$1,699

COST OF BFR

MANUAL

B STRONG

VOODOO BANDS

KAATSU



\$150-\$2000



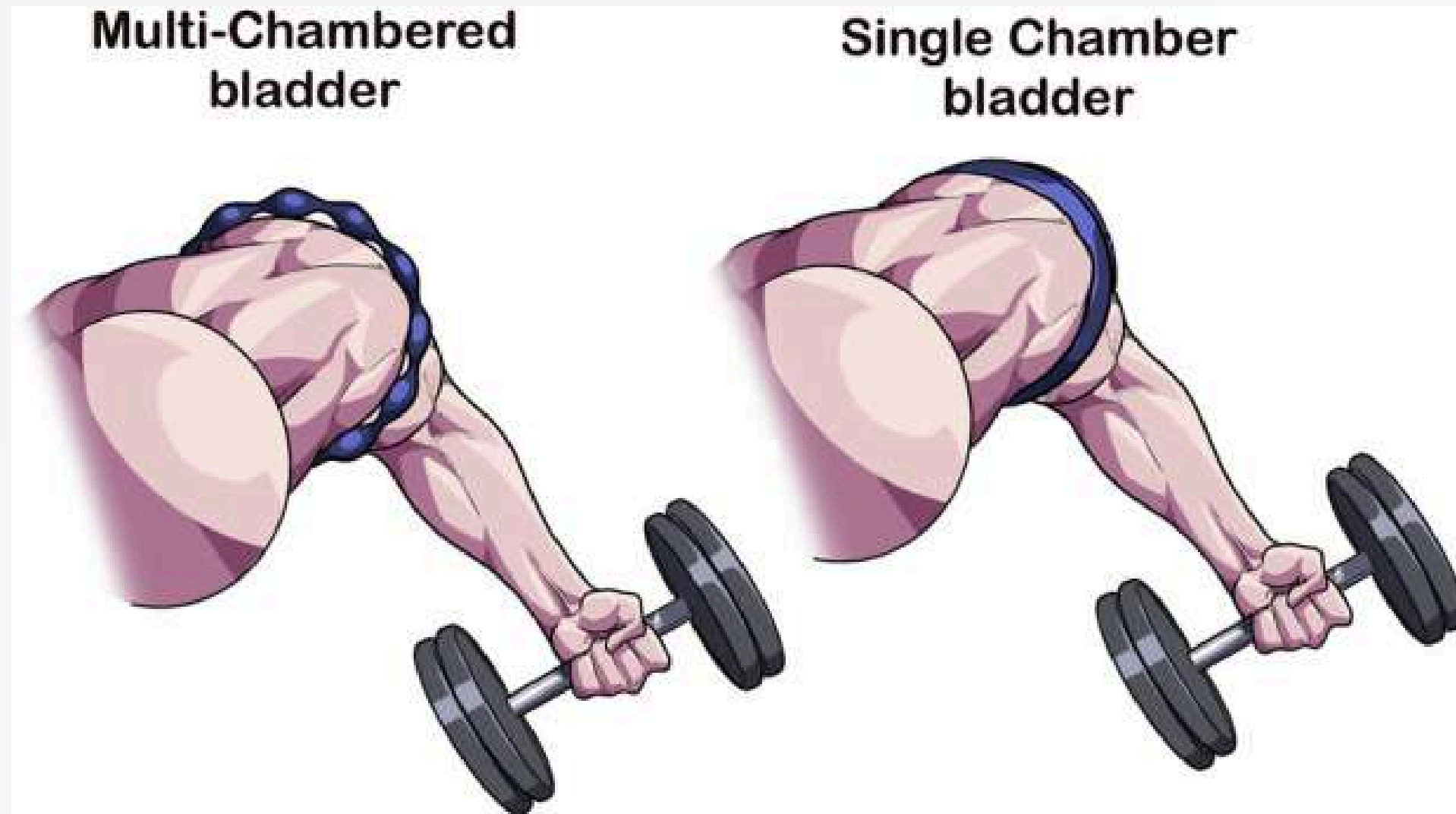
\$450



\$25-\$50

CUFF DESIGN

Multi-vs. Single-Chambered Bladder System



“Multi-chambered versus single-chambered bladder cuff design. As opposed to traditional tourniquets whose function is to occlude arterial flow, multi-chambered bladders are composed of sequential bladders that when inflated, leave regions where minimal compression occurs. This cuff feature reduces the ability for the device to occlude arterial flow making it difficult to obtain a personalized pressure. The inability to occlude has been hypothesized to enhance safety during BFR exercise.”

Rolnick N, Kimbrell K, De Queiros V.
Beneath the cuff: Often overlooked and under-reported blood flow restriction device features and their potential impact on practice—A review of the current state of the research. *Frontiers in Physiology*. 2023;14.
doi:10.3389/fphys.2023.1089065

CUFF DESIGN

Autoregulation of Applied Pressure

Not autoregulated



Autoregulated



“Autoregulation is a design feature that accommodates for the changes in limb circumference because of muscular contraction. In current available devices, the BFR cuff is attached to a pneumatic air compressor via an air tubing that adjusts according to the pressure sensed at the cuff-limb interface. The speed at which this adjustment occurs varies across devices, making it a cuff-specific feature. Autoregulation may enhance the acute safety of BFR exercise”.

Rolnick N, Kimbrell K, De Queiros V.
Beneath the cuff: Often overlooked and under-reported blood flow restriction device features and their potential impact on practice—A review of the current state of the research. *Frontiers in Physiology*. 2023;14.
doi:10.3389/fphys.2023.1089065

CUFF DESIGN

Contour vs. Straight Cuff

Straight



Contour

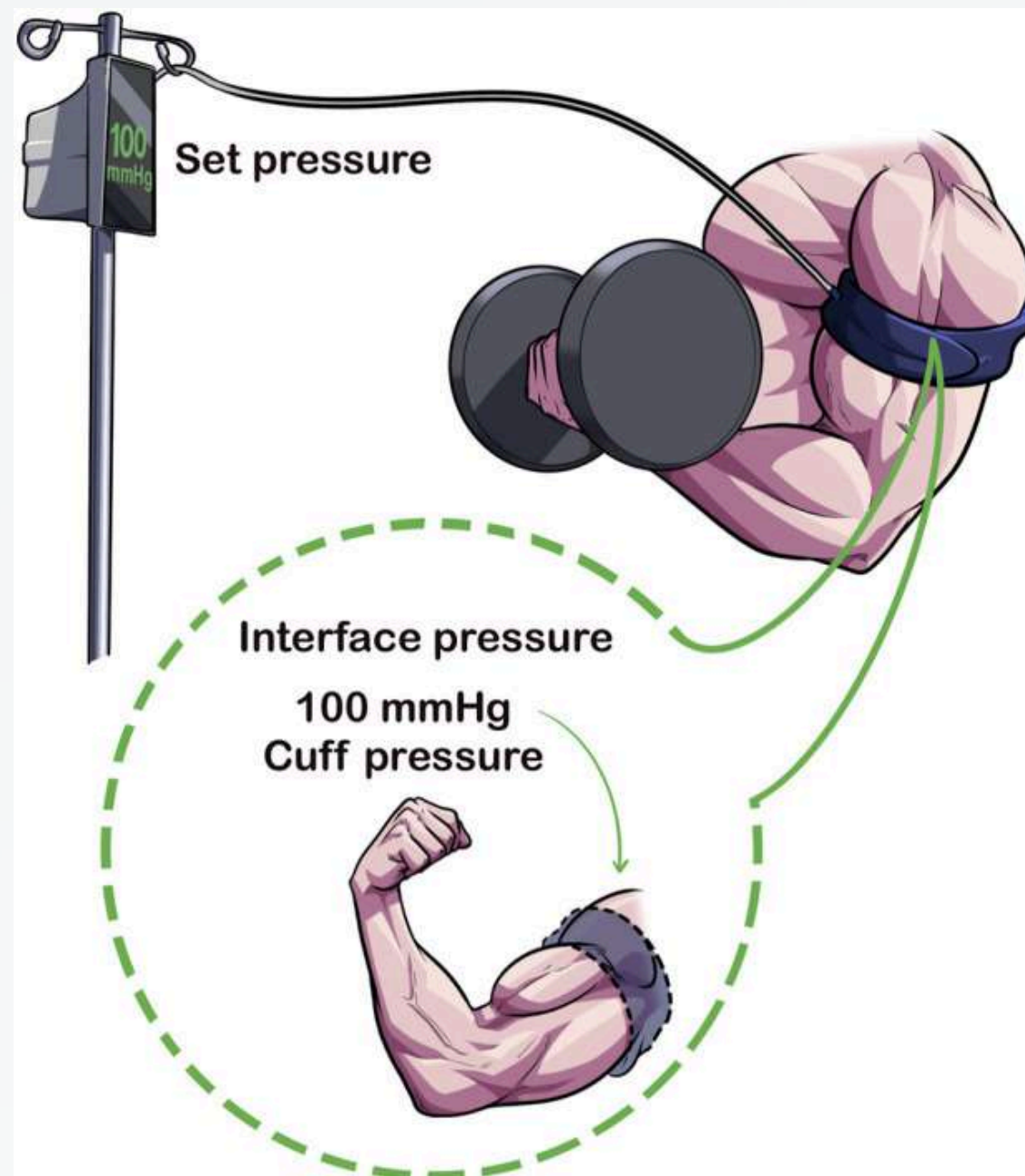


“Differences in limb fit between contoured and straight BFR cuffs. contour cuffs provide a more secure fit due to the conical shape of the limb compared to a straight cuff. This may enhance the safety profile of BFR exercise.”

Rolnick N, Kimbrell K, De Queiros V.
Beneath the cuff: Often overlooked and under-reported blood flow restriction device features and their potential impact on practice—A review of the current state of the research. *Frontiers in Physiology*. 2023;14.
doi:10.3389/fphys.2023.1089065

CUFF DESIGN

Set Pressure Versus Interface Pressure

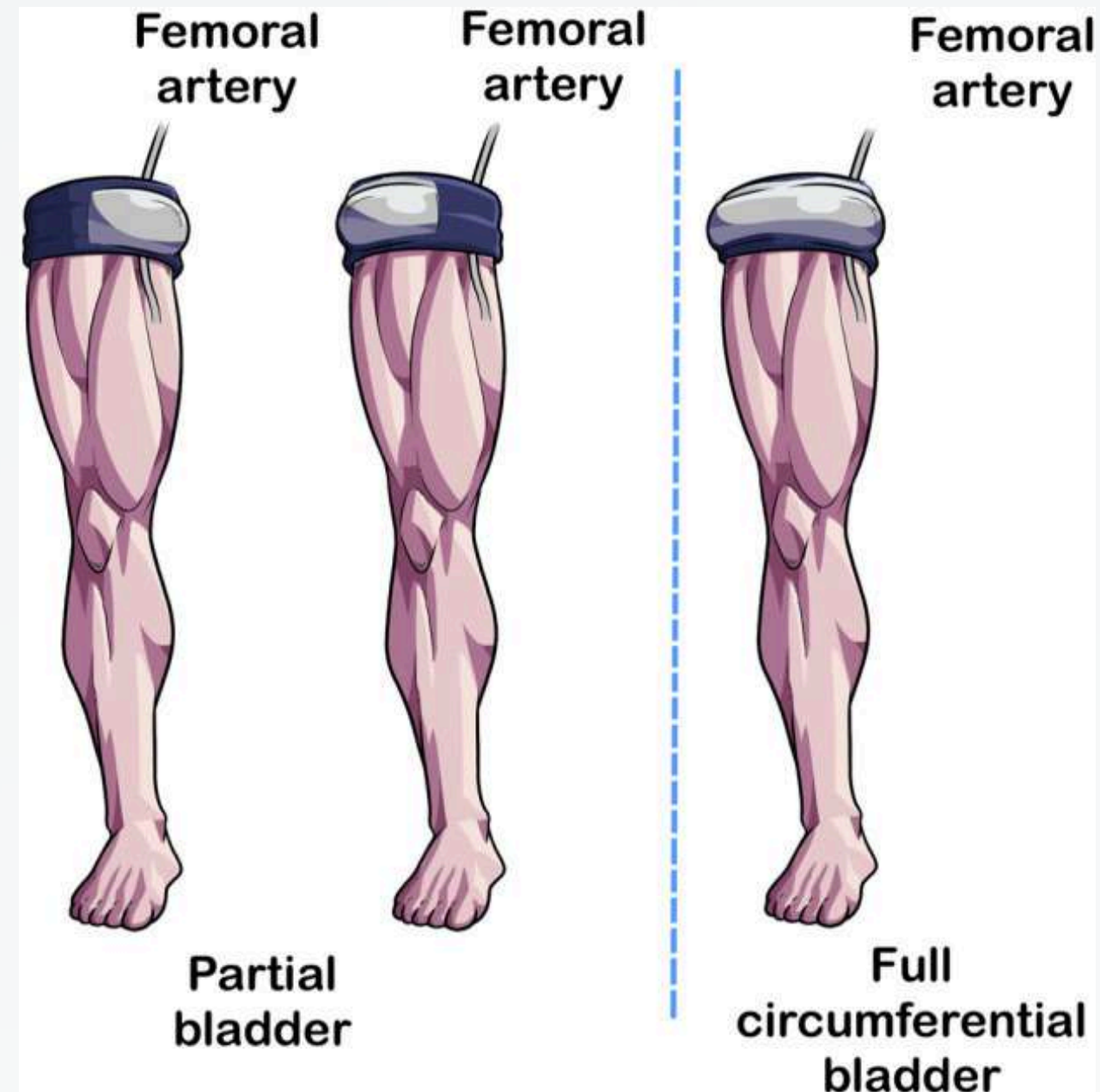


“ The set pressure is the pressure that the pneumatic cuff is inflated to by the clinician/exerciser/researcher whereas the interface pressure is the amount of pressure applied to the limb from the cuff. Cuffs that can maintain a similar set and interface pressures may enhance acute safety of BFR exercise.”

Rolnick N, Kimbrell K, De Queiros V.
Beneath the cuff: Often overlooked and under-reported blood flow restriction device features and their potential impact on practice—A review of the current state of the research. *Frontiers in Physiology*. 2023;14.
doi:10.3389/fphys.2023.1089065

CUFF DESIGN

Bladder length: Circumferential vs. Partial Circumferential



“In traditional tourniquets, the bladder extends the length of the cuff (Right Image) whereas in some BFR cuffs, the bladder extends partially not covering the entirety of the length of the cuff (Left and Center Illustrations). Studies implementing BFR cuffs with partial circumference bladders should specify the position of the bladder because its placement may impact acute responses to BFR exercise”.

Rolnick N, Kimbrell K, De Queiros V. Beneath the cuff: Often overlooked and under-reported blood flow restriction device features and their potential impact on practice—A review of the current state of the research. *Frontiers in Physiology*. 2023;14. doi:10.3389/fphys.2023.1089065

06

AUTOMATIC APPLICATION

Will be reviewed in lab

1. Patient lies supine
2. Cuffs are applied as proximal as possible around the upper arm or thigh
3. Select settings for upper or lower quarter (if applicable)
4. Select blood pressure calibration option (may be reversed with #3)
5. Identify limb occlusion pressure
6. Verify or modify % occlusion
7. Decide rep scheme/load
8. Start application



06

MANUAL APPLICATION

Will be reviewed in lab

1. Patient lies supine
2. Cuffs are applied as proximal as possible around the upper arm or thigh
3. Use doppler ultrasound to assess radial/brachial artery to find limb occlusion pressure
4. Identify % occlusion pressure based on upper or lower extremity
5. Decide rep scheme/load
6. Start application by pumping to prescribed pressure



06

BOTTOM LINE

1. Patient Population:

a. If population is HIGH RISK = MORE OBJECTIVE

2. Budget:

a. If money isn't an issue = HIGHER END OPTIONS

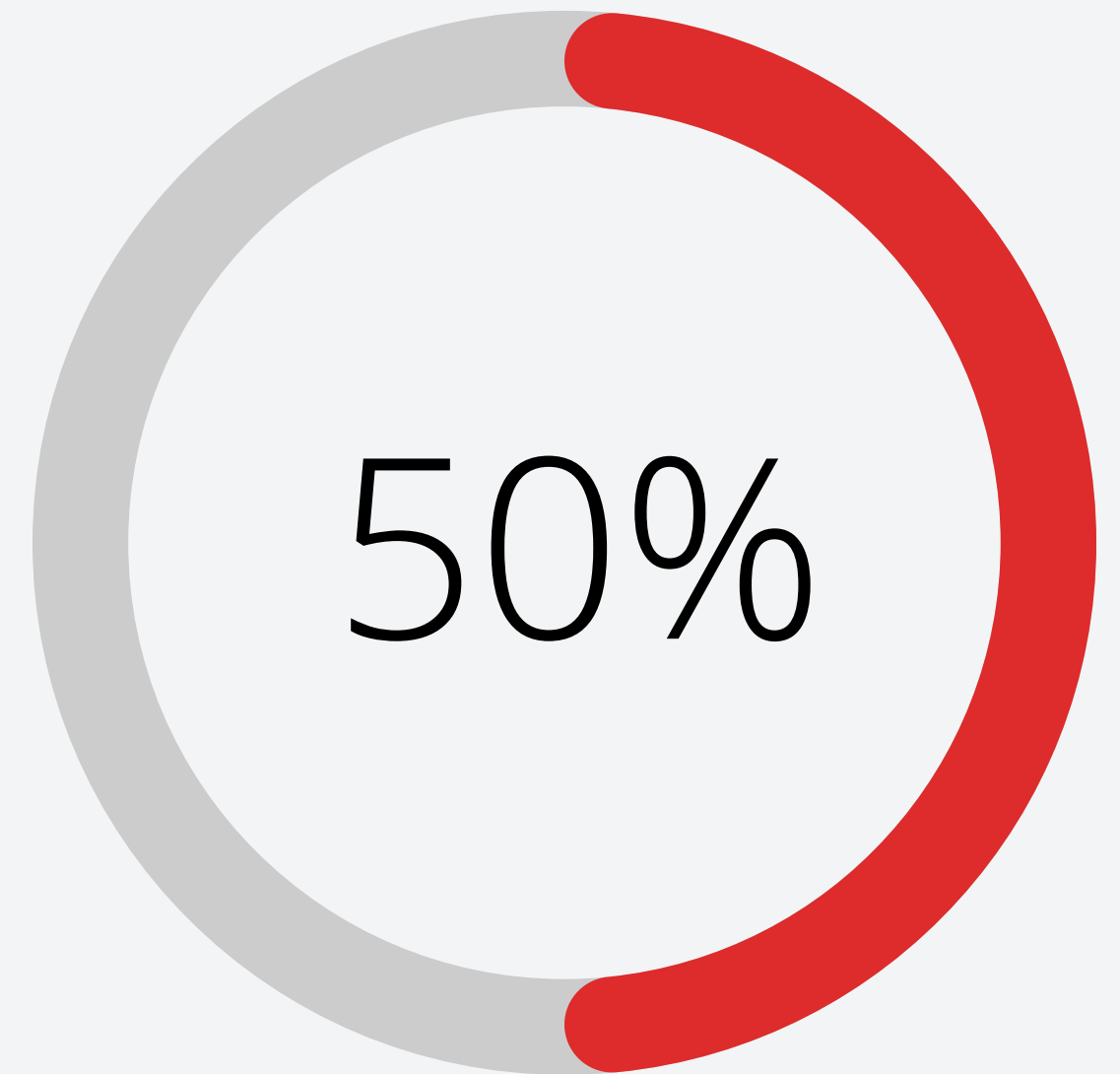
ARTERIAL OCCLUSION PRESSURE (AOP)

Arterial Occlusion Pressure (AOP) is defined as the minimum pressure required to completely occlude arterial blood flow in a limb.

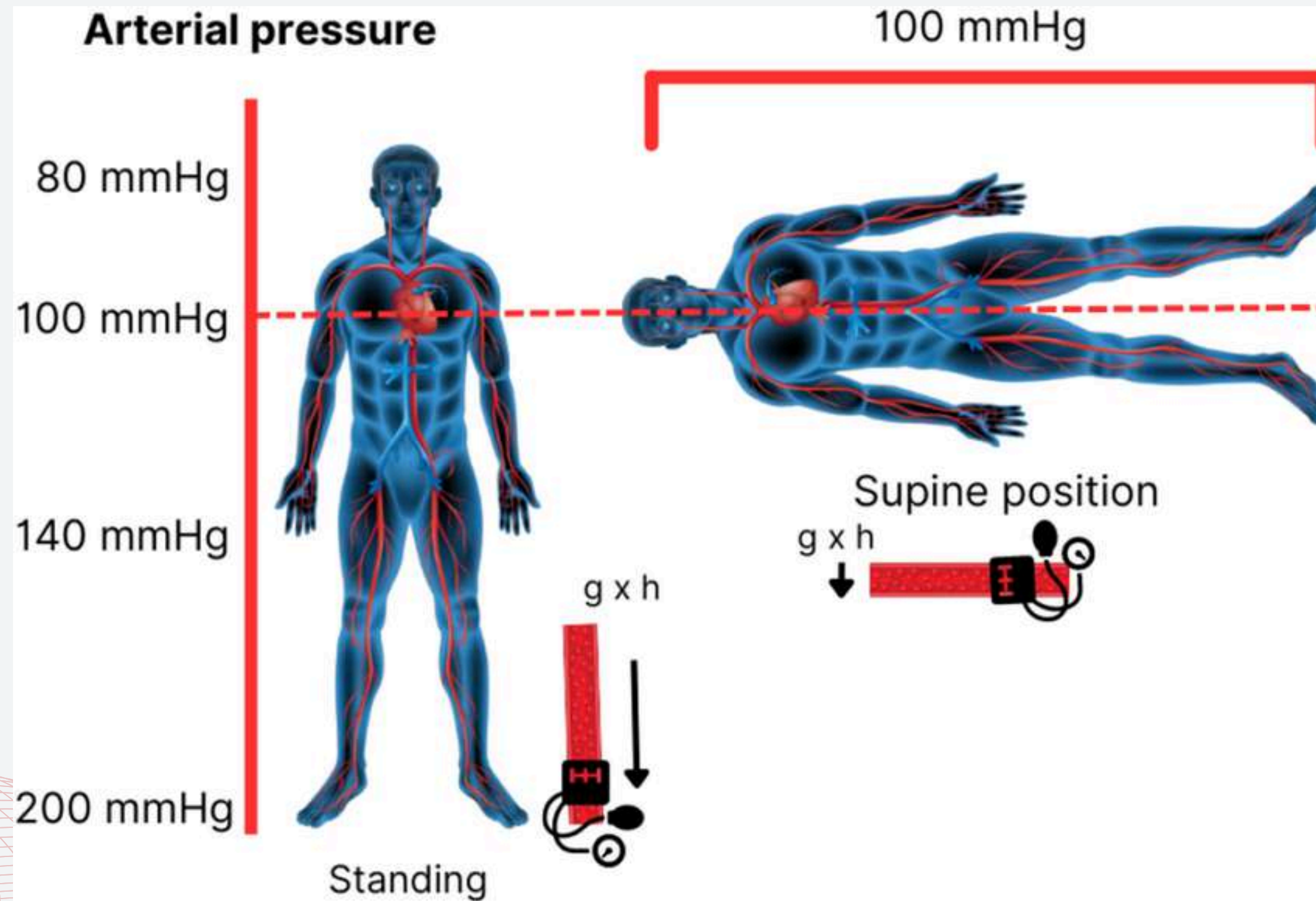
The AOP is typically determined by gradually inflating a cuff around the limb while monitoring the arterial pulse, often using a Doppler ultrasound device. The pressure at which the arterial pulse is no longer detectable is considered the arterial occlusion pressure. This value is then used to set a specific percentage of AOP for BFR training to ensure safety and effectiveness, usually ranging from 40% to 80% of AOP depending on the specific protocol and individual tolerance.

Arterial Occlusion Pressure

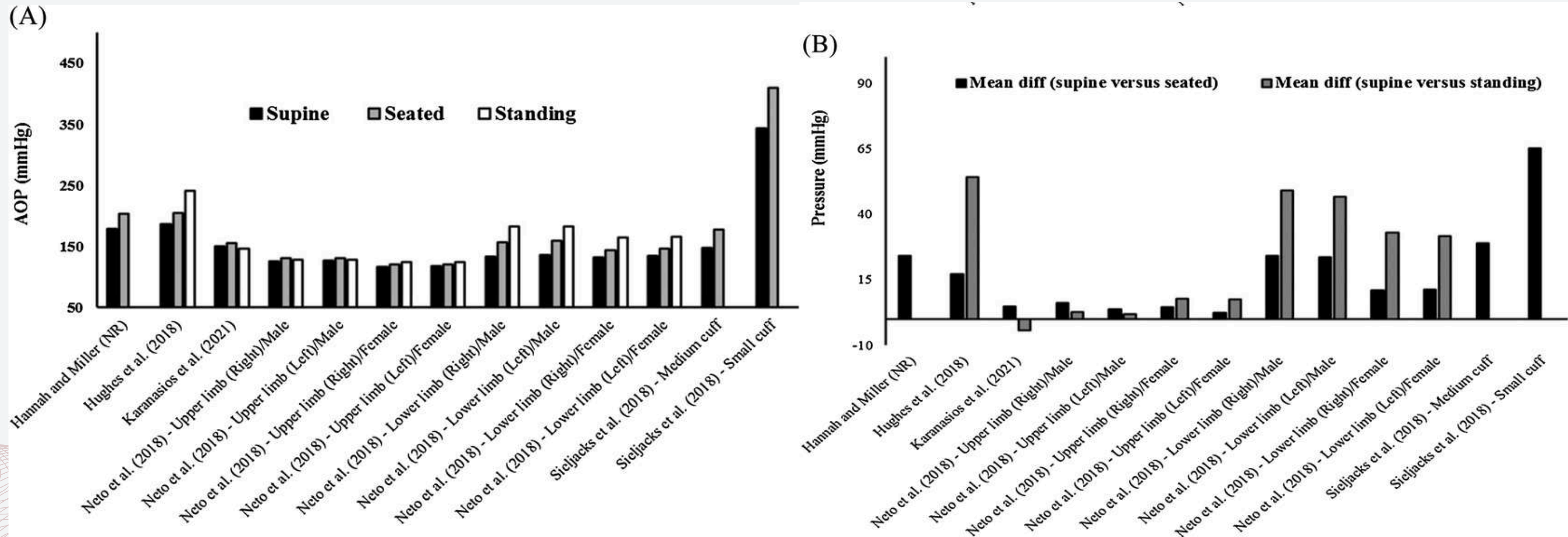
Repetition failure has been demonstrated to be an important normalizing variable when comparing the hypertrophic and strength effects resulting from resistance training and occurs earlier during low-load resistance exercise with high (>50% LOP) but not low blood flow restriction pressures.



Arterial Occlusion Pressure



Arterial Occlusion Pressure



On AOP Sitting

Between 30% to 80% AOP blood flow values were not significantly different (p value range = 1.0 to 0.08) from one another within the superficial femoral artery.

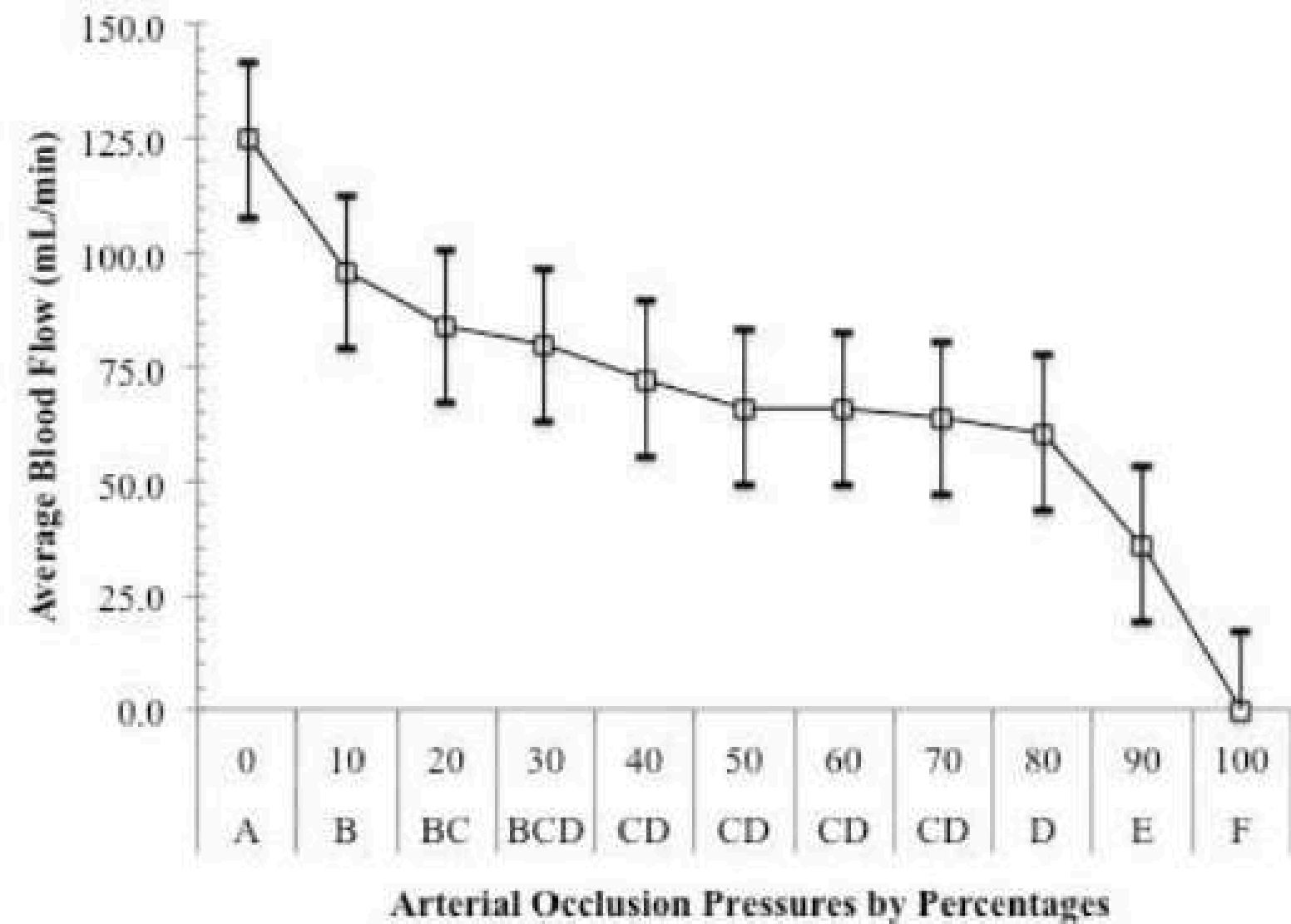


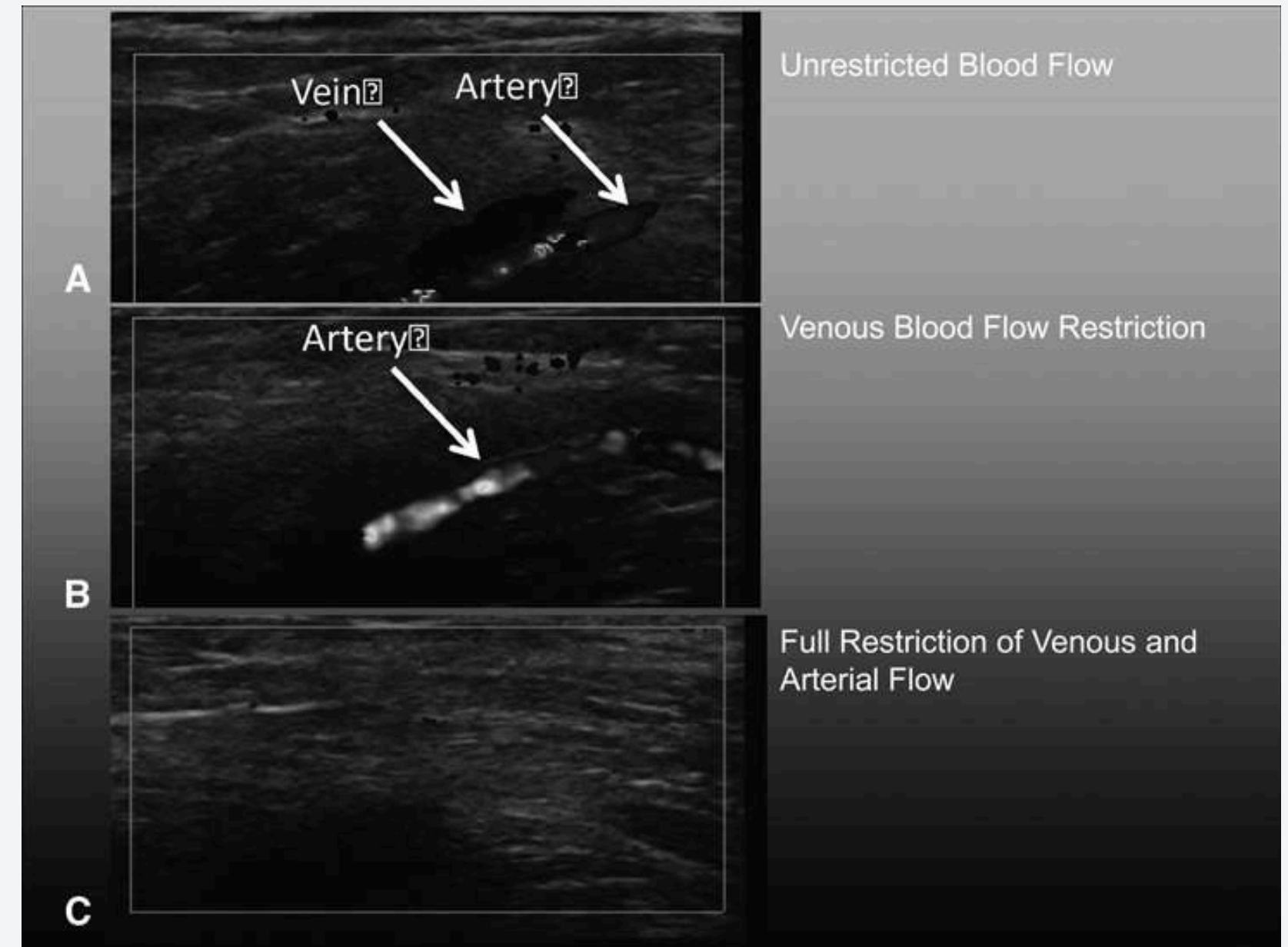
Figure 1: Blood flow/pressure relationship. Average blood flow (mL·min) plot for each %AOP and respective confidence intervals (CIs) (99%). Pressures not connected by the same letter are significantly different ($p < 0.01$).

Crossley KW, Porter DA, Ellsworth J, et al. Effect of Cuff Pressure on Blood Flow during Blood Flow-restricted Rest and Exercise. *Medicine and Science in Sports and Exercise*. 2019;52(3):746-753. doi:10.1249/mss.00000000000002156

Knee wraps

There was complete restriction of the femoral vein but not artery in all the participants at a perceived pressure of 7 out of 10. At a perceived pressure of 10 out of 10, 67% of the participants experienced complete arterial restriction.

“Snug, but not painful pressure”

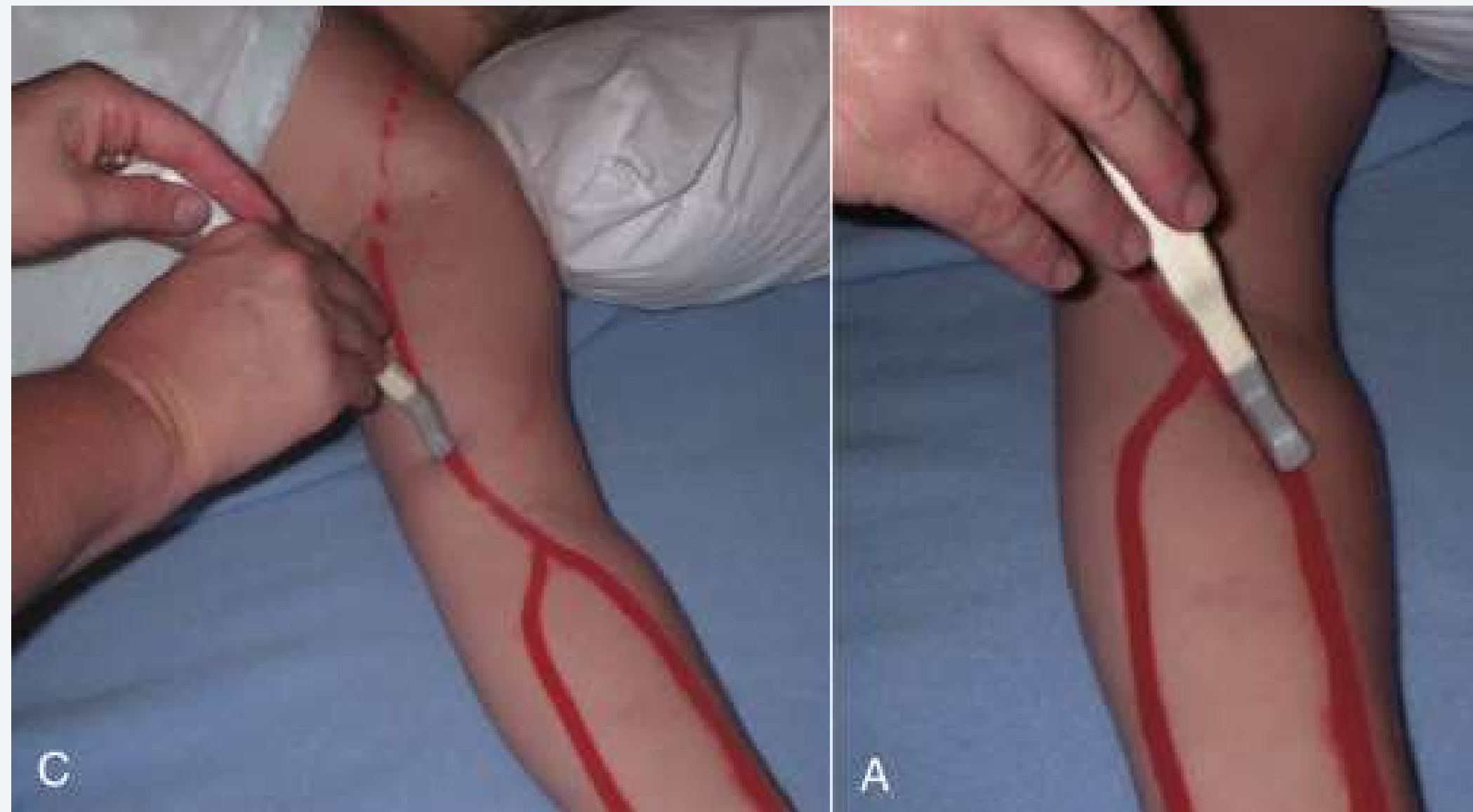
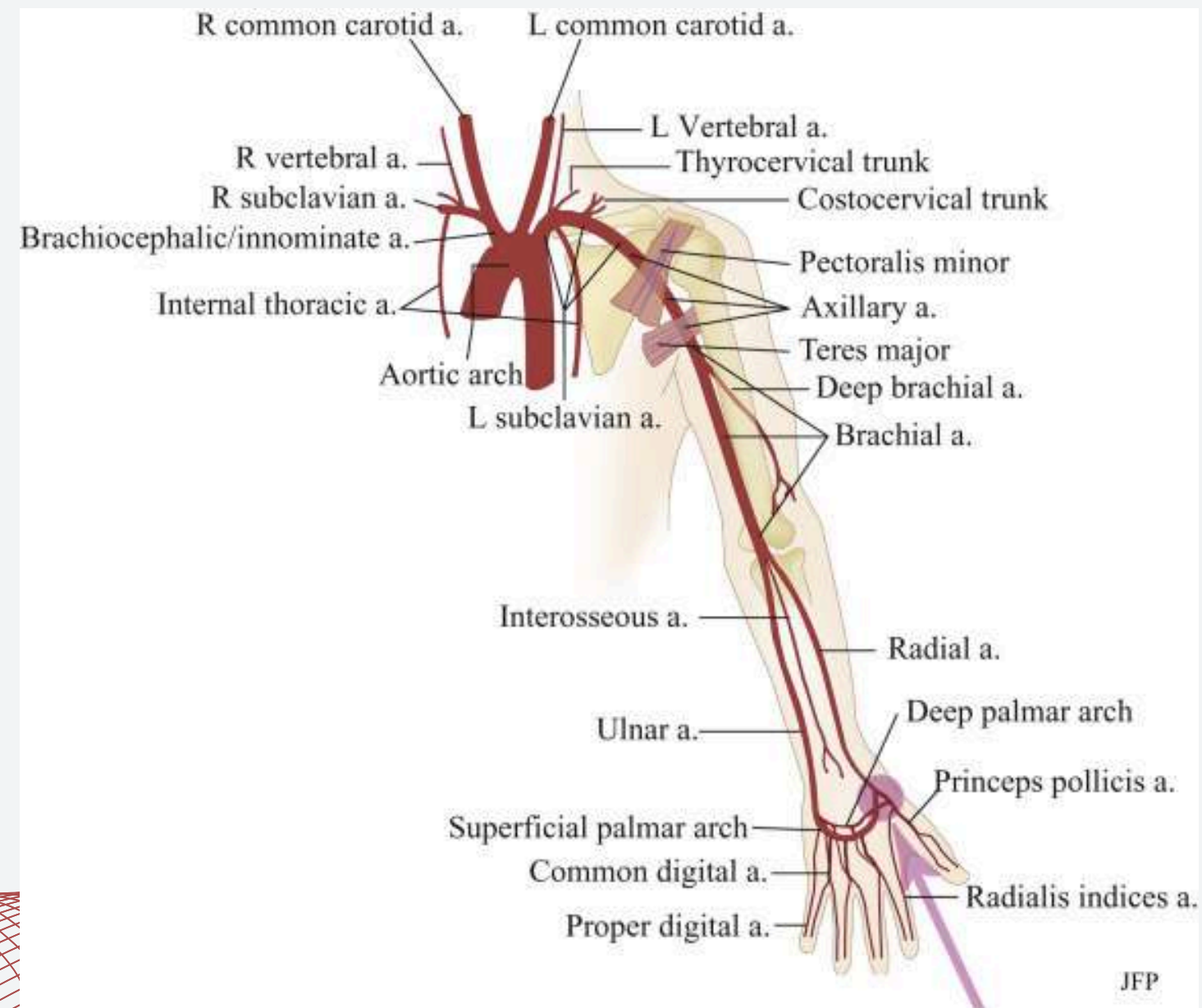


Wilson JM, Lowery RP, Joy JM, Loenneke JP, Naimo MA. Practical blood flow restriction training increases acute determinants of hypertrophy without increasing indices of muscle damage. J Strength Cond Res. 2013;27(11):3068-3075. doi:10.1519/JSC.0b013e31828a1ffa

07

Identifying Upper Extremity Occlusion

Brachial/Radial Artery



Identifying Lower Extremity Occlusion

Femoral Artery

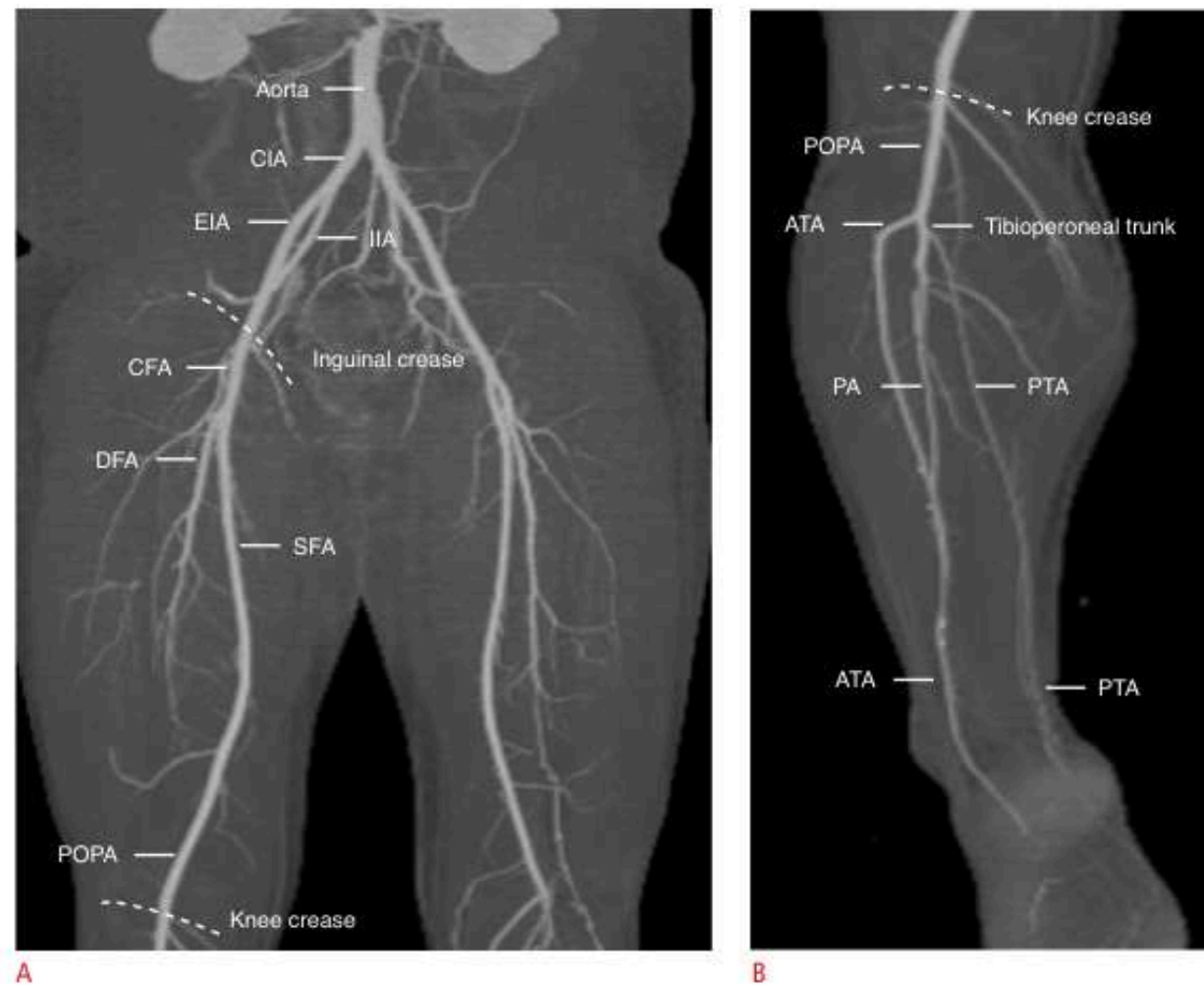


Fig. 1. The anatomy of the lower extremity arteries on computed tomography (CT) angiography.

A. On coronal maximal intensity projection (MIP) CT image above the knee, the external iliac artery (EIA) is continuous with the common femoral artery (CFA) which bifurcates into the superficial femoral artery (SFA) and deep femoral artery (DFA). The SFA is continuous with the popliteal artery (POA). **B.** On coronal MIP CT image below the knee, the POA splits anterior tibial artery (ATA) and tibioperoneal trunk which bifurcates into posterior tibial artery (PTA) and peroneal artery (PA). CIA, common iliac artery; IIA, internal iliac artery.

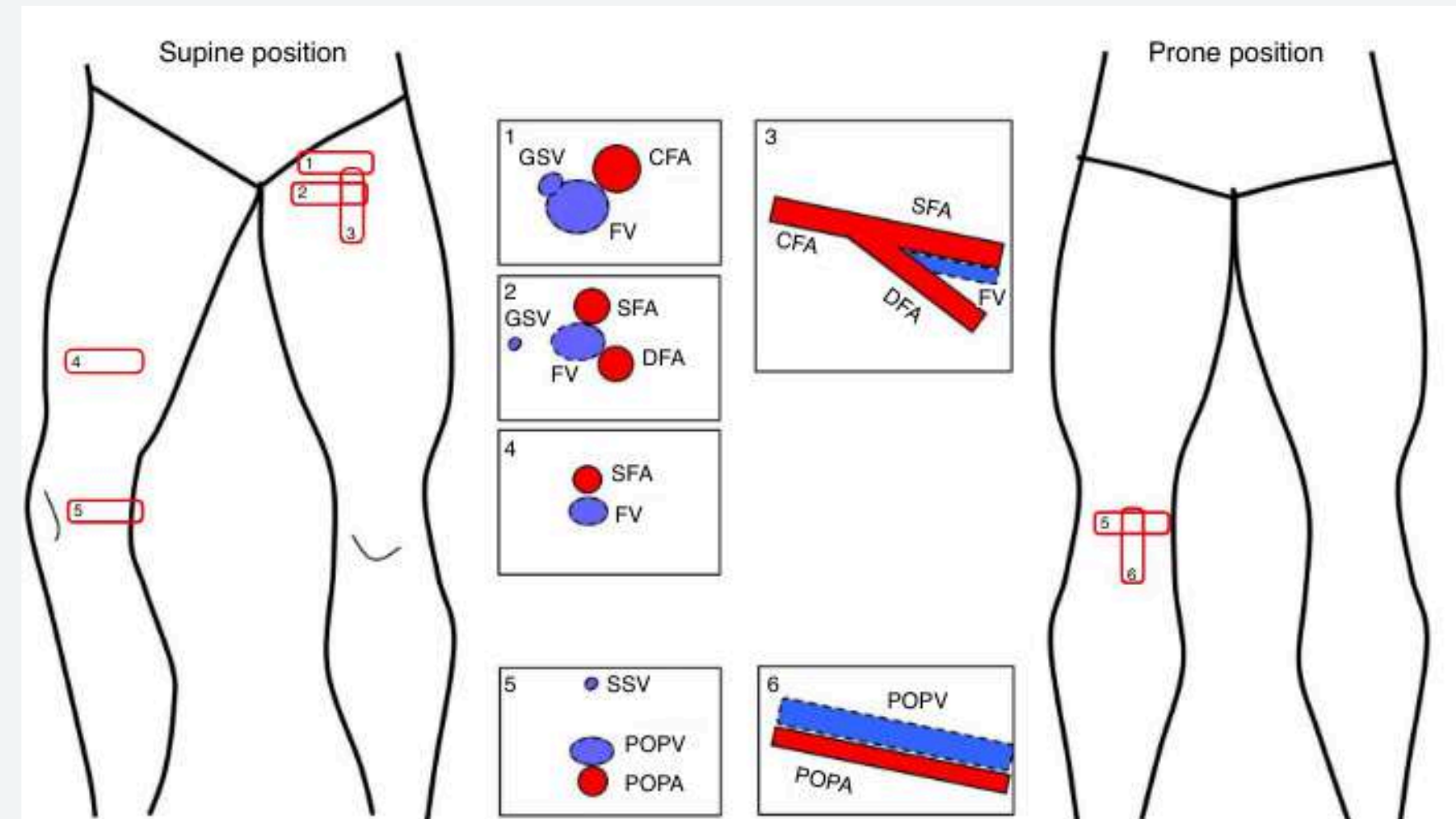
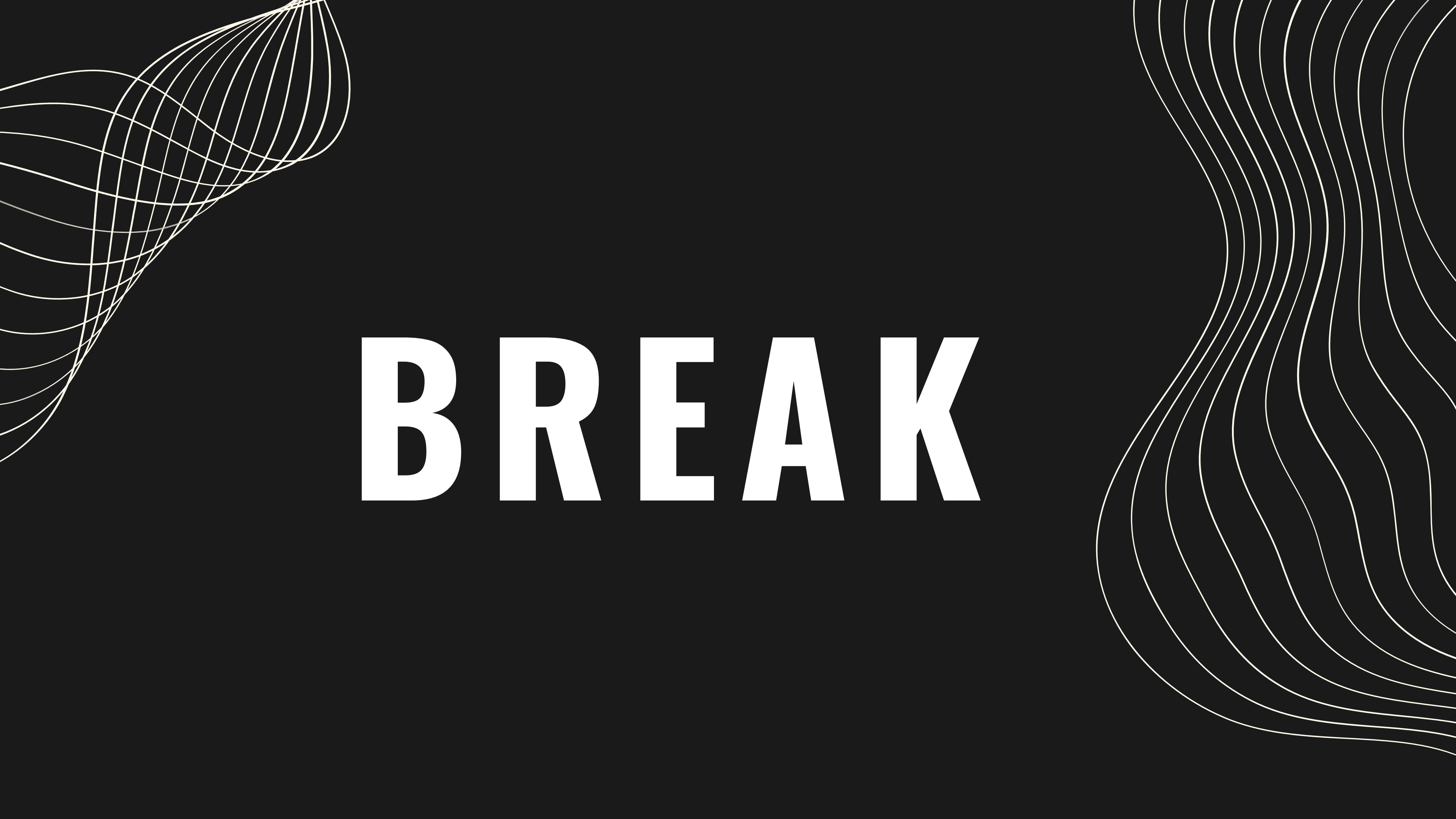


Fig. 2. The steps of color Doppler ultrasonography (US) for the lower extremities above the knee, with the patient's position indicated. The red rectangular boxes are the essential scanning sites and planes for the femoral arteries and the popliteal artery. The numbers within the boxes represent the general steps of scanning. The schema in the box demonstrates the typical US features of arteries and veins at each scanning site. GSV, greater saphenous vein; FV, femoral vein; CFA, common femoral artery; SFA, superficial femoral artery; DFA, deep femoral artery; SSV, small saphenous vein; POPV, popliteal vein; POA, popliteal artery.



BREAK

BFR EXERCISE SELECTION

TYPES OF EXERCISE

Good news... the sky is the limit!



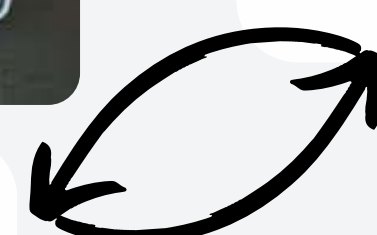
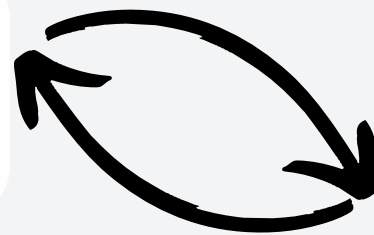
**SINGLE JOINT
UNILATERAL**



**MULTI-JOINT
UNILATERAL
ASYMMETRICAL**



**MULTI-JOINT
BILATERAL**



08

SINGLE JOINT UNILATERAL EXAMPLES

LEG EXTENSION + NMES



MACHINE LEG CURL



CALF RAISE ON LEG PRESS



08

MULTI-JOINT UNILATERAL EXAMPLES

STEP UP



SINGLE LEG PRESS



TRX REVERSE LUNGE



SPLIT STANCE RDL



DB BENCH PRESS



08

COMPOUND MULTI EXAMPLES

HACK SQUAT



BARBELL BACK SQUAT



STEADY STATE WALKING



STEADY STATE CYCLING



RESEARCH

Abe et. al., 2005



15 Male Track and Collegiate Athletes: BFR Squat and Seated Leg Curl

- Frequency: 2 Sessions/Day for 8 days
- Intensity: 3 sets of 15 reps @ 20% 1RM
- Pressure: 160 and 240 mm Hg
- Type: KAATSU-device (unspecified)

Results: Improvement in 1RM Leg Press (20 lb vs 10 lb), 30m sprint (.09 vs .05 sec), mm thickness and cross-sectional area (4% vs 0%)

20 Male Rugby Players: BFR Bench Press, Leg Squat, Wtd. Pullups

- Frequency: 3 sessions/week for 3 weeks
- Intensity: 5 sets of 5 reps @ 70% 1 RM
- Pressure: 180 mmHg - intermittent occlusion
- Type: Occlusion cuff (10.5 cm) (unspecified)

Results: BFR vs control: bench press (5.4 ± 2.6 vs 3.3 ± 1.4 kg), squat (7.8 ± 2.1 vs 4.3 ± 1.4 kg), maximum sprint time (-0.03 ± 0.03 vs -0.01 ± 0.02 s), and leg power (168 ± 105 vs 68 ± 50 W)

Cook et. al., 2014



RESEARCH

Lowery et. al., 2014



20 Male Collegiate Weightlifters: BFR with Bicep Curls

- Frequency: 2 Sessions/wk for 4 weeks
- Intensity: 3 sets of 30 reps @ 20% 1RM
- Pressure: 6-7/10 perceived pressure
- Type: Knee Wraps: Elite FTS, London, Ohio; 76 mm wide

Results: Both the BFR-HI and HI-BFR elbow flexor CSA increased significantly from baseline to week 4 (6.9% and 8.6%, $P < 0.01$) and from weeks 4 to 8 (4.1%, 4.0%, $P < 0.01$), respectively.

62 Male Collegiate Football Players: BFR Bench Press and Squat

- Frequency: 4 sessions/week for 7 weeks, BFR after training
- Intensity: 4 sets of 30, 20, 20, 20, 20 reps @ 20% 1RM
- Pressure: knee wraps pulled to 7.6 cm
- Type: powerlifting elastic knee wraps with hook-and-loop closure (Grizzly Fitness, Kitchener, ON, Canada)

Results: H/S/R Squat Pre 193.2kg SD 25.0, Post 218.1kg SD 24.6
% Change 24.87kg, no change in bench, CSA thigh, arm, or chest

Leubers et. al., 2014



RESEARCH

Manimmanakorn et. al., 2013



30 Female Netball Athletes: BFR with Leg Extension and Leg Curls

- Frequency: 3 Sessions/wk for 5 weeks
- Intensity: 3 sets to failure @ 20% 1 RM
- Pressure: 160 and 230 mmHg
- Type: KAATSUMASTER® mini, on both thighs.

Results:

	CT	KT	HT
MVC3 (%)	1.0 ± 14.3	12.1 ± 7.8	14.9 ± 10.7 ^a
MVC30 (%)	0.4 ± 7.0	11.4 ± 10.1 ^a	16.9 ± 17.9 ^a
Reps201RM (%)	86.4 ± 15.7	140.0 ± 33.5 ^a	129.2 ± 37.1 ^a

12 Male Jiu-Jitsu Athletes: BFR with Squat

- Frequency: 1 session/day for 8 days
- Intensity: 1 set, 10-15 reps @ 20% 1RM, 1 set to failure @ 80% 1 RM
- Pressure: 60%, roughly 110 mmHg
- Type: Twofold 206 latex tube

Results: Looking at fatigue, identified both high load and high load + BFR created similar levels of fatigue, via iso torque.

Neto et. al., 2014



RESEARCH

Sumide et. al., 2009



21 Untrained Healthy Young Males: BFR Hip Flex/Abd/Adduction

- Frequency: 3 Sessions/wk for 8 weeks
- Intensity: 20% 1 RM - 20 reps each in succession
- Pressure: 4 Groups: 0 mmHg, 50, 150, 250
- Type: A tourniquet

Results:

Concentric contractions at angular velocity of 180°/s

0-Pressure group	133.4 ± 30.1	134.2 ± 31.9	NS
50-Pressure group	125.5 ± 17.6	141.8 ± 16.4	<0.05
150-Pressure group	113.2 ± 4.0	126.1 ± 6.4	<0.01
250-Pressure group	131.4 ± 18.2	139.1 ± 22.1	<0.05

21 Male Semiprofessional Soccer Players: BFR with Squat

- Frequency: 3 sessions/wk for 5 weeks
- Intensity: 30-15-15-15, sessions 1-5 20% 1RM, sessions 6-10 25% 1RM, and sessions 11-14 30% 1RM.
- Pressure at 7/10 perceived pressure
- Type: Elastic knee wraps (7.5 × 250 cm, Ironedge)

Results: No significant difference in BFR vs control group for the 3RM squat test, jump testing, sprint testing, or muscle architecture.

Scott et. al., 2017



RESEARCH

Takarda et al., 2002



- 17 Male Elite Rugby Athletes
- BFR with Bilateral Isokinetic Knee Extension
- 4 sets to failure
- 2 Sessions/wk for 8 weeks
- Pressure at 196 mmHg

Results: BFR training showed significant improvements in isometric and isokinetic muscular strength, CSA of quads increased by 12%

32 Male College Football Players: BFR Barbell Squat & Bench Press

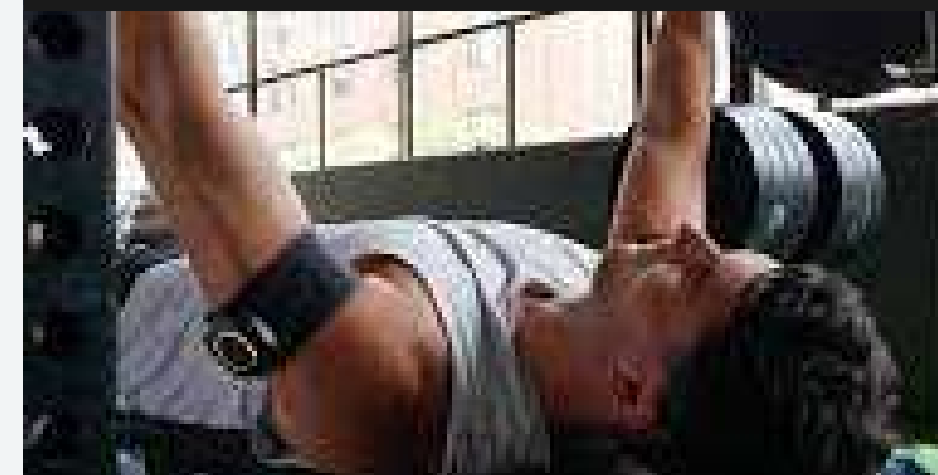
- Frequency: 3 sessions/wk for 4 weeks after normal training
- Intensity: 4 sets of 30,20,20,20 reps @ 20% 1RM
- Pressure: Band at 2 inch overlap of band previously marked
- Type: Elastic Bands with Velcro

Results:

	Experimental group				Control group				Effect size
	<i>M</i>	<i>SD</i>	<i>SEM</i>	% Change	<i>M</i>	<i>SD</i>	<i>SEM</i>	% Change	
Bench press	9.3*	3.4	1.0	7.0*	4.1	4.2	0.9	3.2	1.2
Squat	14.0*	3.8	1.3	8.0*	7.2	5.3	1.1	4.9	1.3

*Significant difference between groups, $P < 0.05$.

Yamanaka et al., 2012



RESEARCH

Rodrigues et al., 2020



48 Women with Rheumatoid Arthritis: BFR Leg Press and Leg Extension

- Frequency: 2 Sessions/wk for 12 weeks
- Intensity: 4 sets of 15 reps @ 30% 1 RM
- Pressure: 70% LOP
- Type: Air cuff

Results: BFR and High Load training increased leg press and leg extension strength by 22-24% and 19-24% respectively. Quad CSA increased 10%, Timed Sit to Stand and Timed Up and Go Test 12.5% and -7%. SF-36 improved by 45%.

60 patients with PFPS: BFR with hip abd/ext machine, leg ext, and single leg press

- Frequency: 3 sessions/wk for 4 weeks
- Intensity: 4 sets of 30-15-15-15 reps @ 30% 1 RM
- Pressure: 70% LOP
- Type: Sports Rehab Tourniquet© cuffs

Results: BFR was as good as typical strength and conditioning for the hip and knee in regards to anterior knee pain. The only true differences involved better worst pain (0.76 vs 1.3) at follow-up and knee extensor strength (459 N vs 380 N).

Constantinou et al., 2022



RESEARCH

Korakakis et al., 2018



40 Male Patients with Anterior Knee Pain >18 y/o: BFR with Leg Extension (Machine)

- Frequency: One Session – assessing effects of BFR on pain relief
- Intensity: 4 sets of max rep, 15, 15, 15 reps
- Pressure: 80% LOP
- Type: Sports Rehab Tourniquet©

Results: Significant immediate pain reduction (>2/10 VAS) with large to very large effect sizes were found in the Low Load Resistance-BFR group in shallow and deep single leg squat, as well as 20 cm step down test, but no significant differences were found in Low Load Resistance Training group where the effect sizes were small to moderate. Following the physiotherapy session (45 min) pain reduction was sustained in LLRT-BFR group in both SLS, and SDT. For the LLRT group significant pain reduction was only found for the shallow SLS, but not for SLSD and SDT.

There was a 117%, 237% and 82% greater reduction in pain immediately post-intervention in the LLRT-BFR group relative to the LLRT group in SLSs, SLSD and SDT, respectively. Also, there was a 92%, 73% and 82% greater reduction in pain post physiotherapy session in the LLRT-BFR group relative to the LLRT group in SLSs, SLSD and SDT, respectively.

RESEARCH

Karanasios et al., 2022



46 Patients with Lateral Elbow Tendinopathy, Ages 18–60: BFR with Elbow Flexion and Extension

- Frequency: 2 x week for 6 weeks
- Intensity: 4 sets of 30,15,15,15 reps
- Pressure at 40–50% LOP
- Type: KAATSU

Results:

1. Pain reduction with a moderate effect size ($d = 0.68$) in favor of LLRT-BFR was observed at the 12-week follow-up (-1.54 , 95% CI: -2.89 to -0.18)
2. Between-group difference in favor of the LLRT-BFR group was found in the PRTEE score at the 6- and 12-week follow-up (-11.92 , 95% CI: -20.26 to -3.59 , and -15.23 , 95% CI: -23.57 to -6.9 , respectively) with a large effect size ($d = 0.88$ and $d = 1.13$, respectively)
3. A between-group difference (0.20 , 95% CI: 0.06 to 0.34) with a large effect size (0.83) was found in PFGS ratio only at the 6-week follow-up
4. Odds of reporting a successful outcome using GROC was found between patients allocated to the LLRT-BFR group compared to patients allocated to the LLRT-with-sham-BFR group at 6-week (OR = 6.0 , 95% CI: 1.5 to 23.9) and 12-week (OR = 4.09 , 95% CI: 1.03 to 16.28) follow-up
5. Between-group differences were found at the elbow flexors strength ratio at both follow-up time points (0.2 , 95% CI: 0.08 to 0.31 , and 0.15 , 95% CI: 0.04 to 0.27 , respectively) with large effect sizes ($d = 1.2$ and $d = 0.9$, respectively) in favor of the LLRT-BFR group

RESEARCH

Ozaki et al., 2010



23 sedentary Men and Women, aged 57 to 76 years: BFR with Treadmill Walking

- Frequency: 4 Sessions/wk for 10 weeks
- Intensity: 20-minute treadmill walking at an exercise intensity of predetermined 45% of heart rate reserve (HRR)
- Pressure: starting at 120 mmHg and progressing up to 200 mmHg over the 10 weeks.
- Type:

Results: Percentage changes in knee extension and flexion strength and thigh muscle CSA were higher in BFR-W (8.7%, 15.0%, and 3.2%, respectively) than in the CON-W (2.7%, 0.3%, and 0.2%).

Carotid arterial compliance improved ($P < .01$) in both CON-W and BFR-W groups. Increase in arterial compliance was similar between 2 walk training groups (CON-W, 59% and BFR-W, 50%). There was no significant change in carotid and brachial blood pressure at rest for either group before and after the training

RESEARCH

Lamberti et al., 2020



12 Patients with Progressive Multiple Sclerosis: BFR with Treadmill Walking

- Frequency: 2 Sessions/wk for 6 weeks
- Intensity: in bouts of 1 min on/off x 3 sets, repeat 5 times.
- Pressure: 30% LOP
- Type: BFR bands

Results: BFR-W group safely walked without limitations due to sleeve compression, with lower increase of perceived exertion (RPE)($p < 0.001$) and heart rate ($p = 0.031$) compared with the CON-W. Gait speed improved significantly in both groups (BFR-W +13%; CON-W +5%) with greater increases in the BFR-W group at end of the training ($p = 0.001$) and at the follow-up ($p = 0.041$).

SUMMARY

A variety of exercises and rep/set schemes can be selected, it all depends on intent.

UPPER EXTREMITY:
BENCH PRESS
BICEP CURL
TRICEP EXTENSION

LOWER EXTREMITY:
SQUAT
LEG PRESS
LEG EXTENSION

STEPS FOR INDIVIDUALIZING BFR

01

02

03

04

**ASSESSMENT
AND
EVALUATION:**

Medical History
Risk Factors
Goals

**CHOOSING
THE RIGHT
EQUIPMENT**

Cuff Size

**PERSONALIZED
PRESSURE
SETTINGS**

Limb Occlusion
Pressure

**INTEGRATING
WITH EXERCISE
PROTOCOLS**

Exercise Selection
Intensity and Volume

HOW MUCH LOAD?

It's kind of gray....

10RM TESTING

Identify 7-10 repetition maximum load

Multiply by the number corresponding to the amount of repetitions to volitional fatigue (below)

Leg press					Leg extension				
Reps	7	8	9	10/10+	Reps	7	8	9	10/10+
	x0.35	x0.36	x0.37	x0.38		x0.37	x0.38	x0.38	x0.39

Example: Leg Press @ 150 lb for 8 = $150 \times 0.36 = 54$ lb with BFR

MORE COMMON IN PERFORMANCE

RATING OF PERCIEVED EXERTION

1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, Etc.
2-3	Light Activity Feels like you can maintain for hours, easy to breathe and carry on a conversation
4-6	Moderate Activity Breathing Heavily but you can still hold a short conversation, Still somewhat comfortable, but becoming noticable more challenging
7-8	Vigorous Activity Borderline uncomfortable, short of breath, can speak a sentence
9	Very Hard Activity Very difficult to maintain exercise intensity, can barely breathe and speak only a few words
10	Maximal Effort Feels almost impossible to keep going, completely out of breathe, unable to talk, cannot maintain for more than a very short amount of time

**MORE COMMON IN REHAB
UNLESS YOU KNOW PREVIOUSLY ESTABLISHED 10 RM**

CASE STUDY

A 18-40 year old male/female underwent left knee arthroscopy with a hamstring graft, ACL reconstruction three days ago. No complications.

Initiate BFR
1 exercise per muscle group
LOP 40-60%
Duration-based, 5 min x 2-3 sets
Incorporate with:

1. Quad sets actively or during NMES (5-10 minutes)
2. Prone Hamstring Curls

WEEKS 0-2

Continue BFR
1-2 exercise per muscle group
LOP 40-80%
30-15-15-15 @ 20-30% 1 RM
Incorporate with:

1. Leg Extension 90-45 deg
2. Partial Squat
3. Partial Leg Press

WEEK 2-6

Continue BFR
1-3 exercise per muscle group
LOP 40-80%
30-15-15-15 @ 20-30% 1 RM
Incorporate with:

1. Squatting
2. Leg Press
3. Lunges
4. Leg Extension

WEEK 6+

Once able to tolerate heavier loads, use PRN.

CASE STUDY

A 18-40 year old male/female underwent right supraspinatus repair 3 weeks ago. No complications.

Initiate BFR
One exercise per muscle group
LOP 30-40%
Duration-based, 5 min x 2-3 sets
Incorporate with:
1. ER/IR isometrics or during NMES (5-10 minutes)
2. Bicep/Tricep

WEEKS 2-4

Continue BFR
One exercise per muscle group
LOP 40-50%
30-15-15-15 @ 20-30% 1 RM
Incorporate with:
1. Assisted Motions
2. Bicep/Tricep

WEEK 4-6

Continue BFR
One exercise per muscle group
LOP 40-60%
30-15-15-15 @ 20-30% 1 RM
Incorporate with:
1. Overhead Press
2. Scaption
3. Row
4. Bicep/Tricep

WEEK 6+

Once able to tolerate heavier loads, use PRN.

CASE STUDY

A 18-40 year old male/female athlete with an acute onset of right anterior knee pain. Unable to tolerate squatting, lunging, plyometric, or running.

Modify current training program if applicable

Initiate BFR

One exercise per muscle group

LOP 40-60%

30-15-15-15 @ 20-30% 1 RM

Incorporate with:

1. Leg Extension
2. Partial Squat or Lunge

WEEKS 0-2

Continue BFR
One exercise per muscle group

LOP 40-80%

30-15-15-15 @ 20-30% 1 RM

Incorporate with:

1. Leg Extension
2. Full Squat or Lunge

WEEK 2-4

Work slowly back into running
Continue BFR
One exercise per muscle group
LOP 40-80%
30-15-15-15 @ 20-30% 1 RM

Incorporate with:
1. Squat or Lunge

WEEK 6+

Once able to tolerate heavier loads, use PRN.

EMERGENCY PROCEDURES

BRUISING/DISCOMFORT

A bruise forms when blood vessels under the skin break. The trapped blood creates a bruise that's black, purple or blue then changes color as it heals.

You can enhance bruise healing with a few simple techniques.

1. Elevate the bruised area above heart level, if possible.
2. Apply an ice pack wrapped in a thin towel. Leave it in place for 20 minutes. Repeat several times for a day or two after the injury. This helps to reduce the pain.
3. If the bruised area is swelling, put an elastic bandage around it with light compression.

If the skin isn't broken, you don't need to bandage a bruise. Consider taking a nonprescription pain reliever if needed.

FAINTING

1. Position the person on the back. If there are no injuries and the person is breathing, raise the person's legs above heart level if possible. Prop up the person's legs about 12 inches (30 centimeters). Loosen belts, collars or other tight clothing.
2. To reduce the chance of fainting again, don't get the person up too fast. If the person doesn't regain consciousness within one minute, call 911 or your local emergency number.
3. Check for breathing. Check for a pulse and to see if the person is breathing.
4. If the person is not breathing, begin CPR. Call 911 or your local emergency number. Continue CPR until help arrives or the person begins to breathe.

DOCUMENTATION GUIDELINES

CHECKLIST FOR LIABILITY

1. DEVICE USED
2. ARTERIAL OCCLUSION PRESSURE
3. POSITION AOP ASSESSED
4. % AOP USED DURING EXERCISE
5. EXERCISES PERFORMED
6. REPETITIONS USED
7. TIME UNDER OCCLUSION
8. CONTINUOUS OR INTERMITTENT OCCLUSION
9. SUBJECTIVE ASSESSMENT

EXAMPLE

SMART CUFF 4.0, LARGE, LOP = 140MMHG, ASSESSED IN SUPINE, LEG CURL ON MACHINE, 10 LB @ 50% AOP, 30-15-15-15 REPS, 30 SEC REST B/W SETS, CONTINUOUS APPLICATION, 5 MIN TOTAL TIME UNDER OCCLUSION, PATIENT TOLERATED WITHOUT COMPLAINT