Practical Application of Blood Flow Restriction Training

Stanford Health Care Ortho Sports Medicine Rehab

Orthopedic Residency Elective Course

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Thank you

Hand Therapy Association of California

Educational Committee Co-Chairs

- Minnie Mau
- Chelsey Kratter

Resources

1. Pre-Webinar Slides PDF
2. Blood Flow Restriction Practical Application Manual
3. Live-Webinar Slides PDF
4. Additional Resources: https://www.youtube.com/@MichaelJeanfavre

Presentation – BFR: http://bit.ly/491hPqF

JM4
JM5
JM6

The Objective

Individual Therapists

OP Physical Therapy Department

Stanford Health Care Physical Therapy

Individual Patients

~ 600 Patients / week
~ 800 Visits / week

Collective Mind

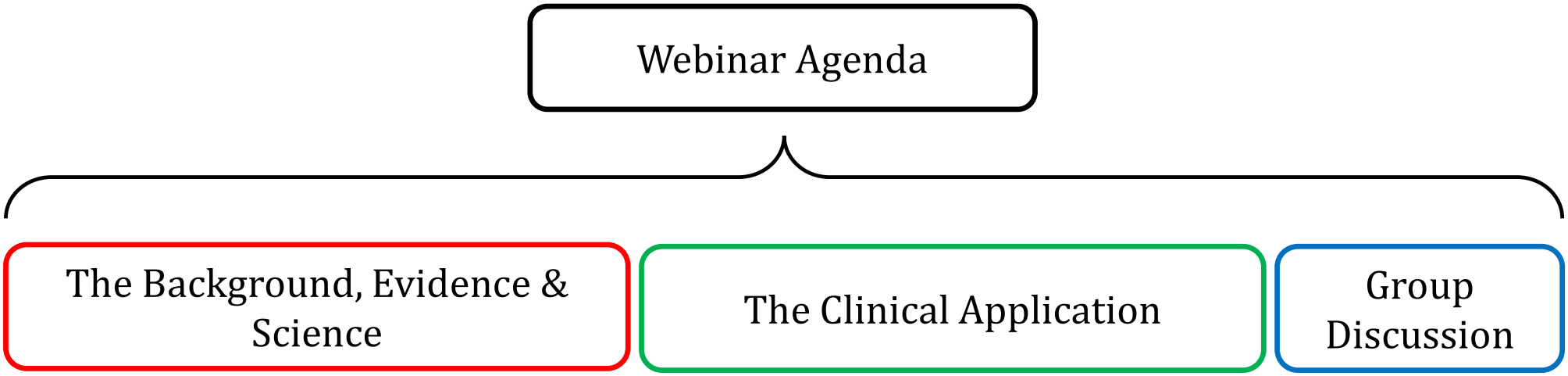
Slide 4

JM4 add in THE PEOPLE YOU WANT TO DIRECTLY EFFECT and the PEOPEL YOU WANT TO INDIRECTLY AFFECT
Jeanfavre, Michael, 4/1/2019

JM5 Tell people how we should view the WORLD and how we should view OURSELVES inthe world of PT
Jeanfavre, Michael, 4/1/2019

JM6 We should be a beacon of excellence! No from a place of ego but from a place of raising the bar and inspiring others to do the same.
Jeanfavre, Michael, 4/1/2019

Outline


Webinar Agenda
The Background, Evidence & Science
The Clinical Application
Group Discussion

Objectives

Be	The audience will be able to:
Algorithm	Describe an algorithmic decision making process to identifying appropriate patients for blood flow restriction training (BFRT)
Utilize	Utilize best evidence screening process to stratify patients' risk of adverse response(s) to BFRT
Perform	Perform a limb occlusion pressure (LOP) using the ultrasound doppler for the upper and lower extremity
Determine	Determine the optimal occlusion and exercise parameters for BFRT
Verbalize	Verbalize evidence and criterion-based clinical progression of BFRT

Objectives

The audience will be able to:

- Describe an **algorithmic decision-making process to identifying appropriate patients** for blood flow restriction training (BFRT)
- Utilize best **evidence screening process** to stratify patients' risk of adverse response(s) to BFRT
- **Perform a limb occlusion pressure (LOP)** using the ultrasound doppler for the upper and lower extremity
- Determine the **optimal occlusion and exercise parameters** for BFRT
- Verbalize **evidence and criterion-based clinical progression** of BFRT

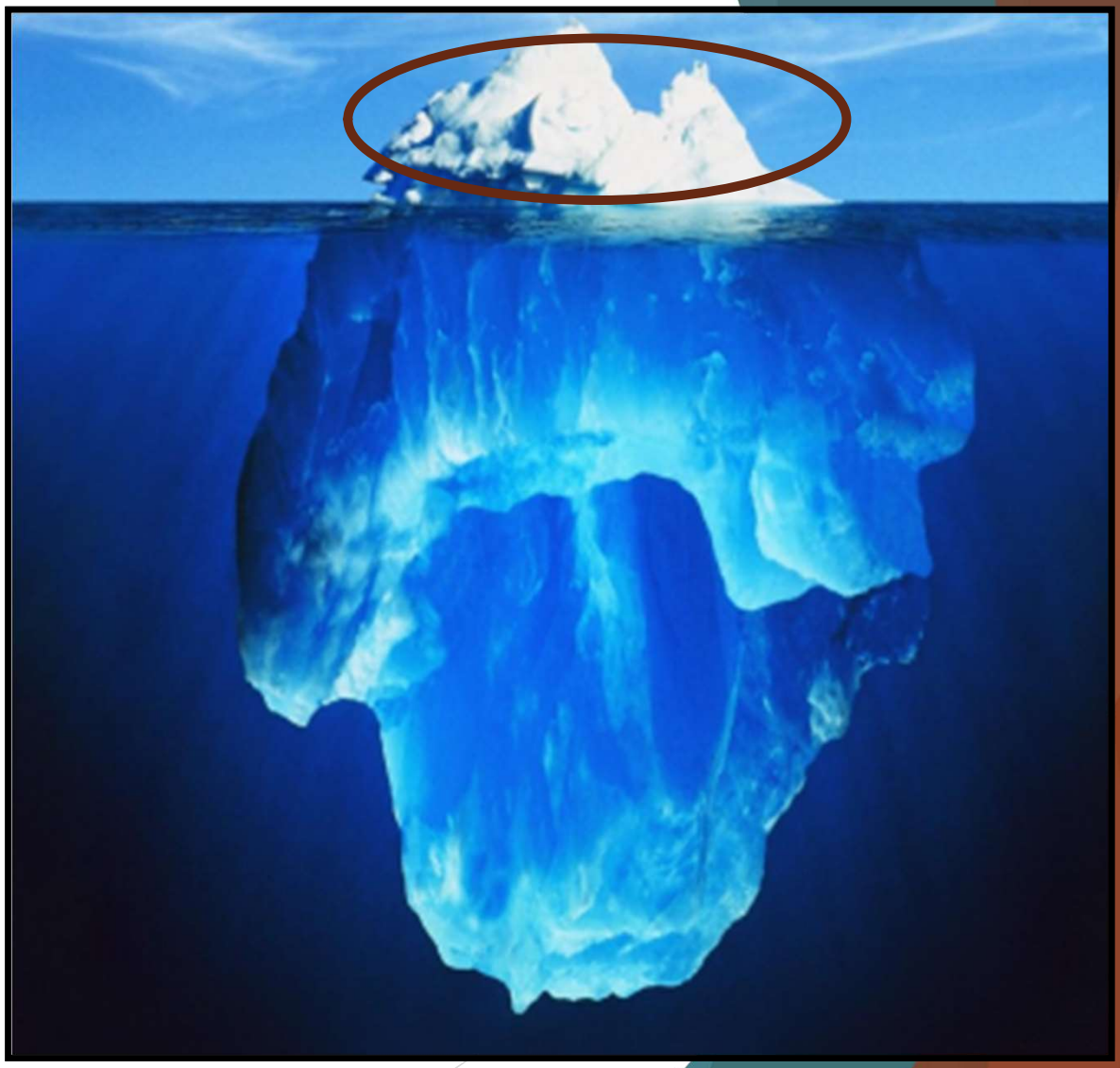
Objectives

The Background & Science

1. What is blood flow restriction training (BFR)?
2. How does it *actually* produce said adaptations? *(Pre-material)*
3. Why would I consider using BFR? AND Who can benefit from BFR?
4. What does the evidence say about the effectiveness of BFR? *(Pre-material)*
5. How do I safely apply BFR in the clinical setting?
    1. Is it *truly* safe? And for who?
    2. What are the risks & side effects?
    3. How do I know if my patient is appropriate?
6. Practical/Clinical Application

JM4
JM5
JM6

The Objective



Slide 9

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Introduction

Defining the problem

The Problem

Injury & immobilization leads to:

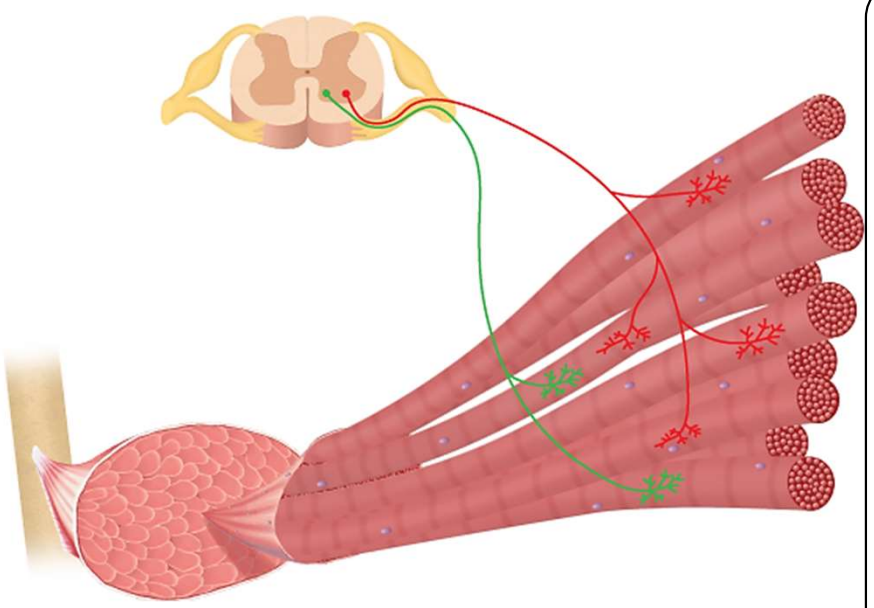
- ⬆ Pain
- ⬆ Inflammation
- ⬇Tissue integrity
- ⬇ Threshold to mechanical stimuli

Secondary implications of:

- ⬆ Muscle atrophy within 5 days of immobilization
- ⬇ Muscle strength (⬇ 14.8% in 14 d, ⬇ 21% after 23 d,) endurance, power
- ⬇ Tendon stiffness & CSA (⬇ 30% in 21 d)
- ⬇ Neural excitability & neural drive within 7 days

Muscular Adaptation to Aging & Immobilization

- ⬇Cross Sectional Area
- ⬇ # of Muscle Fibers
- ⬆ Size of Motor Units
- ⬇ # of Motor Units
  (⬇40% by age 70)
- ⬆ Muscle Fiber Grouping
- ⬇ # of Type I<Type II



- ⬆ Muscle Fiber Variability
- ⬆ Non-Contractile Tissue
- ⬆ Intra-muscular Adipose Tissue
  (⬆ Intra-muscular inflammatory markers)

- ⬇ # of Satellite Cell
- ⬇Vascular Conductance
  (⬇ O^2 Demand, ⬆ sympathetic vasoconstriction)
- ⬇Vascular Compliance
  (⬇ Blood Flow, Nutrient & Metabolite Exchange)

Resultant Muscle Functional Impairments

- ⬇ Muscle Force
  (⬇ CON & ISO > ECC)
  (⬇ M: 3-4%/yr | F: 2.5-3%/yr)
- ⬇ Muscle Power
  (⬇ ~12.5%/Decade)
- ⬇ Insulin Sensitivity
- ⬇ Response to Mechanical Stimuli
- ⬇Amino Acid Sensing
- 40%⬇Muscle Fiber Contraction Velocity

Stanford University

Defining Blood Flow Restriction Training

Objective #1: **What is Blood Flow Restriction training (BFR)?**

Objective #2: **How does it induce the proclaimed adaptations? (*Pre-material)***

Blood Flow Restriction – Definition

- Entails apply a **tourniquet-style cuff** on the proximal aspect of a limb(s)
- Cuff is tightened & pneumatically inflated to a pressure that **occludes venous flow yet allows arterial inflow**

VanWye 2017

The Solution?

= Deflated Cuff = Inflated Cuff = Arterial Blood Flow = Venous Blood Flow = Metabolite

= Active Motor Neuron = Fatigued Motor Neuron = Active Muscle Fiber = Fatigued Muscle Fiber

The Solution?

= Deflated Cuff = Inflated Cuff = Arterial Blood Flow = Venous Blood Flow = Metabolite

= Active Motor Neuron = Fatigued Motor Neuron = Active Muscle Fiber = Fatigued Muscle Fiber

Mechanisms of BFR – Hypertrophy: Primary Factors

Mechanical Tension - formed by active (cross bridge) muscle elements & exerted via passive elastic components, such as fascia & tendon, both in series and in parallel[19]

↑ External Force/Intensity

↓

↑ Active/Passive Contraction

↓

↑ Force Production

↓

↑ Mechanical Tension

(Goldberg 1975, Spangenberg 2008, Vandenburgh 1979)

Metabolic Stress - physiological process that occurs during exercise in response to low energy that leads to metabolite accumulation [lactate, phosphate inorganic (Pi) and ions of hydrogen (H^+)] in muscle cells[20]

High Volume Training

{4-5 sets with 6-12 reps per set}

↓

More Metabolic Stress

↓

Accumulation of Metabolites like lactate, hydrogen ion, etc

↓

More Anabolic hormones and other growth factors

Mechanisms of BFR – Hypertrophy: Primary Factors

Mechanical Tension

Leads to hypertrophy via:

- Mechanotrasduction[27, 29, 30]
- ↑ localized hormone production[31]
- Muscle damage[32]
- ROS production[32, 33]
- ↑ fast twitch fiber recruitment[24-26]

Metabolic Stress

Leads to hypertrophy via:

- ↑ systemic hormone production[34]
- ↑ fast-twitch fiber recruitment[35, 36]
- Cell swelling[37]
- Muscle damage[27, 38]
- ↑production of ROS[27, 39-41]

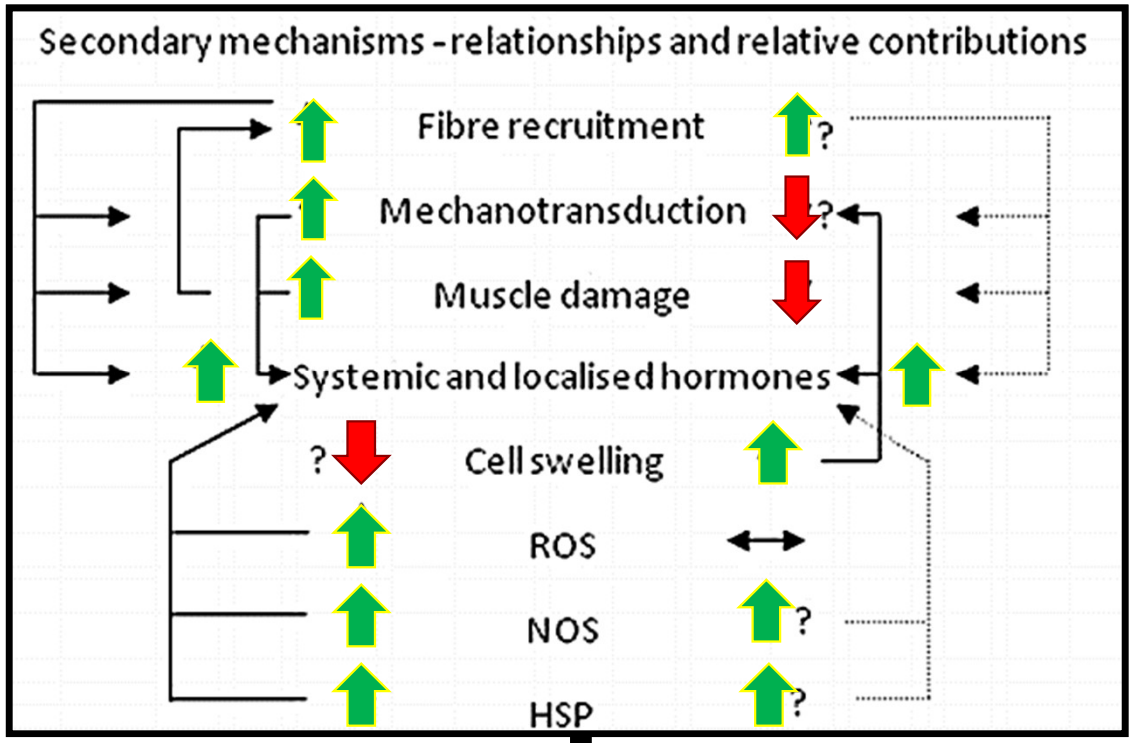
Mechanical Tension + Metabolic Stress = Muscle Hypertrophy

High Intensity Resistance Training

Low Intensity + BFR Resistance Training

LOW **Metabolic Stress** HIGH

HIGH **Mechanical Tension** LOW

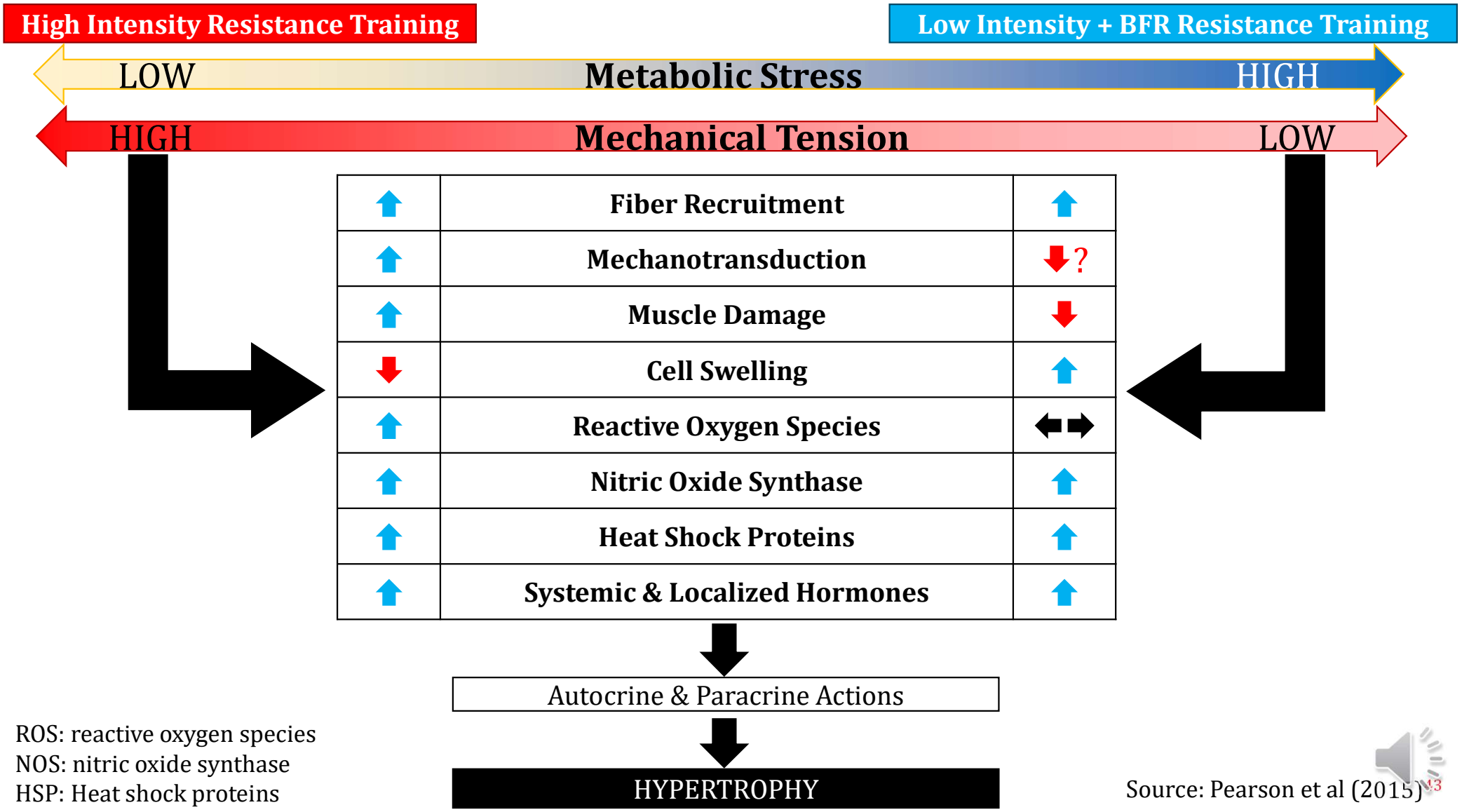


Autocrine & Paracrine Actions

HYPERTROPHY

ROS: reactive oxygen species
NOS: nitric oxide synthase
HSP: Heat shock proteins

Source: Pearson et al (2015)



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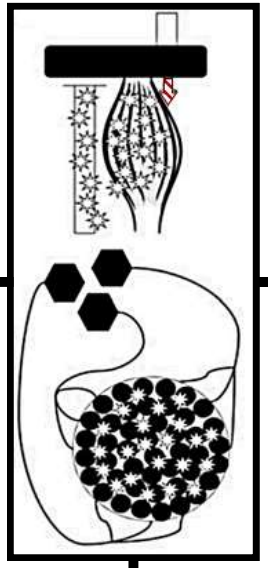
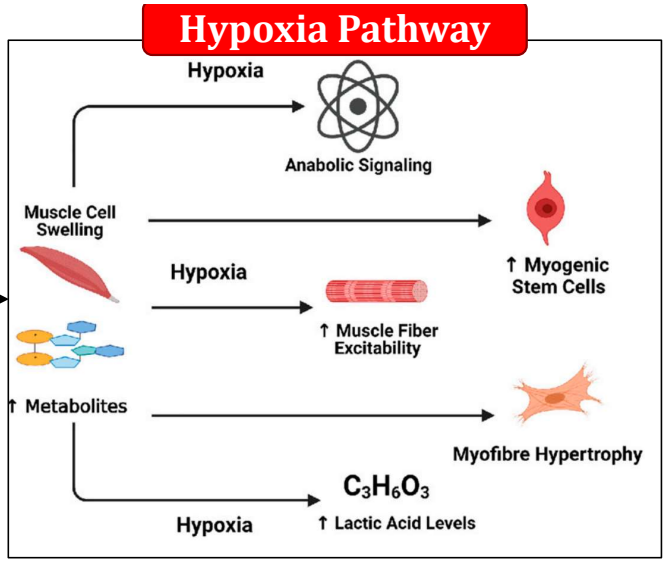
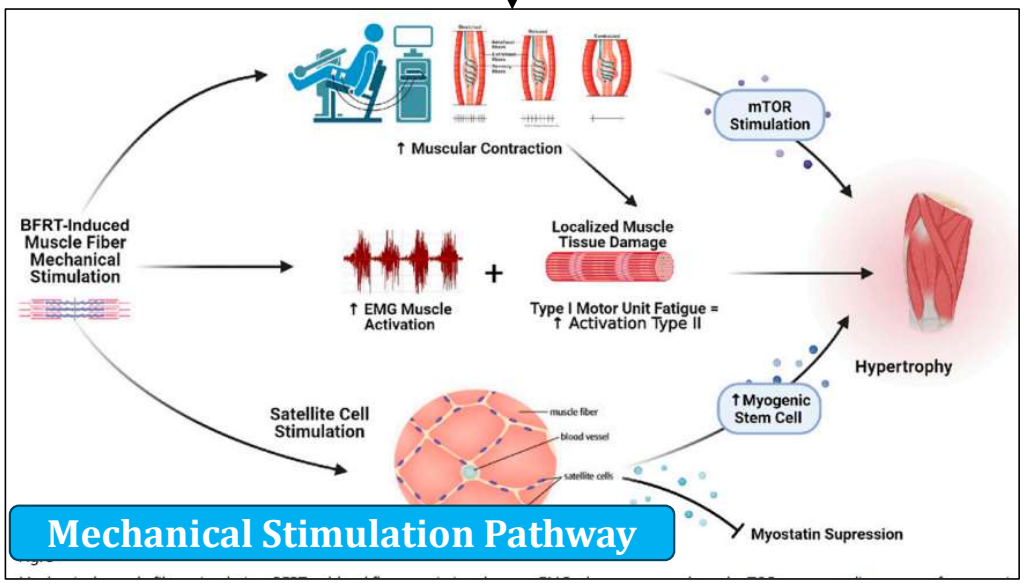
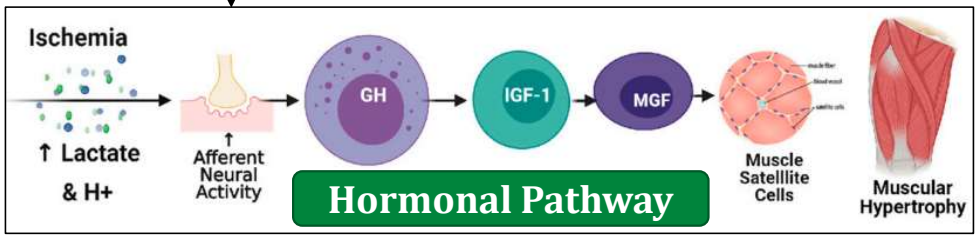
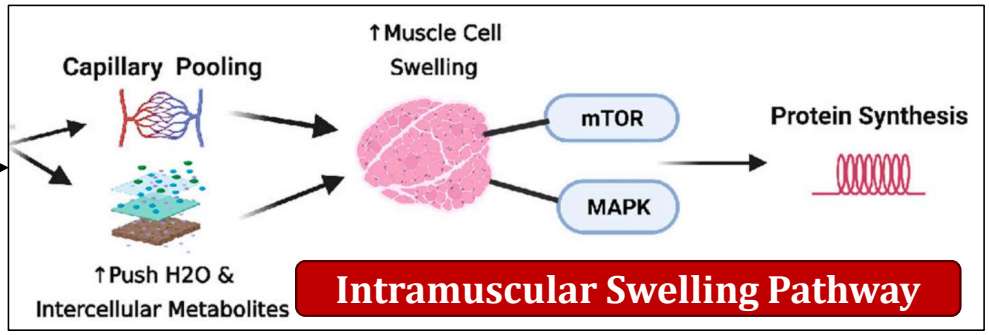
Mechanisms of BFR



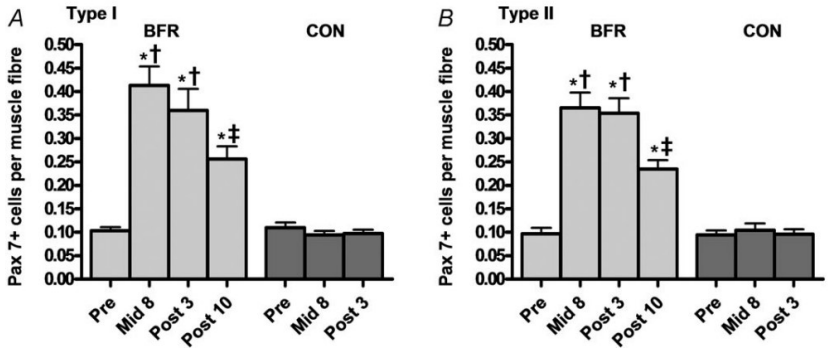








Mechanisms of BFR

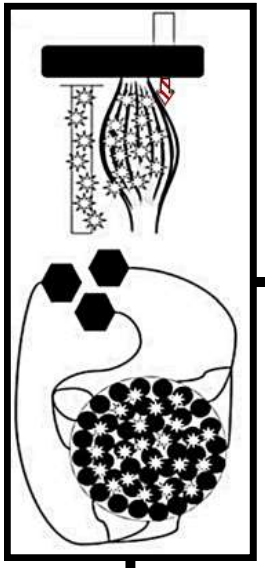


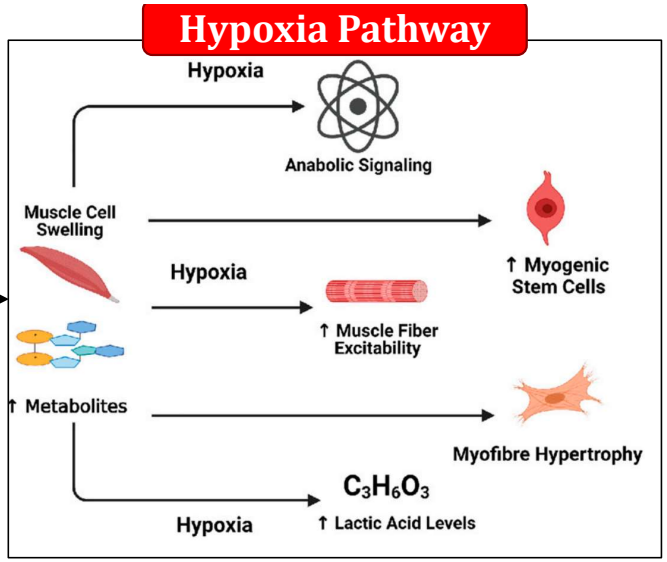
Nielsen 2012

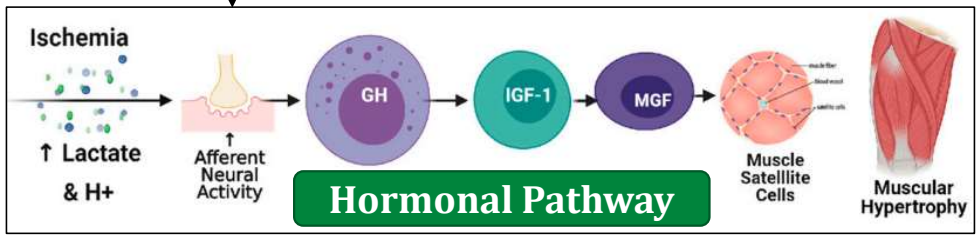
Blood flow-restricted strength training displays high functional and biological efficacy in women: a within-subject comparison with high-load strength training

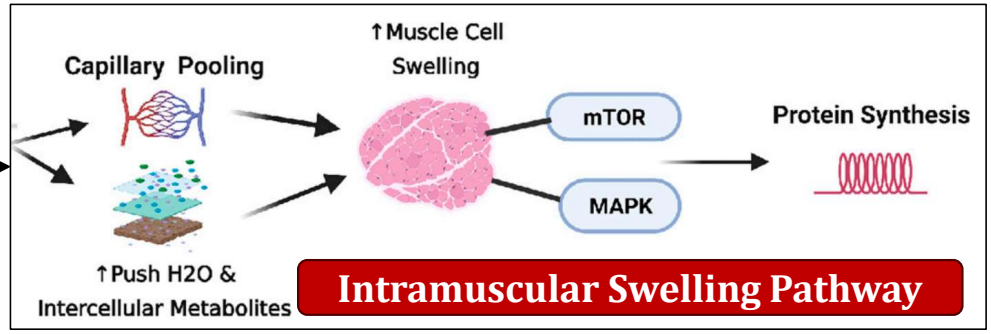
Ellefsen 2015

Crossover Design Study.
12 weeks 2x/wk of BFR & HST resulted in **similar changes in 29 genes involved in skeletal muscle function** (after single session & after12 sessions)

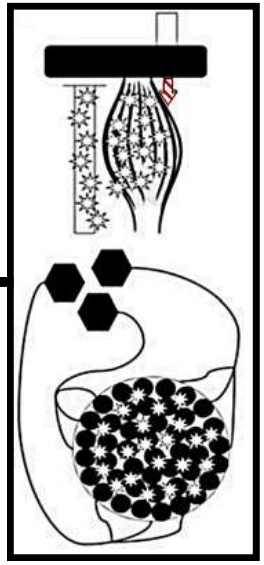


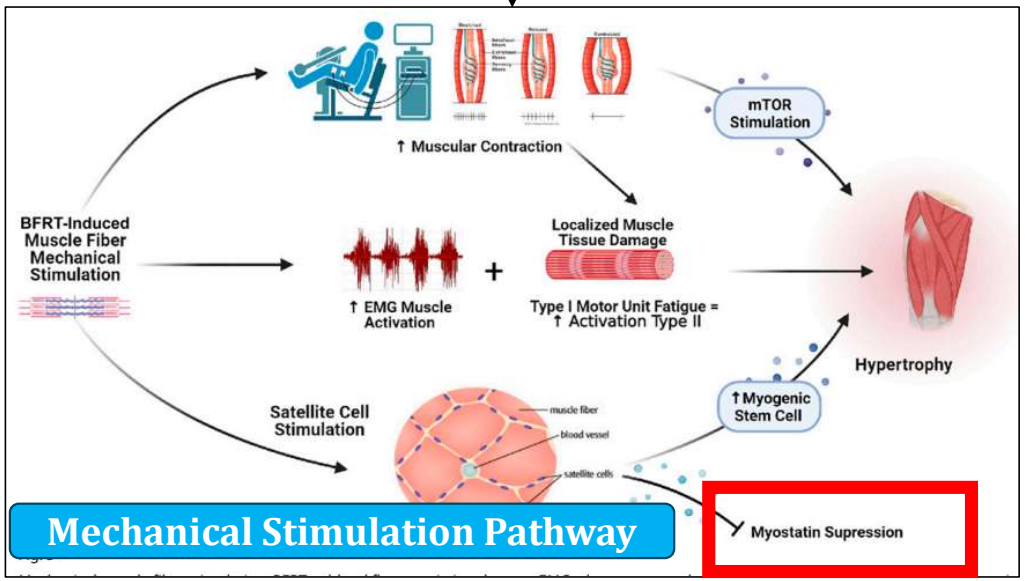


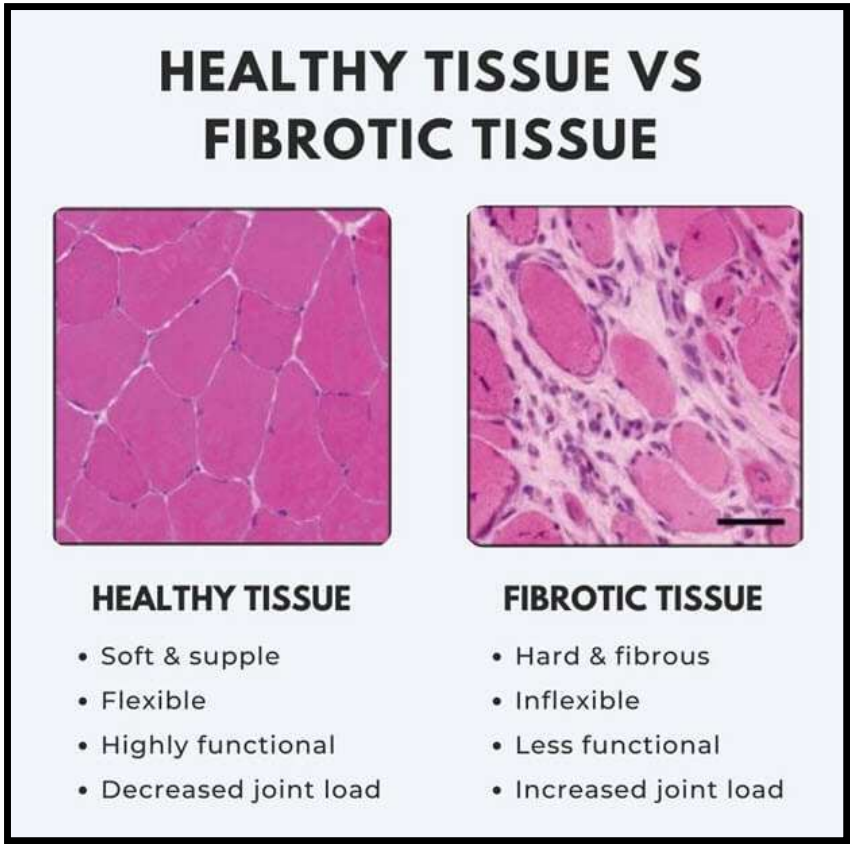




Mechanisms of BFR

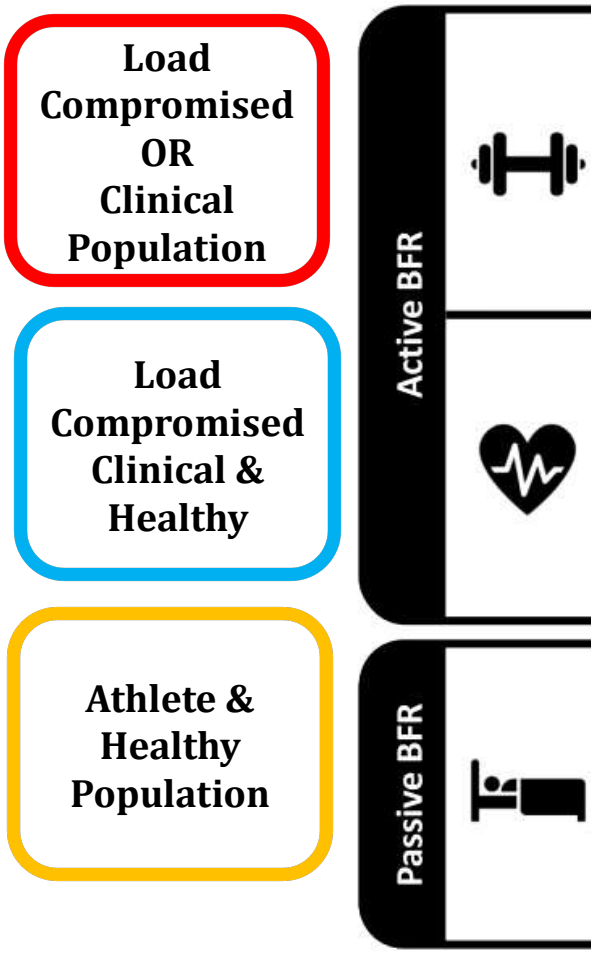






Blood Flow Restriction – Definition

Scott 2023



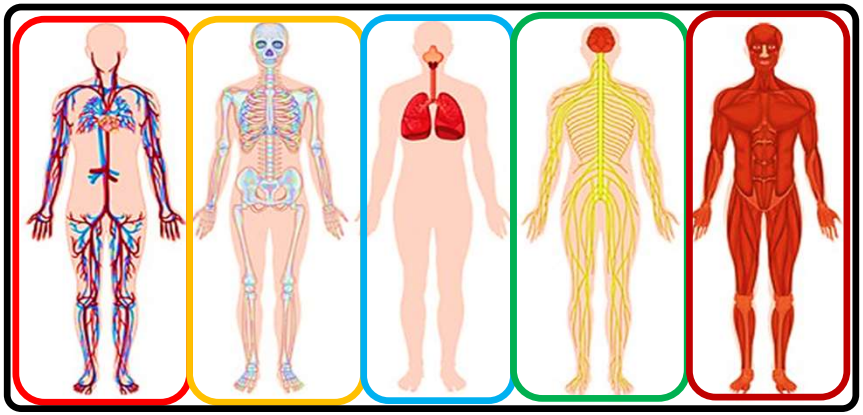
Indications of Blood Flow Restriction

Objective #3: **WHY would I consider using BFR? And for WHO?**

Indications of Blood Flow Restriction: Why?

Cardiovascular System
- ⬆ Peak VO2 by 4x (vs control)[1,2]
- ⬆ 70% Heart Index[1]
- Improved arterial compliance[13]
- 15.4% ⬆ Time to Cycle Exhaustion[4]
- ⬆ Peripheral Vasodilation[1]
- ⬆ Hypoxia-inducible factor 1 alpha (HIF-1A)➡vascular endothelial growth factor (VEGF) expression & angiogenesis[1]
- ⬇ SBP (chronic adaptation) & improved HR recovery in HTN[12]

Nervous System
- ⬆ EMG by 50% (vs LL-RT)[7,2]
- ⬇ short-interval intracortical inhibition (SICI)[8]
- ⬆ NM fatigue via group III & IV afferent fibers[1]
- ⬆ Corticospinal excitability ➔ influence in force capacity of the NM system → long term changes in recruitment pattern[9]
- ⬇ Pain & ⬆ Exercise induced hypoalgesia[10,11]



Muscular System
- ⬆ Type II MFs & ⬆ EMG [3,2]
- ⬆ Muscle hypertrophy, strength & endurance (vs LL-RT)[3]
- ⬆ activation of mm stem cells[1]
- ⬆ mm ATP & glycogen stores ➡ improved mm endurace[5]
- ⬆ GLUT-4 translocation & glycogen synthase activity[5]
- ⬆ Tendon CSA & stiffness comparable to HL-RT[17]
- ⬇ pain & ⬆ tendon function in tendinopathy population[17,18]

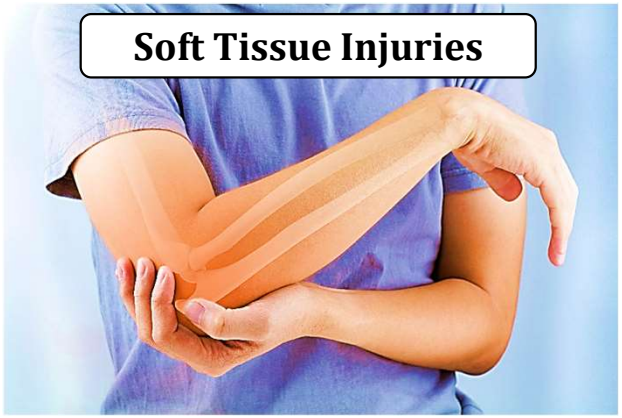
Bone
- Acute ⬆ bone-specific alkaline phosphate (BALP) & osteocalcin (BGP)[14]
- ⬆ BMD & bone microstructure (vs LL-RT)[14]
- ⬆ preservation of BMD & bone microstructure & muscle mass in bone stress injuries[4]

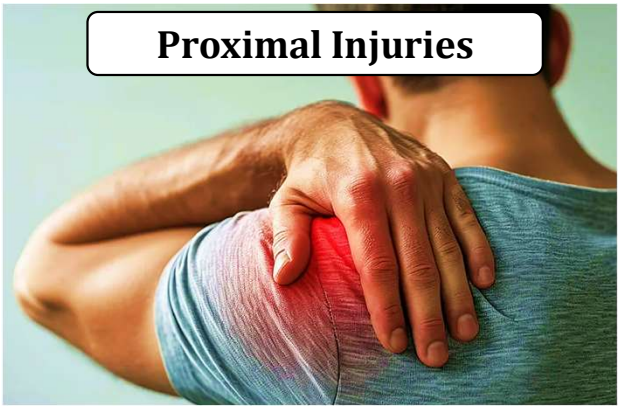
Metabolism
- ⬆ GLUT-4 expression & glucose uptake[5]
- ⬆ mitochondria biogenesis & density & function[16]
- ⬆ mitochondrial pro synth rates & oxidative capacity[19]

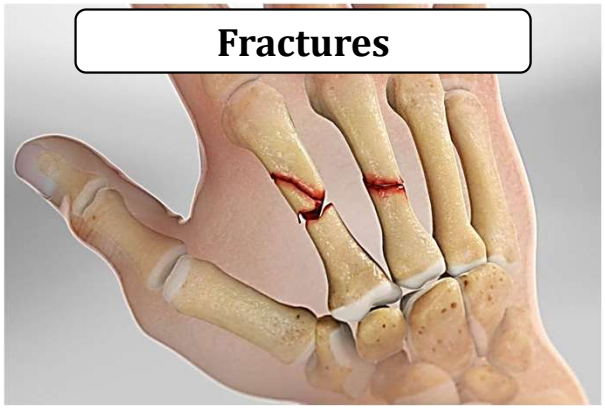
Endocrine System
- ⬆ GF (290x)[6], Cortisol, IGF-1[3,2]
- ⬆ Stimulation of mTOR[3]
- ⬆ Testosterone (acute elevation)[14]
- ⬆ VEGF (promote angiogenesis & ⬆ blood flow & volume to occluded limb

Cahalin 2022[1], Tanaka 2018[2], Pope 2013[3], Abe 2010[4], Burgomaster 2003[5], Cartee 1985[6], Tanaka 2000[6], Morintani 1992[7], Centner 2020[8], Jessee 2018[9], Song 2021[10], Hughes 2020[11], Zhao 2022[12], Liu 2021[13], Bemben 2022[14], Golden 2024[15], Franz 2023[16], Cetner 2021[17], Karanasios 2022[18], Kristian 2020[16]

Indications of Blood Flow Restriction: Why?

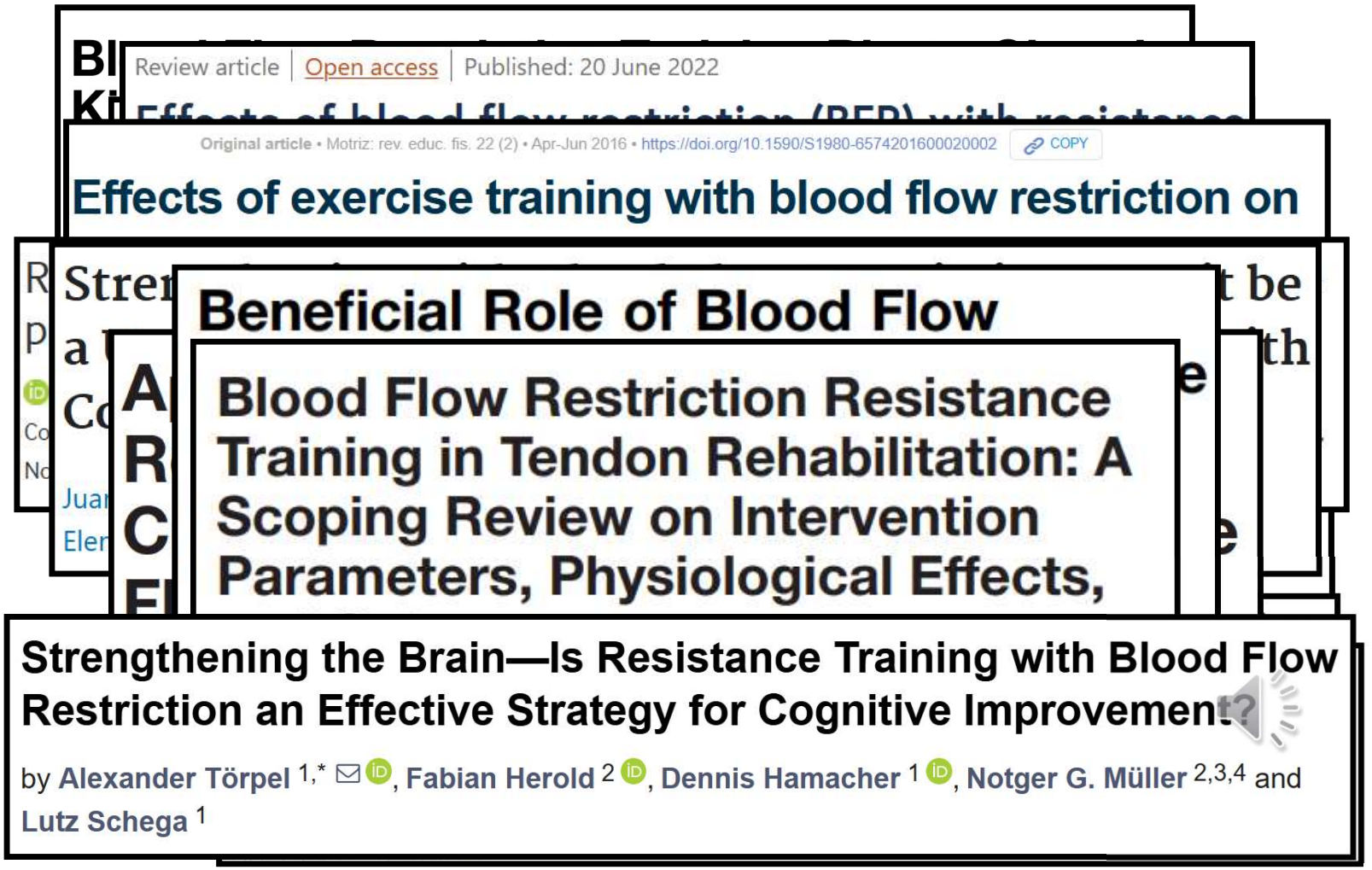






Indications of Blood Flow Restriction: Who?

- **Any Gender**
- **Ages: 13+**
- **Healthy**
- **Injured**
- **Athletic**
- **CVD**
- **HTN**
- **Osteoporosis**
- **TII Diabetes**
- **Post COVID**
- **COPD**
- **Neurological Diseases**
- **Cognitive Decline**
- **Kidney Disease**
- **COPD**
- **Tendinopathy**



Efficacy, Effectiveness, & Evidence of Blood Flow Restriction Training

Objective #4: **What does the evidence say about the effectiveness of BFR?** ***(Pre-material)***

So What?!

KEY POINTS

Key Summary Points & Take Aways

Practical Implications

- **Low load BFR** with *proper screening* is **safe & effective** for a variety of **clinical populations** and particularly individuals **rehabbing from musculoskeletal injuries**[1-6]
- Individuals with **non-communicable diseases** (i.e., DMII[3], CVD[2], Neurodegenerative[4], CKD[6], COPD[5], etc.), with **proper precautions**, may also *benefit* from LL-BFR regimens.
- BFR offers a variety of positive physiological adaptations beyond just muscle specific adaptations[1]
  - ⬆ **bone turnover**[7]
  - ⬆ **metabolic function** & ⬆ **mitochondrial biogenesis, density & function**[8,9]
  - ⬆ **cardiovascular peripheral** & **central adaptations** (arterial compliance, angiogenesis, blood flow)[10,11]
- Incremental **graded exposure** & **systematic progression** of BFR, with i**ndividualized LOP**, exercise **prescription**, and of sufficient **duration** (≥4 weeks) & **frequency** will assist with optimizing physiological adaptations.[1]

Hughes 2017[1], Angelopoulos 2023[2], Saatmann 2021[3], Vinolo-Gil 20223[4], Kohlbrenner 2023[5], Corrêa 2021[6], Bemben 2022[7], Franz 2023[8], Cetner 2021[9], Cahalin 2022[10], Liu 2021[11]

So What?!

KEY POINTS

Key Summary Points & Take Aways

Practical Implications

- Low load BFR on the upper extremity improves **muscle strength**, muscle **hypertrophy**, and **pain reduction** than is low load resistance training[1,3-5]
- Positive muscle performance improvements in the **proximal muscle** groups is dependent upon:
  - LOP Pressure & duration of occlusion
  - Training volume threshold (i.e., proximity to muscle failure) [1,4]
  - Duration (>6 weeks) and frequency (3x/wk > 2x/week) [1,5]
  - Methods of measurement (i.e., DEXA > circumference measurement)[4]

Bowman 2020[1], Dankel 2016, Fan 2023[3], Pavlou 2023[4], Chang 2023[5],

So What?!

KEY POINTS

Key Summary Points & Take Aways

Practical Implications

- Low load BFR on the upper extremity improves **muscle strength**, muscle **hypertrophy**, and **pain reduction** than is low load resistance training[1,3-6]
- Particular emphasis on **eccentric muscle contraction (if resistance is normalized to ECC 1 RM)**[6] aspect of the exercise may help to enhance the strengthening & muscle performance of the **contralateral limb**[3]
- (1) **volume (fatigue sets),** (2) **multiple exercises (≥4),** (3) ⬆ **EMG activity** seem to be important prescription variables in order to induce **proximal** **muscle hypertrophy**, **strength**, and **endurance (work capacity)** during UE LL-BFR.[7]
- LL-BFR is not only **safe & effective,** but offers **significantly** ⬇pain, ⬆ muscle strength, and ⬆ function in the acute post operative phases of upper extremity rehabilitation (compared to traditional a protocol)[7-9]

Bowman 2020[1], Hill 2020, Fan 2023[3], Pavlou 2023[4], Chang 2023[5], Yasuda 2012[6], Lambert 2022[7], Fan 2023[8], Yang 2023[9]

Risk Stratification of Blood Flow Restriction

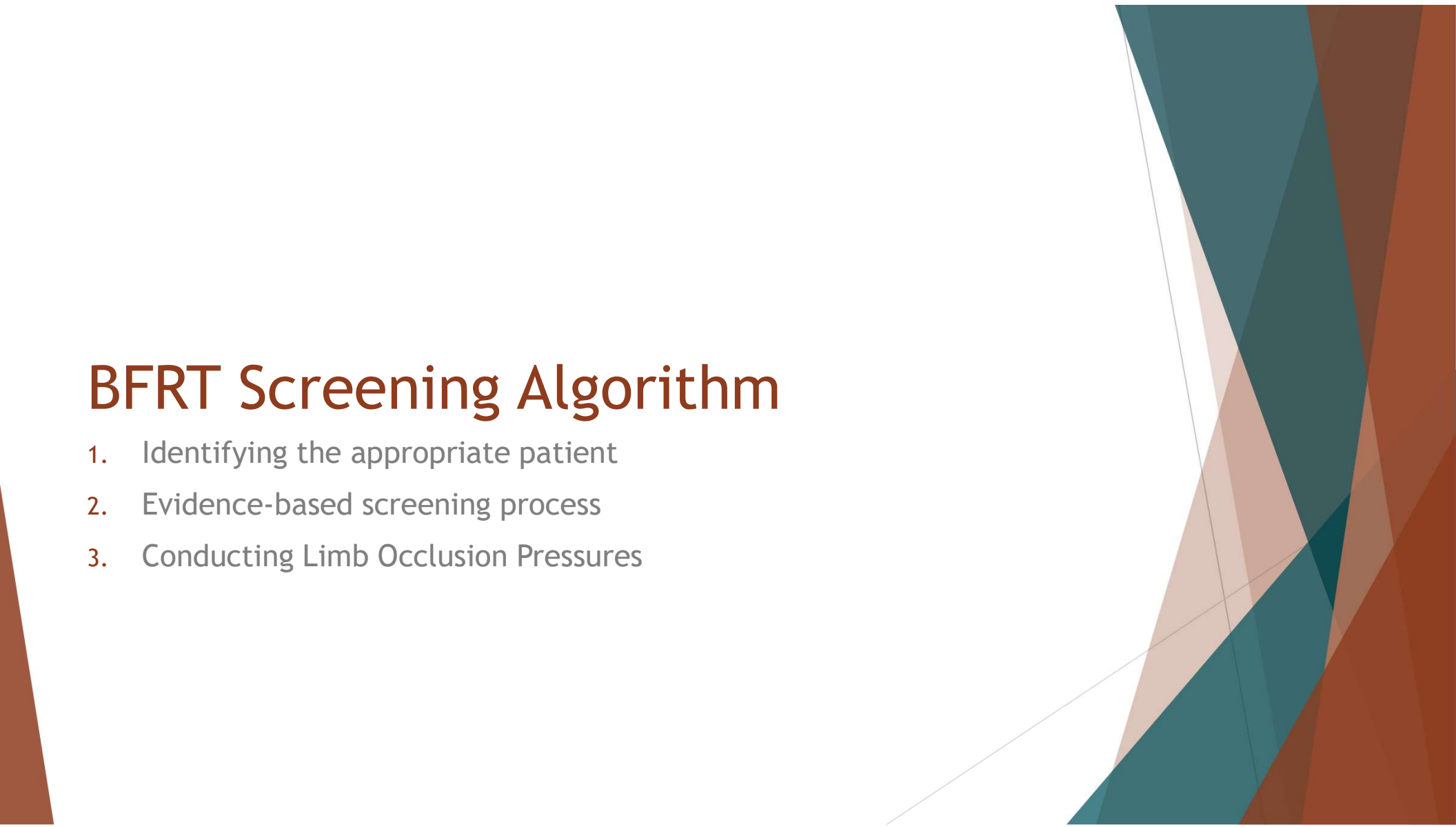
Objective #5: **How do I safely & effectively apply/use BFR in clinic?**

The Structured Process of BFR Implementation

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Screening	**Cuff Application**	**Cuff Pressure**	**Exercise Stimulus**	**Exercise Parameters**	**Monitoring & Progression**
Precautions & Contraindications	Location & Cuff Properties	Specific & Individualized Pressures	Type of Exercise	Dosage of Exercise	When & How to Progress

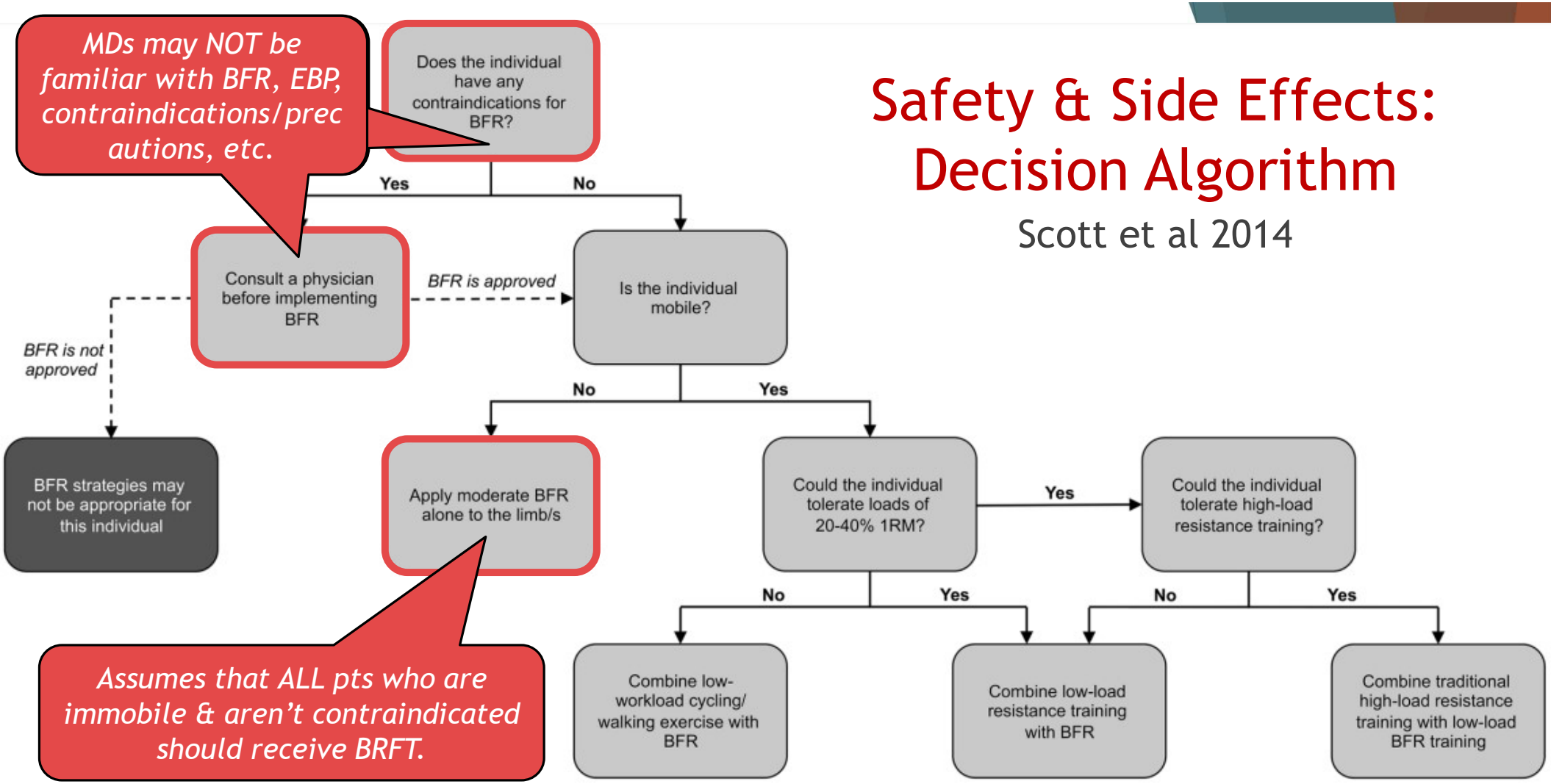
BFRT Screening Algorithm

1. Identifying the appropriate patient
2. Evidence-based screening process
3. Conducting Limb Occlusion Pressures



Safety & Side Effects: Decision Algorithm

Scott et al 2014



Algorithm biased toward BFRT application

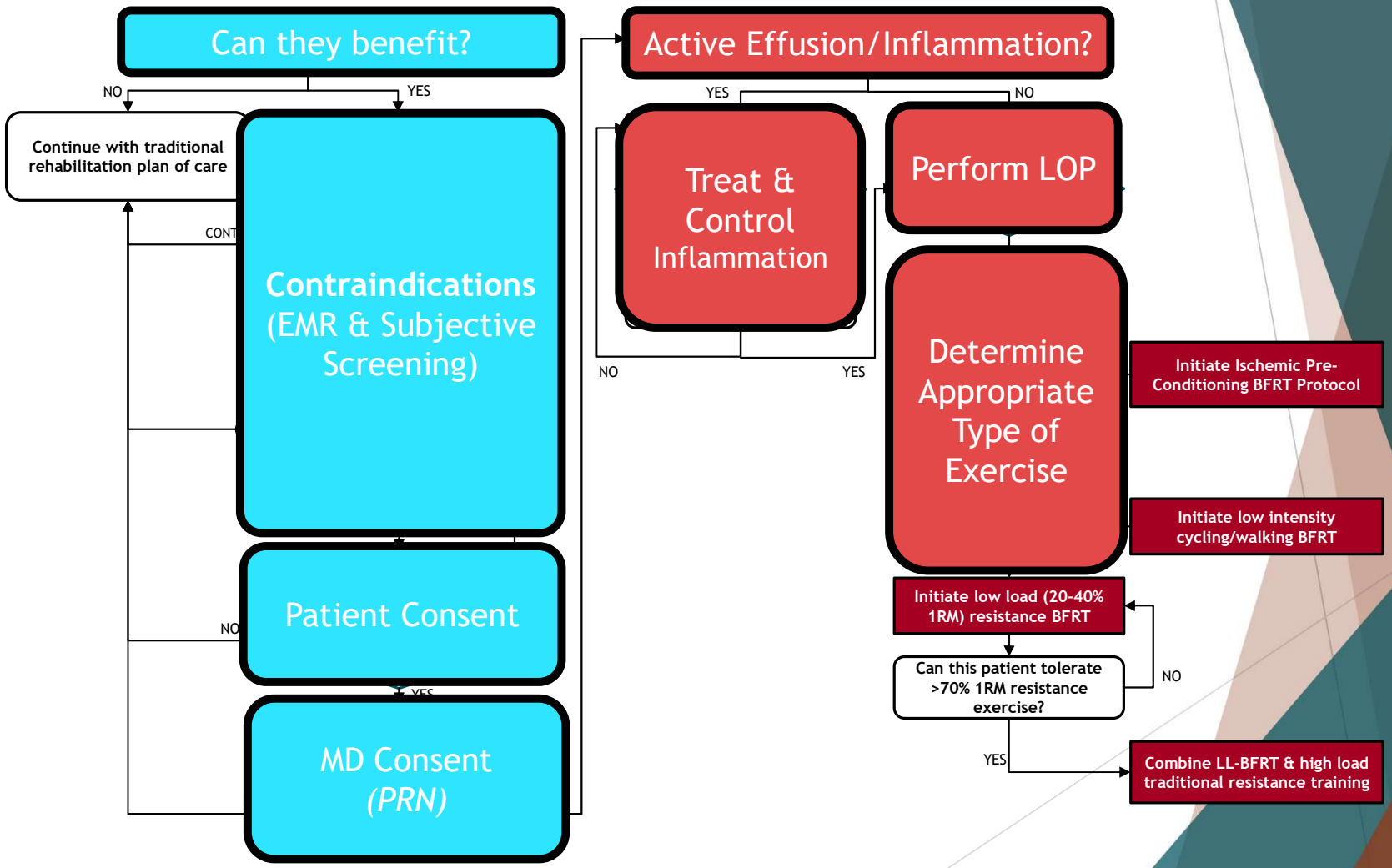
Metacognition of BFR Application

The clinician should contemplate some specific questions before the application of BFRT:

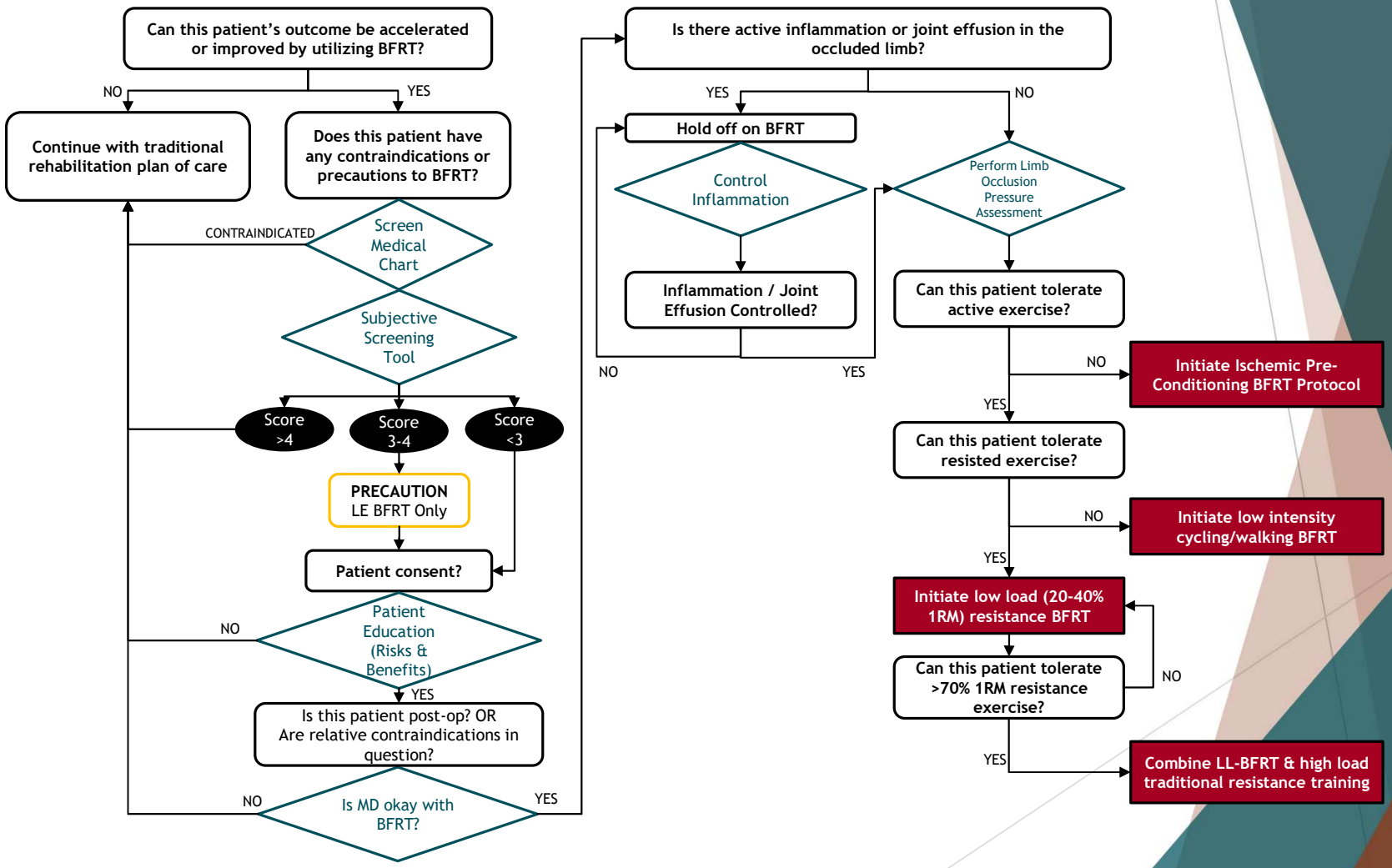
- Is my patient like the participants in the studies with BFRT?
- Does BFRT have a clinically relevant *benefit* (e.g., improved function or hypertrophy) that outweighs the potential *risks* of application?
- **Yes. Proceed with BFR screening algorithm**
- **No. Reconsider proceeding & BFR application**

Nascimento 2022

Blood Flow Restriction Training Screening Algorithm



Blood Flow Restriction Training Screening Algorithm

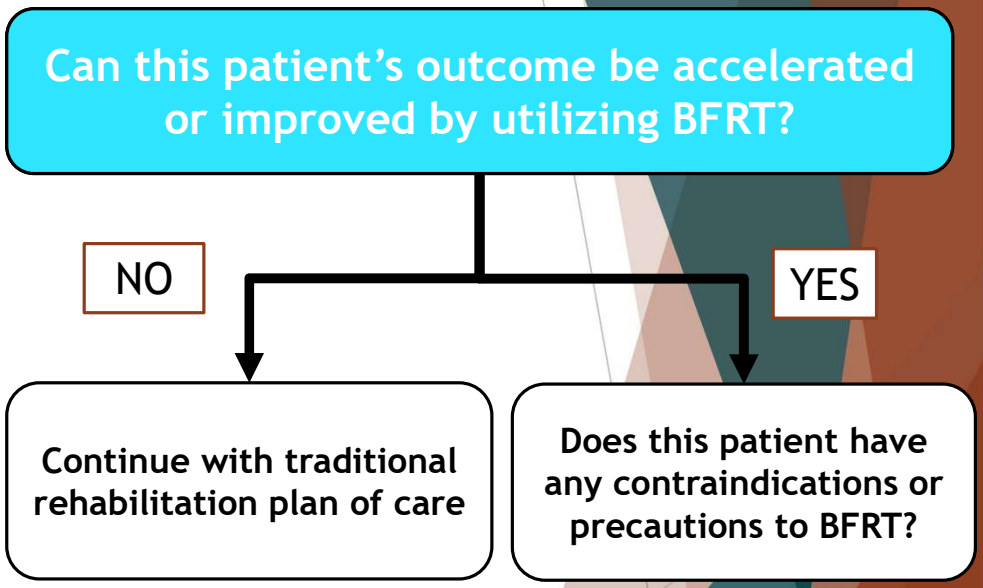


JM1

BFRT Screening Algorithm

Would the following physiological adaptations aid in this patient's rehabilitation?

Local Adaptation[3,4]	Systemic Adaptations[3,4]
Muscle Strength	Cardiovascular conditioning[2]
Muscle Hypertrophy	Vascular endothelial growth factor (VEGF) *formation of new blood vessels*
Satellite and progenitor cell activation for tissue healing and repair	Soft tissue repair (*endogenous growth factor and IGF-1*)
Blood flow and nutrient delivery	Cardiovascular compliance
Bone healing, growth, &/or positive remodeling[1]	Insulin Sensitivity
Tendon remodeling & ⬆ Cross Sectional Area	Ability to recovery from MACE or HIT



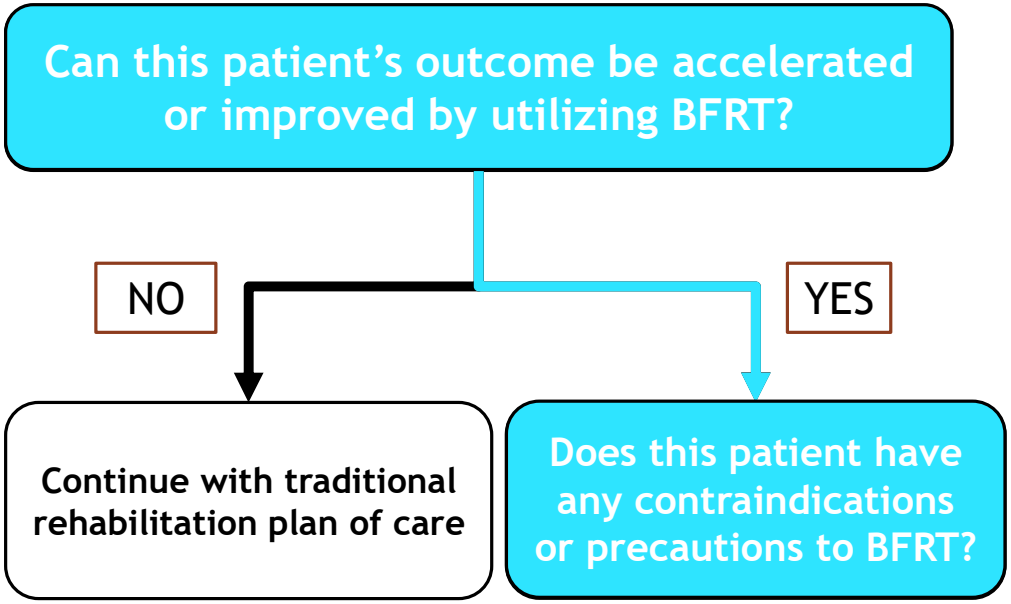
Bittar 2019[1], Centner 2019[2], Le Cara 2019[3], Owens 2015[4]

Slide 40

JM1 Add references
Jeanfavre, Michael, 1/11/2020

JM1

BFRT Screening Algorithm



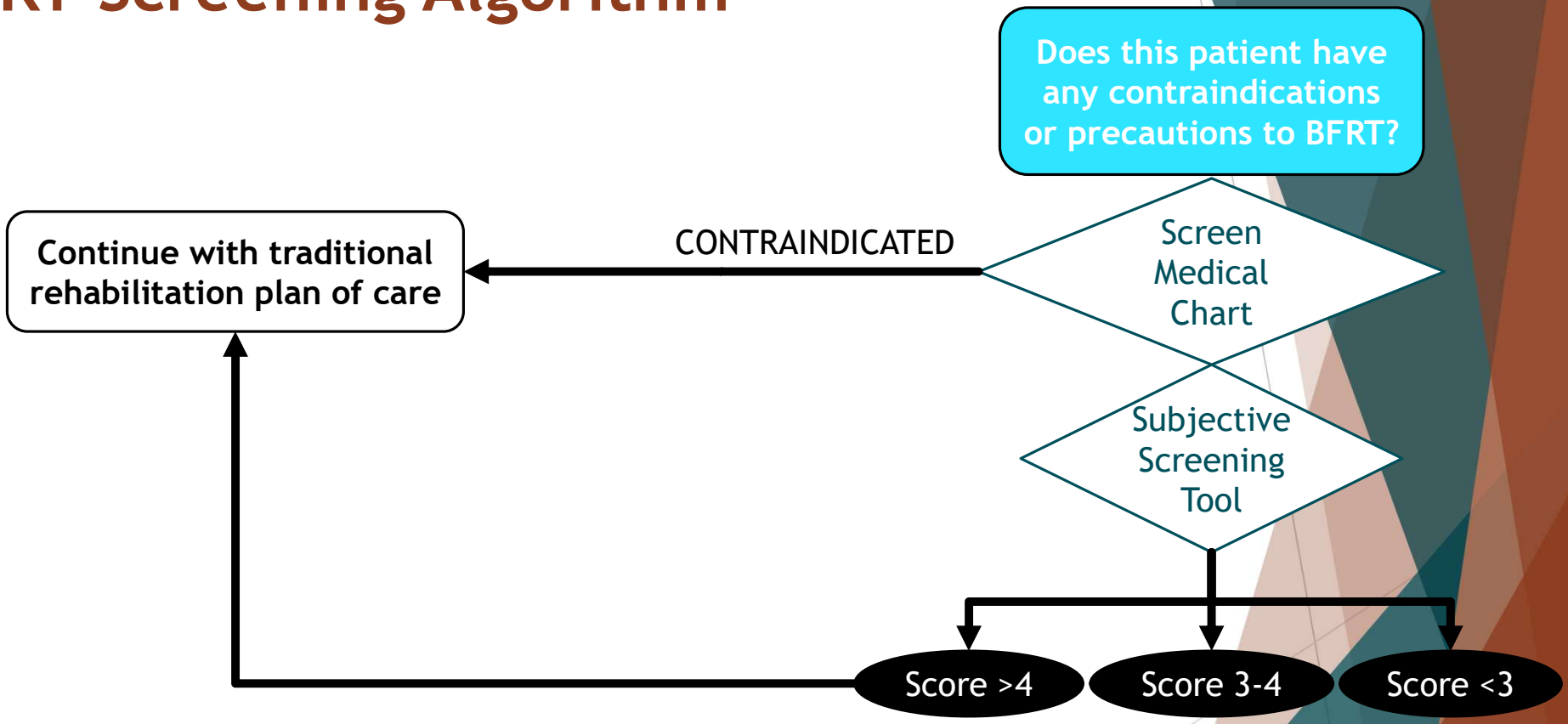
Scott 2014, Le Cara 2019, Owens 2015, Nakajijma 2011

Slide 41

JM1 Add references
Jeanfavre, Michael, 1/11/2020

JM1

BFRT Screening Algorithm



Scott 2014, Le Cara 2019, Owens 2015, Nakajijma 2011

Slide 42

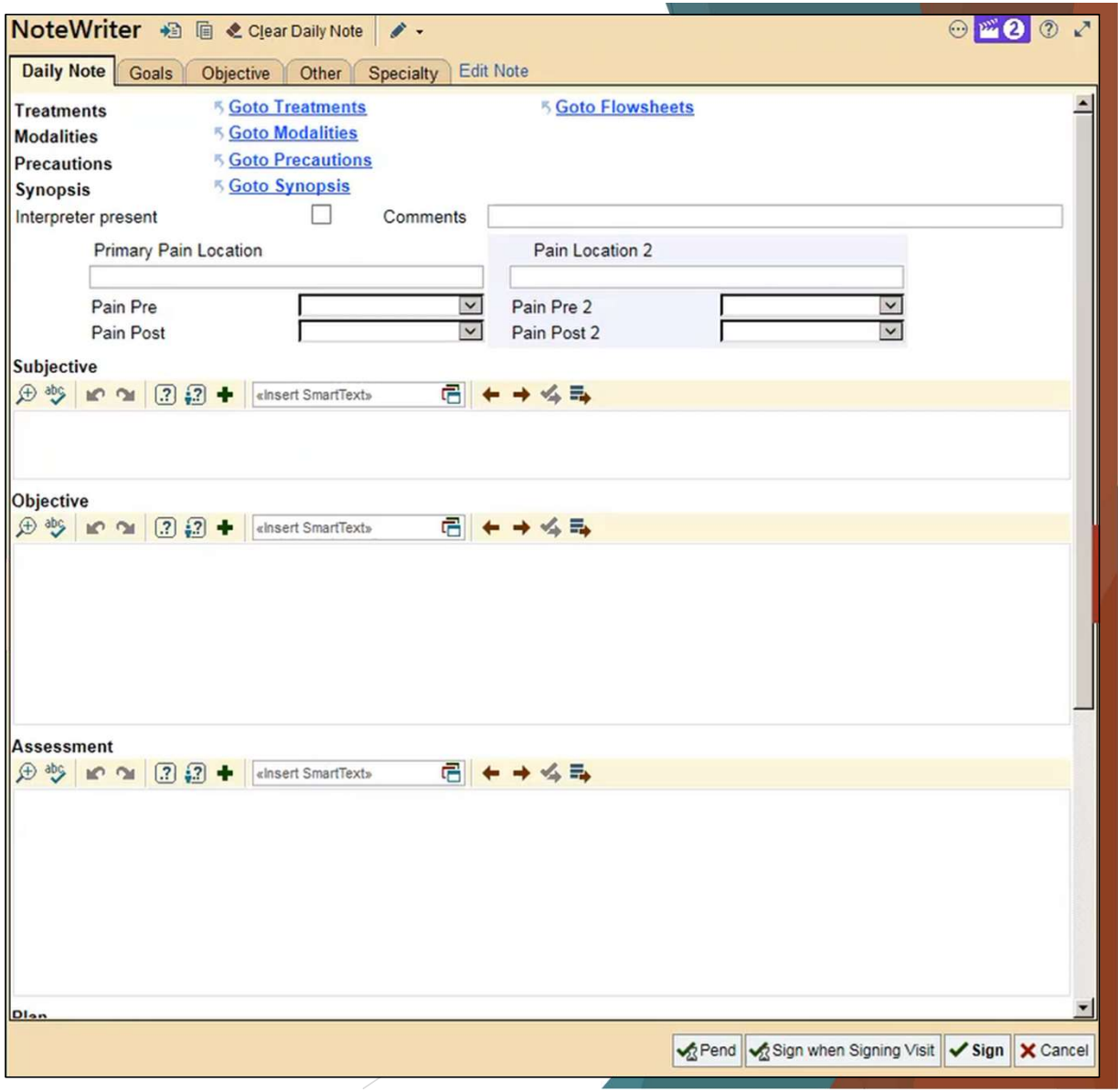
JM1 Add references

Jeanfavre, Michael, 1/11/2020

JM1

BFRT Screening Algorithm

See BFR Manual



Slide 43

JM1 Add references

Jeanfavre, Michael, 1/11/2020

MJ1

Conditional Select Subsequent Screening

- If patient answers "**Yes**" to the following questions:
  1. Hyperlipidemia or High Triglycerides
  2. Diabetes
  3. Hypertension
  4. Obesity
  5. Hypercoagulability

Slide 44

MJ1 Voice over these 6 slides
Michael Jeanfavre, 11/10/2024

Symptom Severity Assessment[39]

Dx	Indications	Precautions	Contraindications	
HTN	- 140-159/90-94 mmHg	- 160-179/95-99 mmHg*	- >180/>100 mmHg - Cardiothoracic ratio >55%	- Uric protein:100mg/dl - Life threatening Arhythmia
Diabetes	- FBG: 110-139 mg/dl	- FBG: 140-249 mg/dl*	- HTN in fundus oculi - FBG: ≥250 mg/dl	- Urinary ketone body (+) - Diabetic Retinopathy (+)
HLD	- TC: 220-249 mg/dl - TG: 150-299 mg/dl	- TC: 250 mg/dl* - TG: 300 mg/dl*		
Obesity	- BMI: 24.0 – 29.9	- BMI: 24.0 – 29.9 & LE joint damage (orth exam) - BMI: 30-35.0	- BMI: >35	

Note. BMI, body mass index; FBG, fasting blood glucose; LE, lower extremity

Conditional Select Subsequent Screening: **Blood Clot Risks**

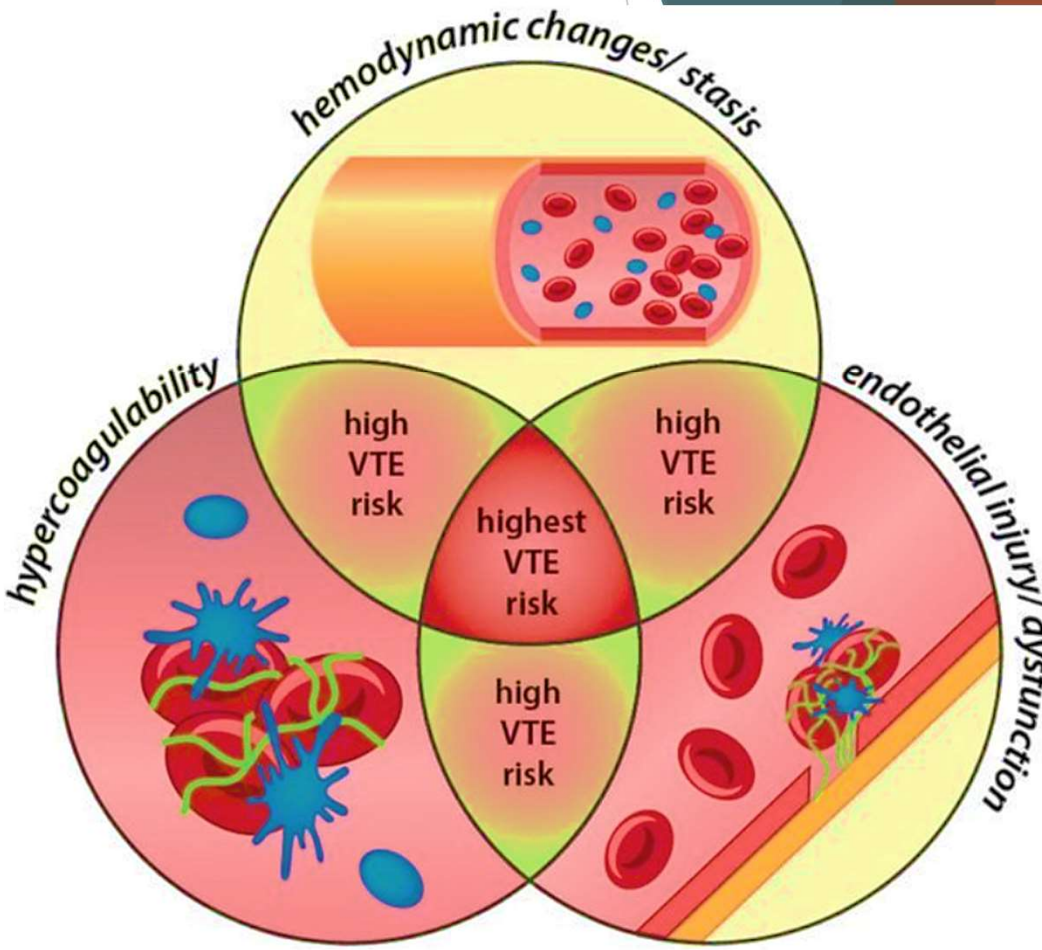
- In the first 6 weeks s/p orthopedic surgery, there is an estimated 100-fold ⬆ in risk of VTE[3] secondary to the combination of "endothelial damage"and "stasis" (2 of 3 conditions of Virchow's Triad)
- However, current evidence suggests that use of a tourniquet in surgery ("stasis") does not seem to amplify this risk (⬆ fibrolytic effect post tourniquet)[3,6,7]
- **Surgery:** application of up to **120 min** of **full occlusion** with **2-3x pressure** (given cuff width) during[4]
- **BFR Post Op:** significantly less risk of acquiring a VTE during or following the application of a **brief (5-20 min)**, **sub-occlusive** pressure with **exercise**.[4]
- To date, no study has provided any evidence that BFR exercise amplifies markers associated with the coagulation system[3-6]

Sweetland 2009[3], Bradner 2015[2], Madarame 2010[3], Rolnick 2021[4], Nakajima 2007[5], Clark 2011[6], Bond 2019[7], Australian Institute of Sport CPG 2016[8]

Conditional Select Subsequent Screening: **Blood Clot Risks**

Virchow's Triad

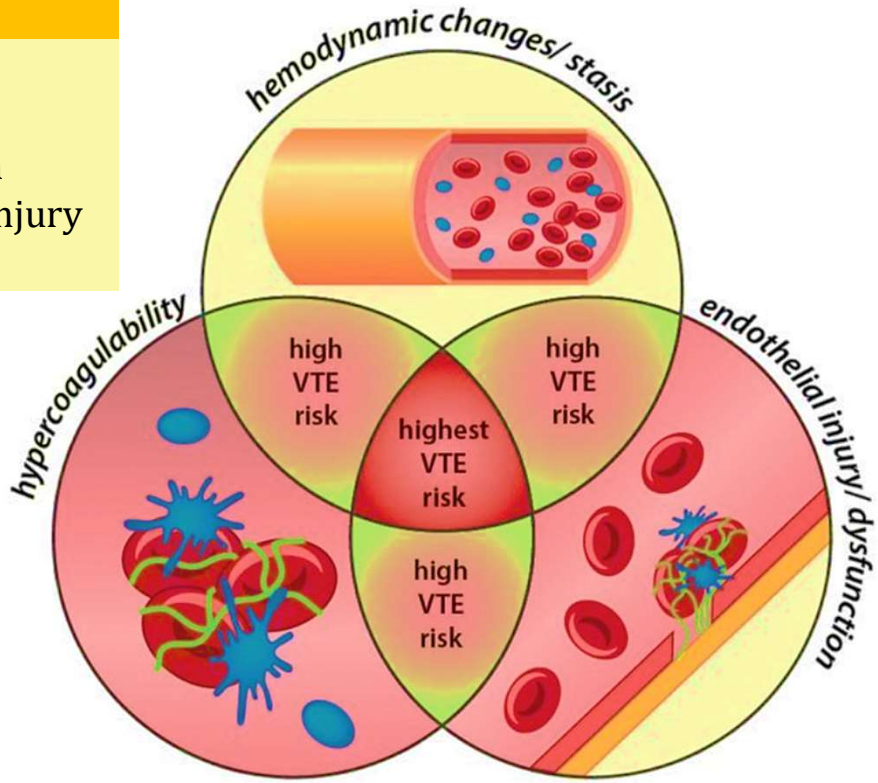
- Describes the three broad categories of factors contributing to the risk of venous thrombosis:
  - Hemodynamic Changes/Stasis
  - Endothelial Injury
  - Hypercoagulability.



Kovačič 2019

Stasis

Immobility/Paresis	Failure
Age >40 y/po	Stroke
Varicose veins	Polycythemia
Obesity	Spinal Cord Injury
Hear or Respiratory	Anesthesia



Endothelial Injury

Surgery (pelvis especially)
Trauma
Smoking
Previous DVT/PE
Central Venous Catheterization

Hypercoagulability

Age >70 y/o	Pregnancy	(Active) Infection
Malignancy	Postpartum (6 mo)	Anti-thrombin III deficit
Cancer Therapy	Thrombophilia	Protein S & C deficit
Estrogen Therapy	Nephrotic Syndrome	IBS
Hormone Replacement		

Kovačič 2019

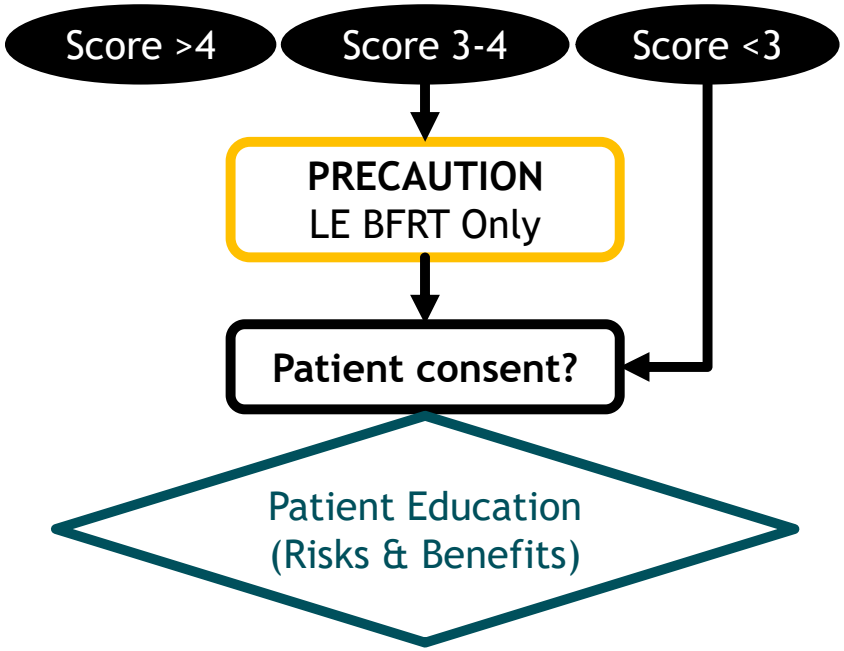
Conditional Select Subsequent Screening: **Blood Clot Risks**

- In a surgical tourniquet setting, VTE is usually listed as a potential complication *BUT* a direct correlation remains unclear[1,2]
- There have been case reports of DVT & PE however, risk remains low[2] AND with proper screening risk can be negligible[1,2,4]
- Current Physical Therapy Practice Guidelines on DVT recommends both activity and intermittent pneumatic compression[3]
- The proposed screening questionnaire and algorithm incorporates the questions of *thrombophilia* and *hypercoagulability* as well as *other risk factors* contributing to Virchow's Triad.

Bond 2019[1], Australian Institute of Sport BFR CPG 2016[2], Hillegass 2016[3], Rolnick 2021[4]

JM1

BFRT Screening Algorithm



Scott 2014, Le Cara 2019, Owens 2015, Nakajijma 2011

Slide 50

JM1 Add references
Jeanfavre, Michael, 1/11/2020

JM12

BFRT Screening Algorithm

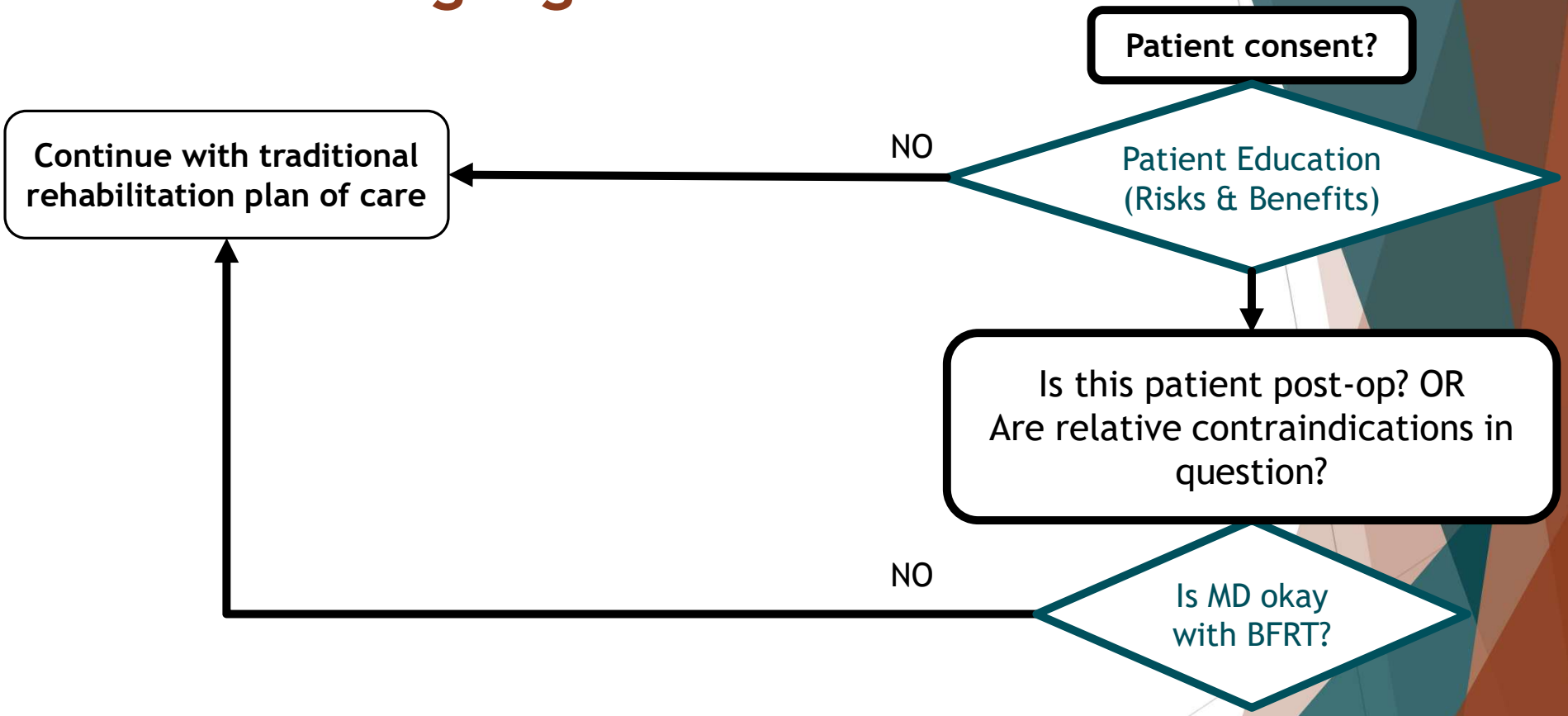
Bittar 2019[1], Centner 2019[2], 2019[1]

Slide 51

JM12 Add references

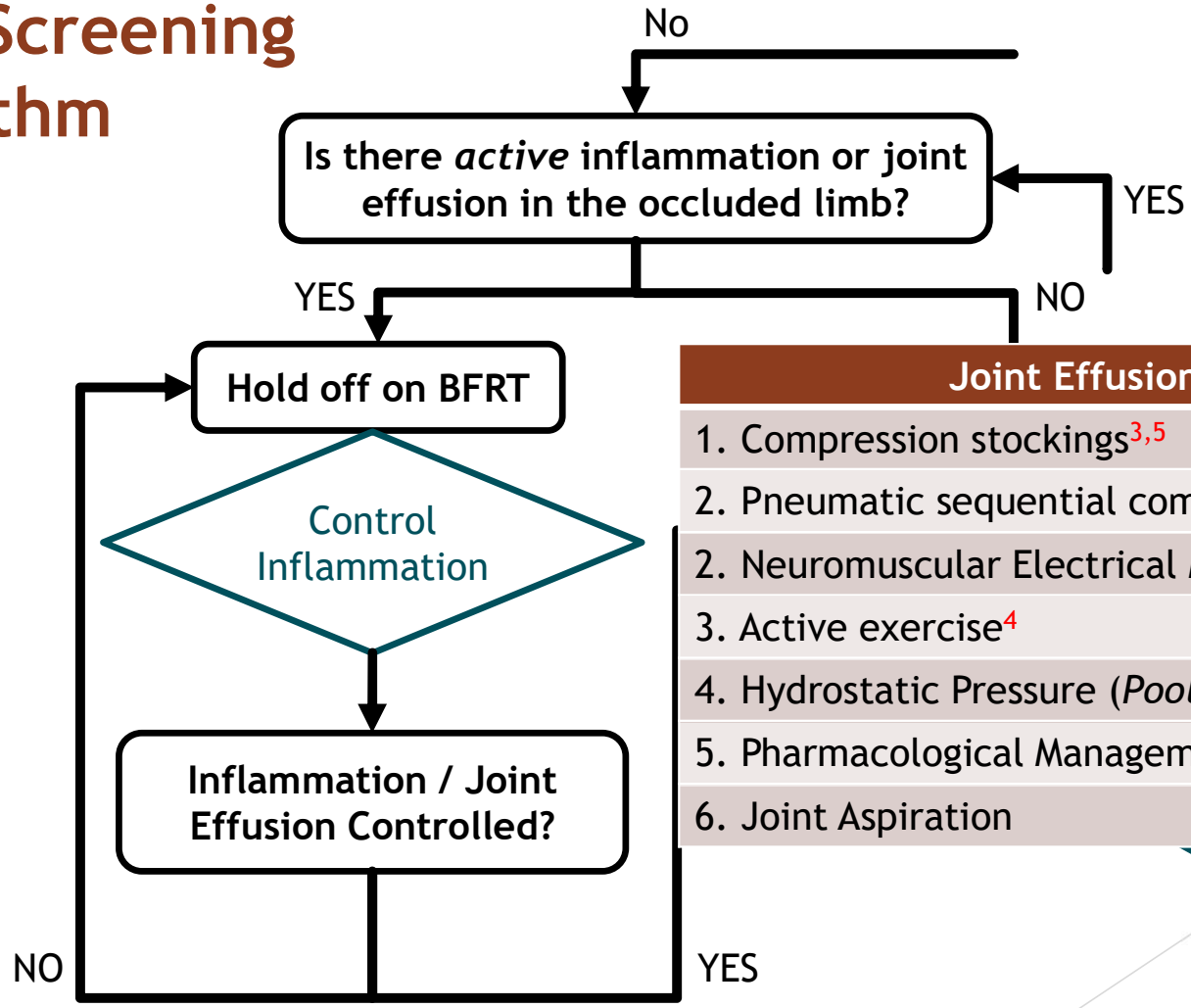
Jeanfavre, Michael, 1/11/2020

BFRT Screening Algorithm



Scott 2014, Le Cara 2019, Owens 2015, Nakajijma 2011

BFRT Screening Algorithm



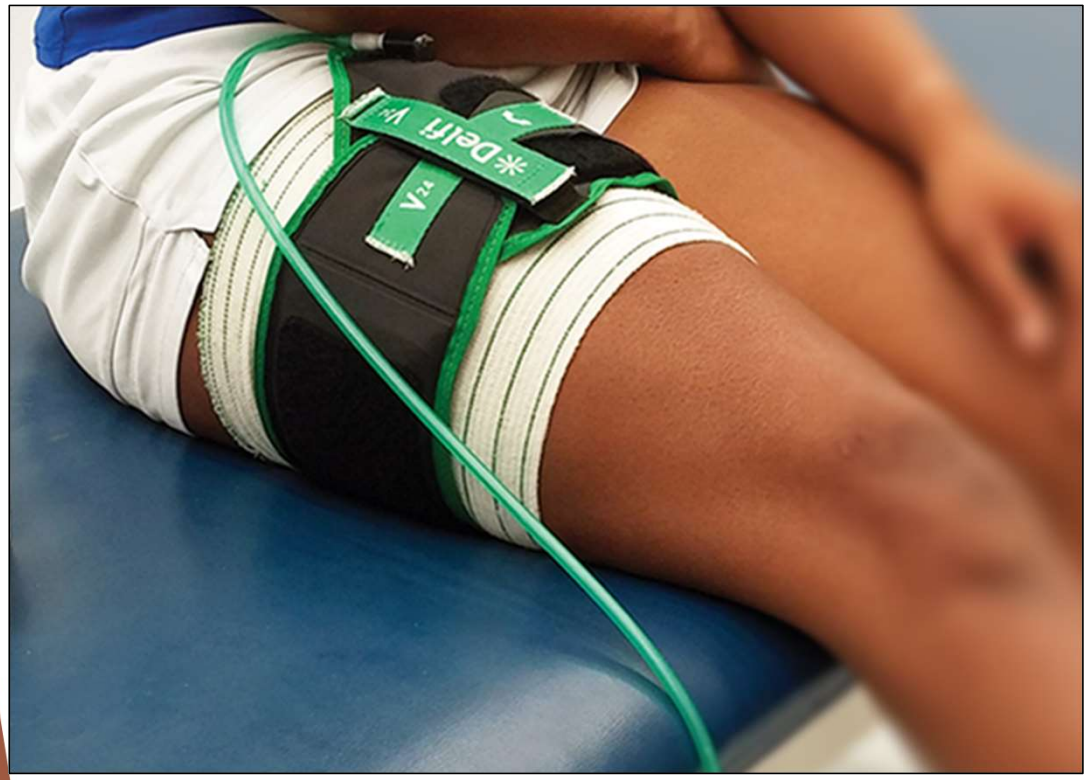
Joint Effusion Interventions
1. Compression stockings[3,5]
2. Pneumatic sequential compression[4]
2. Neuromuscular Electrical Muscular Stimulation (NMES)[6]
3. Active exercise[4]
4. Hydrostatic Pressure (*Pool Therapy*)[7]
5. Pharmacological Management
6. Joint Aspiration

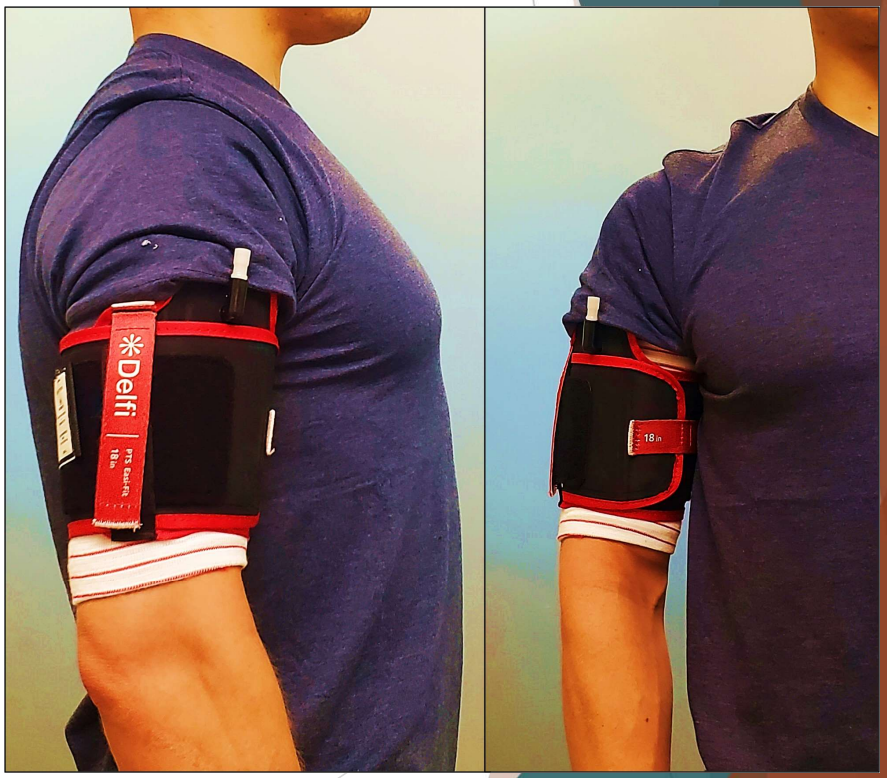
Bittar 2019[1], Centner 2019[2], Mooventhan 2014[3], Sari 2019[4],Tischer 2019[5], Editz 2012[6], Bamigboye 2007[7]

The Structured Process of BFR Implementation

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Screening	**Cuff Application**	**Cuff Pressure**	**Exercise Stimulus**	**Exercise Parameters**	**Monitoring & Progression**
Precautions & Contraindications	Location & Cuff Properties	Specific & Individualized Pressures	Type of Exercise	Dosage of Exercise	When & How to Progress

Location of the Cuff





Practical Application – Cuff Selection

What are pneumatic tourniquets?

- **Definition:** a **pneumatic tourniquet** is a medical device consisting of a pressure-regulating unit which can be operated manually or automatically, connecting tubing, and an inflatable cuff.
- **Purpose:** intended to reduce or totally occlude circulation to a patient's limb to enable a licensed healthcare practitioner to perform a therapeutic function.

Note that this definition covers pneumatic tourniquets intended ***to restrict OR completely occlude blood flow*** to a limb

- **Pneumatic Tourniquet vs Blood Pressure Cuff**
  - For patient safety, the special design of tourniquet cuffs allows a user to safely and accurately apply a desired pressure level and gradient uniformly around a limb for a prolonged time period sufficient for performing a therapeutic function.

McEwen 2024

Practical Application – Cuff Selection

Why does the FDA regulate pneumatic tourniquets as medical devices?

- In the United States, **pneumatic tourniquets (PT)** are regulated as **medical devices** by the Food and Drug Administration (FDA)
- **PT** meet the **"diagnose, cure, mitigate, treat or prevent disease"** and **"affect the structure or function of the body"** clauses in the definition of a medical device[1] in section 201(h) of the Federal Food Drug & Cosmetic (FD&C) Act.

How does the FDA regulate pneumatic tourniquets?

- Pneumatic tourniquets are regulated as **Class I medical devices under 21 CFR 878.5910 "Pneumatic Tourniquet"** which requires the manufacturer to comply with specific **regulations AND to maintain evidence that the device is safe and effective** for its intended use and indications for use

McEwen 2024

Practical Application – Cuff Selection

What 3 key questions should a clinician ask prior to deciding whether to purchase a specific pneumatic tourniquet to restrict or occlude circulation?

1. **Is the pneumatic tourniquet's manufacturer registered as an establishment with the FDA and has the manufacturer device listed the pneumatic tourniquet product with the FDA?**
   1. Look on company website (often used for marketing)
   2. Look on [FDA Establishment Registrations and Device Listings Database]
      1. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfRL/rl.cfm
   3. Contact manufacturer directly to request the "Established Registration Number and the description & device Listing Number" of the tourniquet's device listing

Practical Application – Cuff Selection

What 3 key questions should a clinician ask prior to deciding whether to purchase a specific pneumatic tourniquet to restrict or occlude circulation?

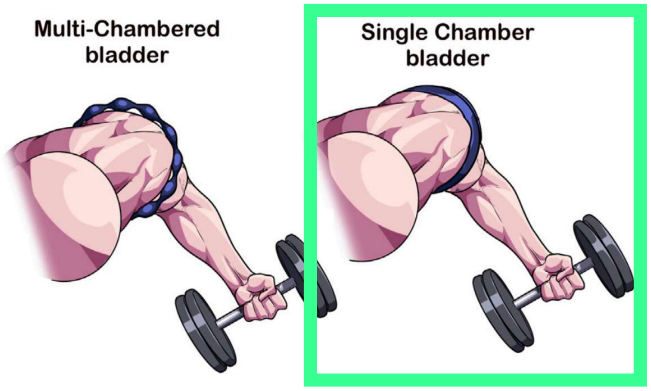
2. Can the cuff pressure be individualized to the patient/client or user

- The cuff/system should allow for *specific* (1) *individualized* and (2) *limb specific,* **Limb Occlusion Pressures**

3. Can the cuff pressure be adjusted during (either manually or electronically) during the exercise

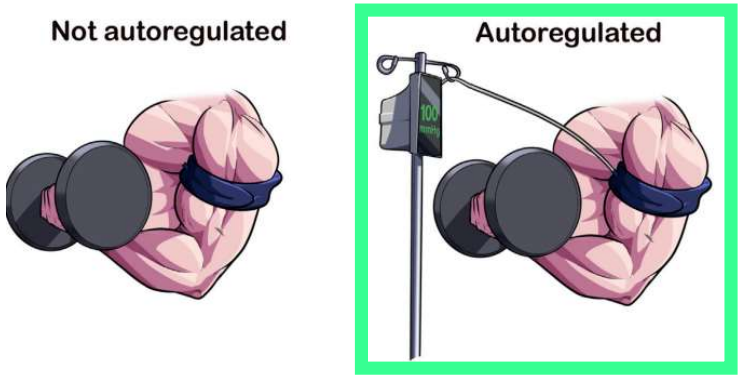
- The cuff/system should allow for either *manual or electronic* control of the pressure
- Pressure autoregulation is a *nice to have* (but not need to have feature of the cuff)

Cuff Properties



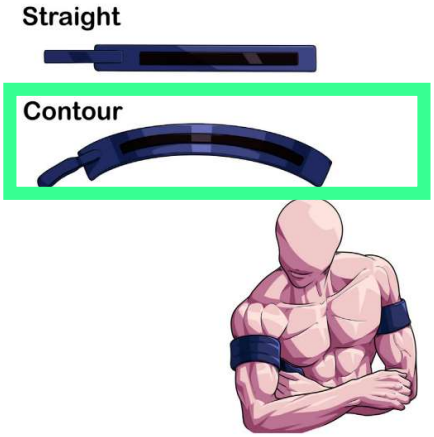
Multi-chambered cuffs:

- composed of sequential bladders that when inflated, **leave regions where minimal compression occurs**
- **⬇ 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



Autoregulation:

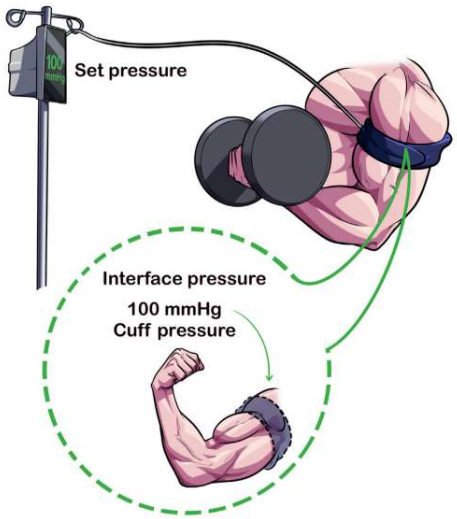
- design feature that accommodates for the changes in limb circumference because of muscular contraction.
- In current available devices, the BFR cuff is attached to a pneumatic air compressor via an air tubing that adjusts according to the pressure sensed at the cuff-limb interface.
- **The speed at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



Contoured cuffs:

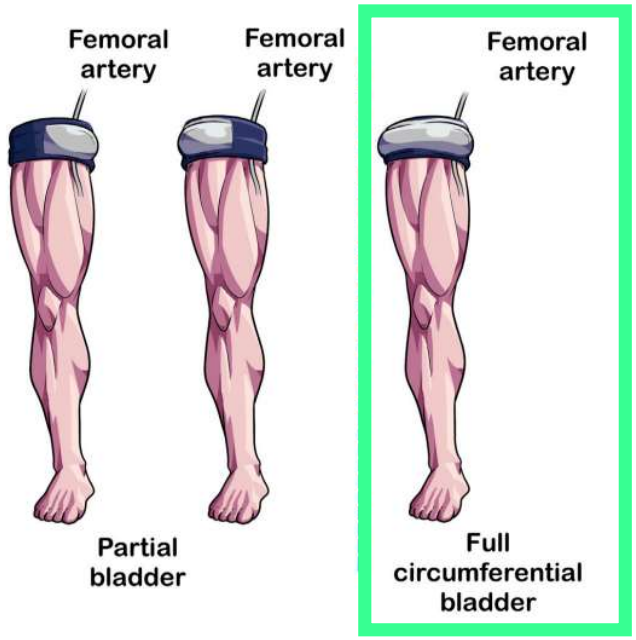
- provide a ⬆ secure fit due to the conical shape of the limb (compared to a straight cuff)
- ⬆ the safety profile of BFR exercise

Cuff Properties



Set Pressure = Interface Pressure

- **set pressure:** the pressure that the pneumatic cuff is inflated to by the clinician
- **interface pressure** the 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



Circumferential Bladder

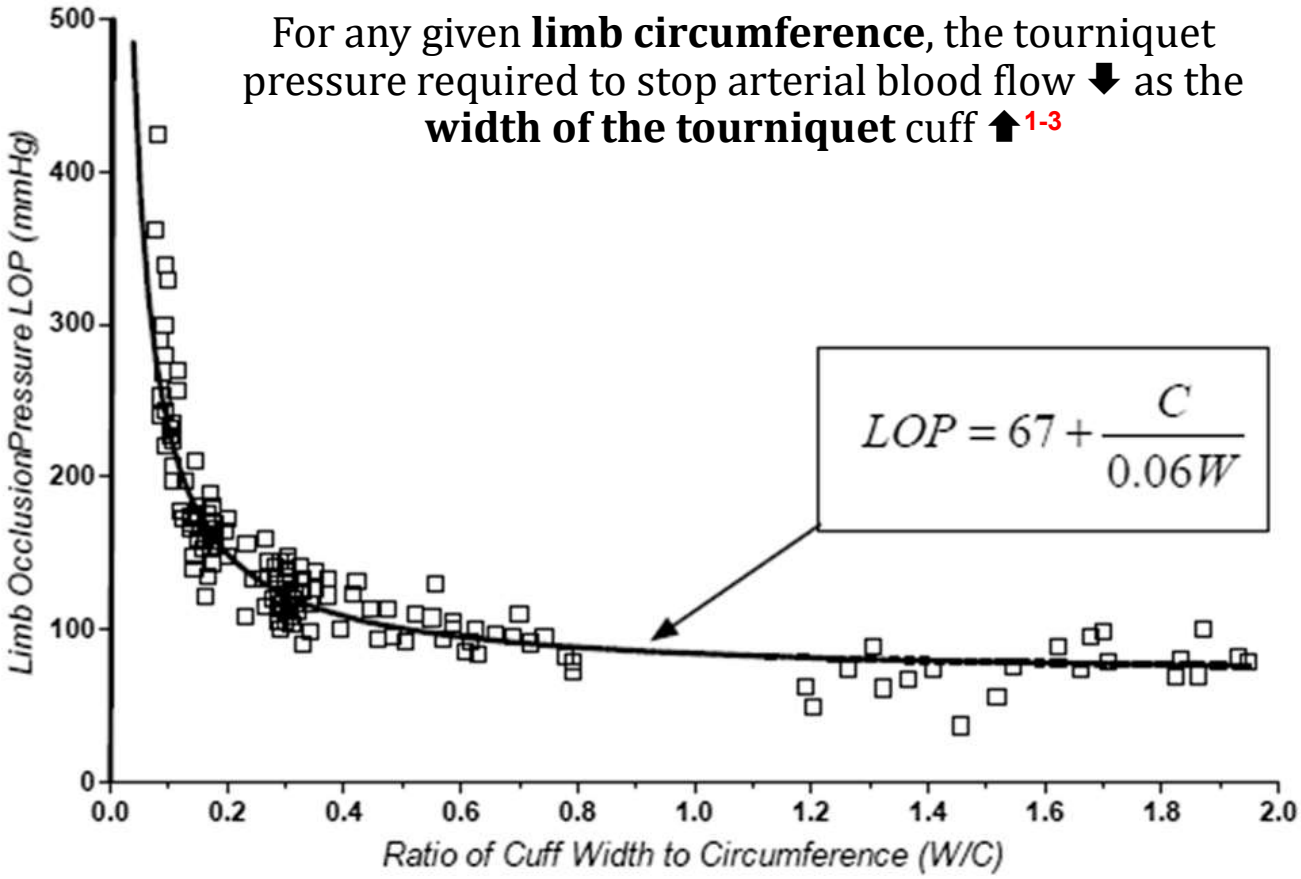
- The bladder extends **the length of the cuff** (Right Image)
- **Partial bladder does NOT** cover the entirety of the length of the cuff
- Circumferential bladder ensures homogenous circumferential pressure, ⬆ efficacy and ensuring sufficient target vessel occlusion

Other Considerations:

- Nylon vs Elastic
- Wide vs narrow
- Personalized pressure calibration

Practical/Clinical Application – Cuff Specifications

For any given **limb circumference**, the tourniquet pressure required to stop arterial blood flow ⬇ as the **width of the tourniquet** cuff ⬆[1-3]



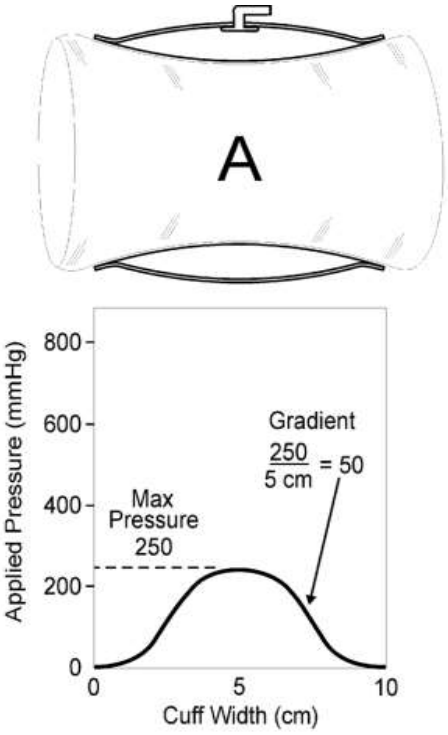
Additional variables that can influence limb occlusion pressures:

- Systolic Blood Pressure[7]
- Body position[4]
- Sex/Race[5]
- Limb Density
- Laterality[6]

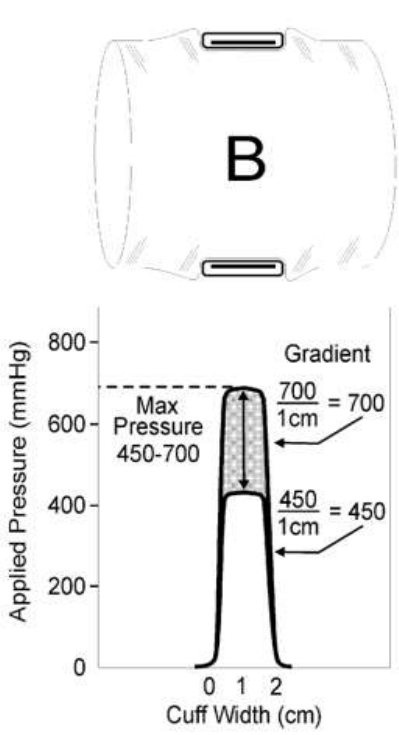
McEwen 2019[1], Graham 1993[2], Weatherholt 2019[3], Leonneke 2015, Hughes 2018[4], Jessee 2016[5], Evin 2020[6] ,Leonneke 2015[7]

Practical/Clinical Application – Cuff Specifications

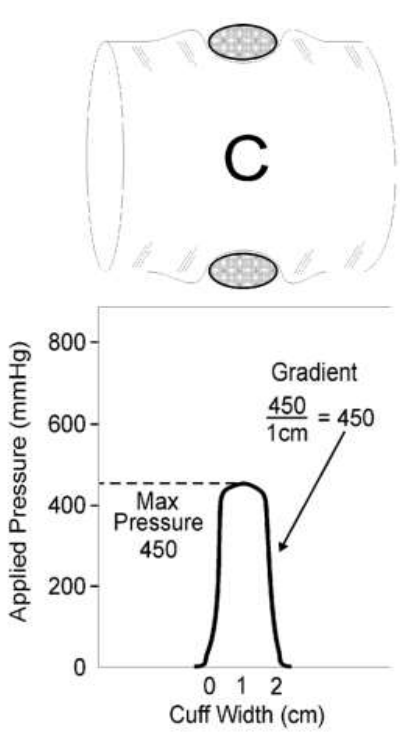
Modern Pneumatic Tourniquet



Non-surgical, Non-Pneumatic Tourniquet



Non-surgical, Non-Pneumatic Elastic Ring



- Each tourniquet was selected and applied as recommended by the respective manufacturer to stop arterial blood flow in an upper limb.
- Higher levels of pressure and higher-pressure gradients are associated with higher probabilities of patient injuries.
- Risk of nerve related injuries increase with pressure gradients
- Higher demand pressures associated with higher CV demand
- Complete arterial flow ⬇ effectiveness of BFR

McEwen 2019, Graham 1993

So What?!

KEY POINTS

Summary of Cuff Selection

- The cuff always goes on the most proximal location of the limb:
  - Lower Extremity: as close to the groin as possible
  - Upper Extremity: as close to the axilla as possible
- **FDA Registered** (C.Y.A.)
- **Pneumatic tourniquet, single chamber, circumferential bladder, curved cuff**
- Sufficient width Legs (9 -18.5 cm), Arms (5-12 cm)[1]
  - wider cuffs (13.5 cm) restrict blood at lower pressures vs narrow cuffs (5 cm)[2]
  - **Arms: narrow cuffs** may limit normal/required ROM & muscle hypertrophy stimulus may be attenuated directly below the cuff[3]
  - **Legs: wider cuffs** some individuals did NOT reach arterial occlusion using narrow cuffs on Legs at pressure up to 300 mmHg[2]
- **Autoregulation** a nice to have but not a need to have if pressures are assessed post sets.

Scott 2015, Loenneke 2012, Kacin 2011

Practical Application – Cuff Selection

Industry Gold Standard

Direct to Consumer

OWENS RECOVERY SCIENCE

H CUFF

Evidence-Based Blood Flow Restriction

SMART TOOLS

SUJI BFR

Practical/Clinical Applications – Cuff Pressures

- Standardize restrictive pressures relative to brachial systolic blood pressure[11, 45]
  - NO evidence to suggest that this provides a good estimate of BFR to the lower limbs[87]
  - bSBP NOT able to explain additional variance in estimation of Lower Body Arterial occlusion pressures[90]
- Lower Extremities
  - **80% total arterial restriction** ➔ hypertrophic & Strength responses similar to traditional high load training[11]
  - **50% total arterial restriction** ➔ maximize EMG & ↑ acute decrements in torque during & following knee extension exercise (comparable (50% = 60% occlusion)[92]
    - Maximize acute muscle swelling & blood lactate responses[87]
  - VAS: 7/10 (pressure with no pain) = occluded venous return without stopping arterial inflow[93]
    - Limited difference in ratings of discomfort during exercise across a variety of pressures (perception may NOT be best estimate of actual restriction[87]

Practical/Clinical Applications – Cuff Pressures

- **~60%** Complete Arterial Occlusion Pressure can be achieved in LE with correlating pressure with thigh circumference[90]
- **Anatomical Location:** 33% distance from inguinal crease to superior border of patella

Circumference	Pressure
≤50 cm	120 mmHg
51-55 cm	150 mmHg
56-59 cm	180 mmHg
≥ 60 cm	210 mmHg

Most Important Factors to consider for optimal pressure during BFR
1. Width of Cuff
2. Circumference of Limb
3. Arterial Occlusion Pressure of Limb

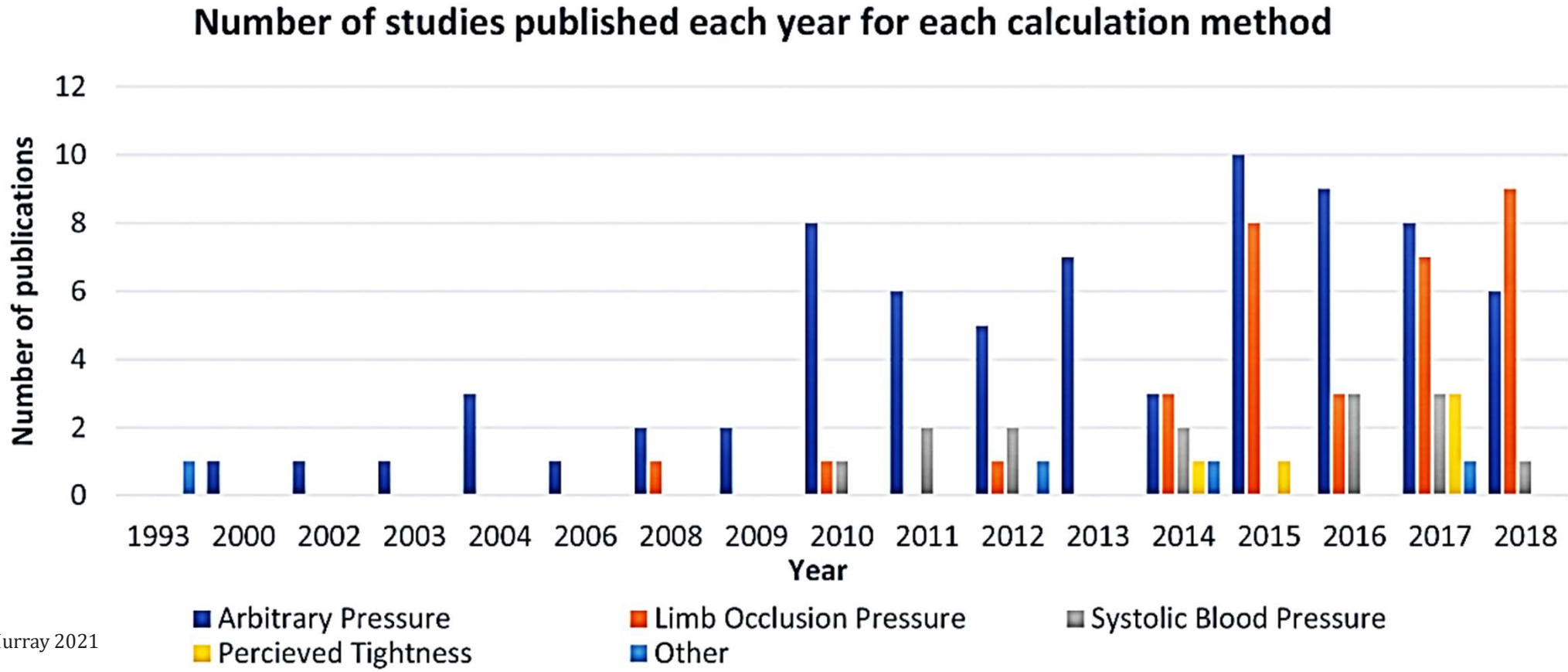
The Structured Process of BFR Implementation

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Screening	**Cuff Application**	**Cuff Pressure**	**Exercise Stimulus**	**Exercise Parameters**	**Monitoring & Progression**
Precautions & Contraindications	Location & Cuff Properties	Specific & Individualized Pressures	Type of Exercise	Dosage of Exercise	When & How to Progress

Practical Application – Cuff Pressure

Approaches to determining occlusion pressure for blood flow restricted exercise training: Systematic review

James Murray [a,b], Hunter Bennett [a,b], Terry Boyle [a,c], Marie Williams [a,d] and Kade Davison [a,b]



Murray 2021

Clinical Application – Cuff Pressure

Optimal Blood Flow Restriction Occlusion Pressure for Shoulder Muscle Recruitment With Upper Extremity Exercise

Tyler Roehl,* PT, DPT, ATC, Bradley S. Lambert,* PhD, Jordan Ankersen,* BS,

Population: 15 Healthy adults
Study Design: Non-RCT
Setting: Controlled laboratory study
Outcomes:
- Muscle activation
- repetitions to failure
- discomfort levels

Exercise Protocol
- 4 Sessions, performing 3 common rotator cuff exercises
  - Standing cable ER & IR
  - Scaption
- Sets & reps: 1 set “to failure”
- Intensity: 20% 1 RM

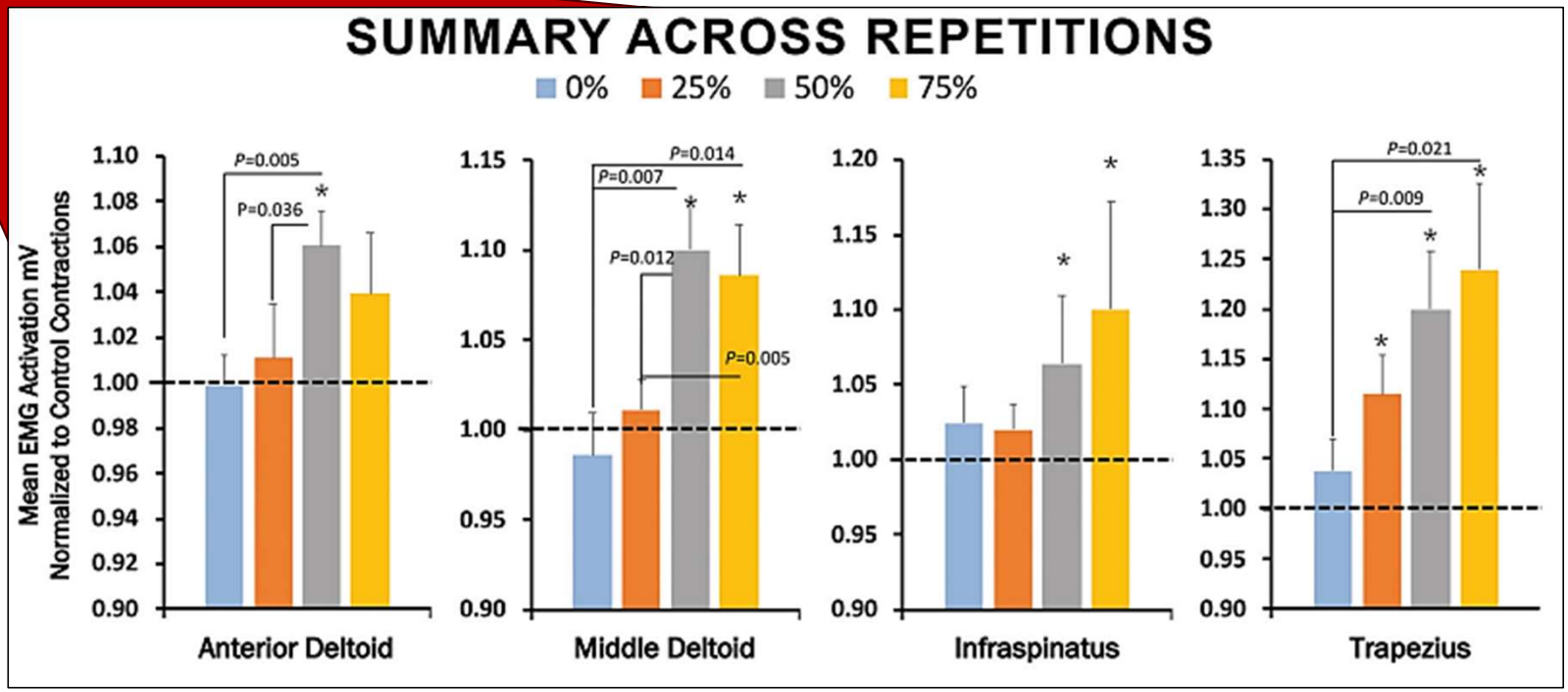
Cuff Pressures: 0%, 25%, 50%, 75% LOP (order randomized)

Roehl 2023

Clinical Application Cuff Application

Optimal Blood Flow Restriction Occlusion Pressure for Shoulder Muscle Recruitment With Upper Extremity Exercise

Tyler Roehl,* PT, DPT, ATC, Bradley S. Lambert,* PhD, Jordan Ankersen,* BS,



Roehl 2023

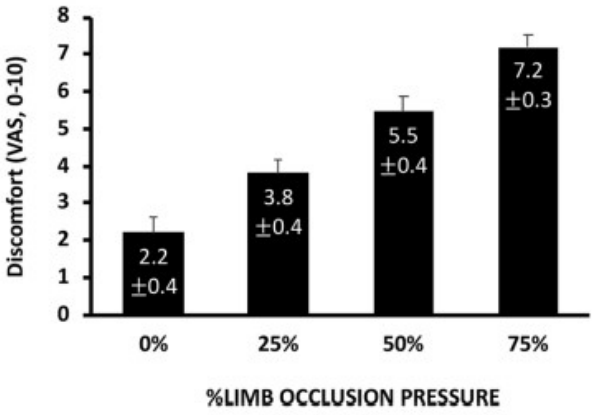
Cuff Application

Optimal Blood Flow Restriction Occlusion Pressure for Shoulder Muscle Recruitment With Upper Extremity Exercise

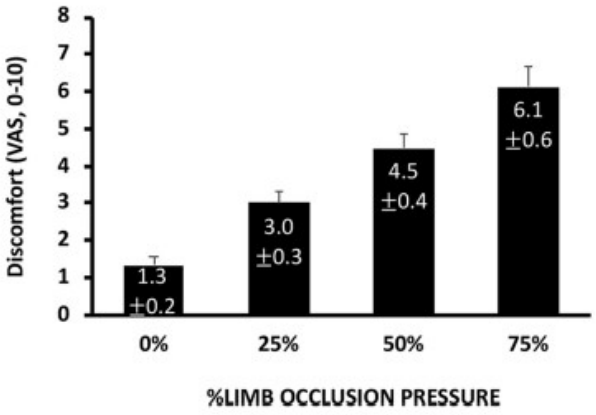
Tyler Roehl,* PT, DPT, ATC, Bradley S. Lambert,* PhD, Jordan Ankersen,* BS,

Discomfort (VAS 0-10)

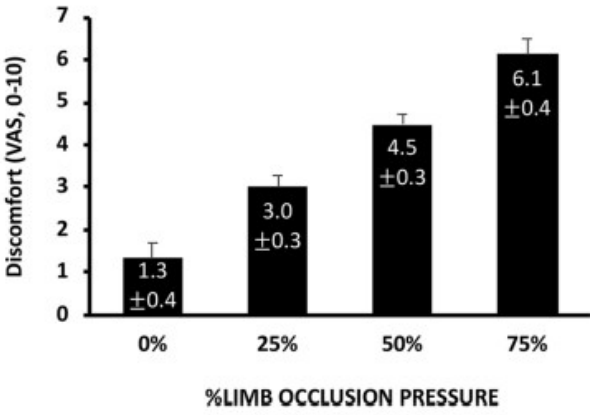
All pairwise comparisons significant at $P < .001$



All pairwise comparisons significant at $P < .01$



All pairwise comparisons significant at $P < .001$

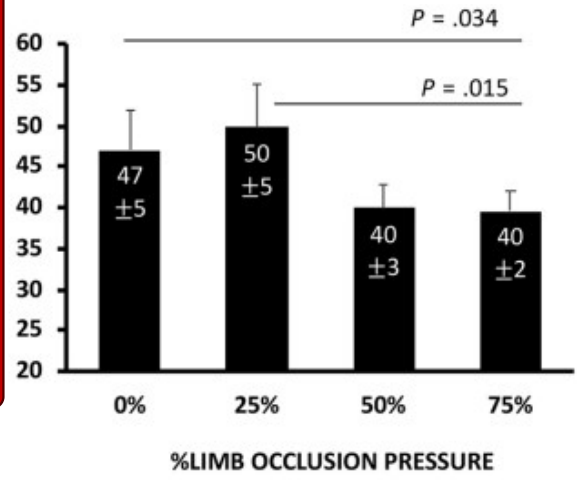


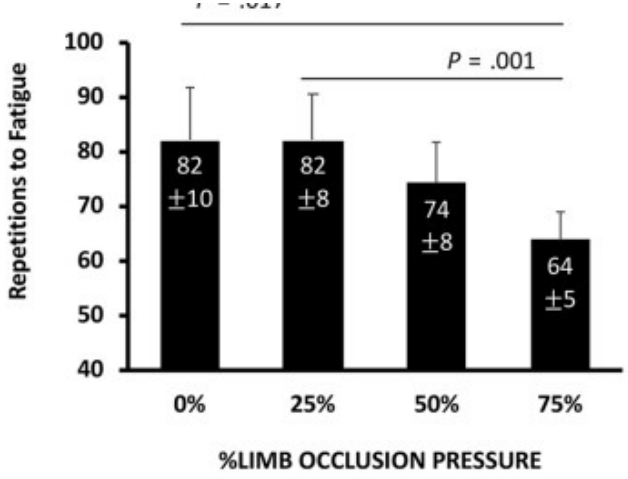
Cuff Application

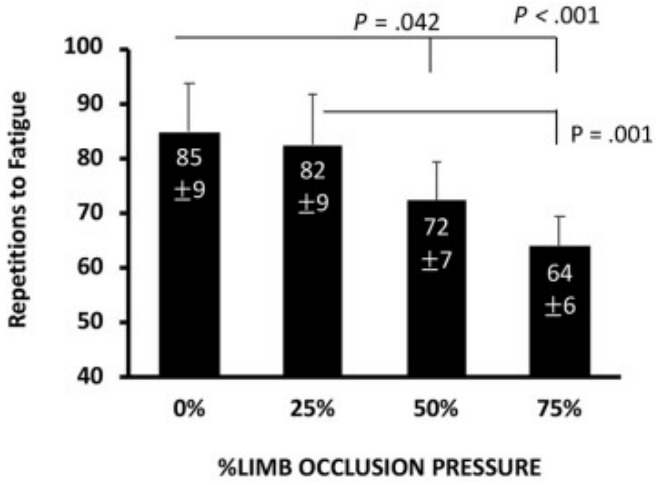
Optimal Blood Flow Restriction Occlusion Pressure for Shoulder Muscle Recruitment With Upper Extremity Exercise

Tyler Roehl,* PT, DPT, ATC, Bradley S. Lambert,* PhD, Jordan Ankersen,* BS,

Reps to Fatigue







Cuff Pressure

Optimal Blood Flow Restriction Occlusion Pressure for Shoulder Muscle Recruitment With Upper Extremity Exercise

Tyler Roehl,* PT, DPT, ATC, Bradley S. Lambert,* PhD, Jordan Ankersen,* BS,

Conclusion:

- There is a linear ⬆ in EMG with ⬆ in % LOP used
- there may be an element of **diminishing returns at >50% LOP** for targeted musculature of the exercises studied with additional, and potentially *unwanted*, co-activation of certain muscle groups, **ultimately limiting efficacy past this occlusion stimulus** when considering **discomfort** or **total achievable exercise volume**

BFRT Screening Algorithm

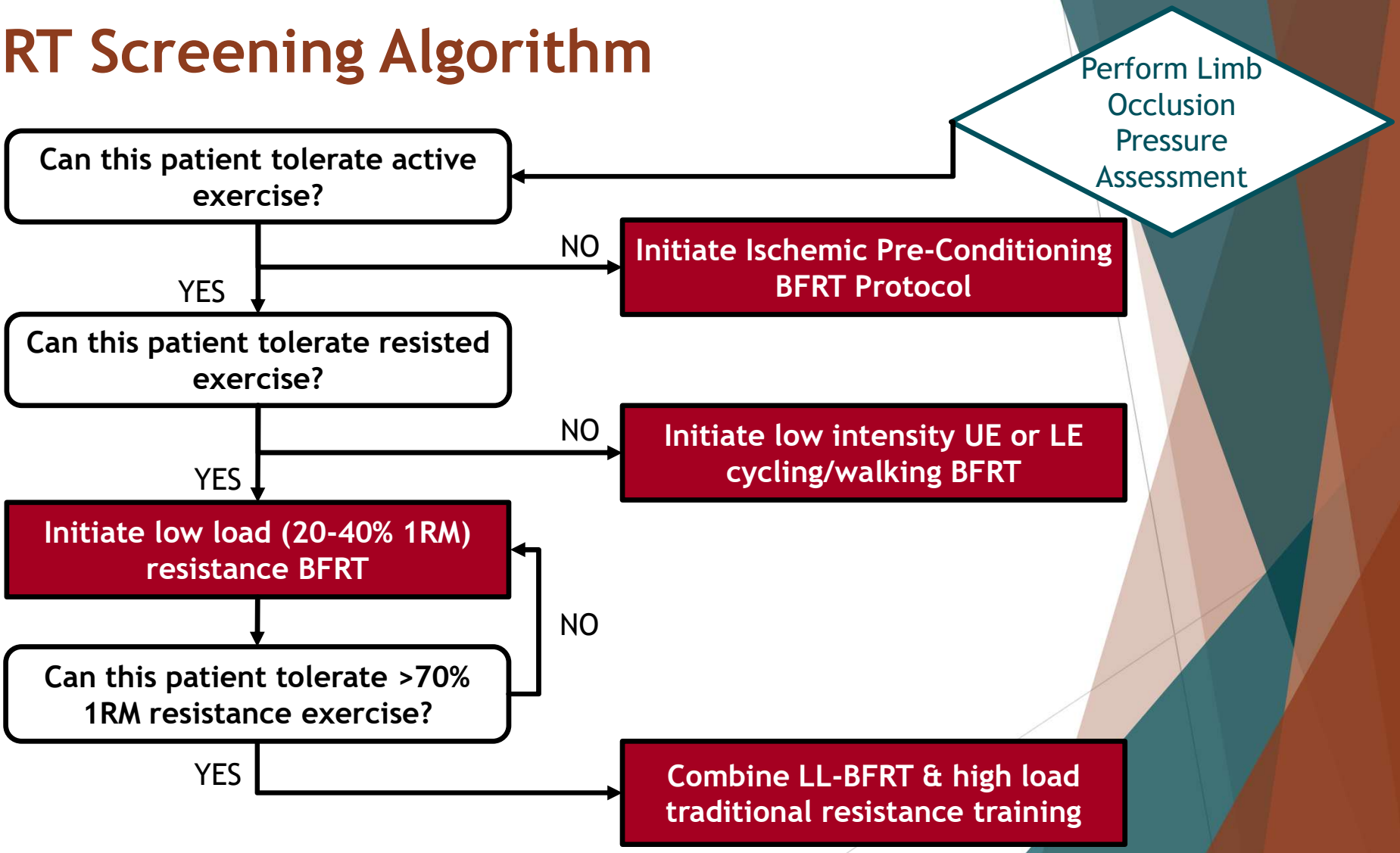
Steps	Description	Images
1	Have the patient lie supine	
2	Place cuff around upper thigh	
3	Palpate dorsalis pedis (or posterior tibial pulse) and mark with dry erase marker	
4	Connect sphygmomanometer with valve closed	
5	Place ultrasound (US) gel over marked artery	
6	Turn on doppler (ensure volume is up) and doppler head lightly over US gel	
7	Begin inflating the cuff	
8	The limb occlusion pressure (LOP) is indicated once arterial pulse disappears	

BFRT Screening Algorithm

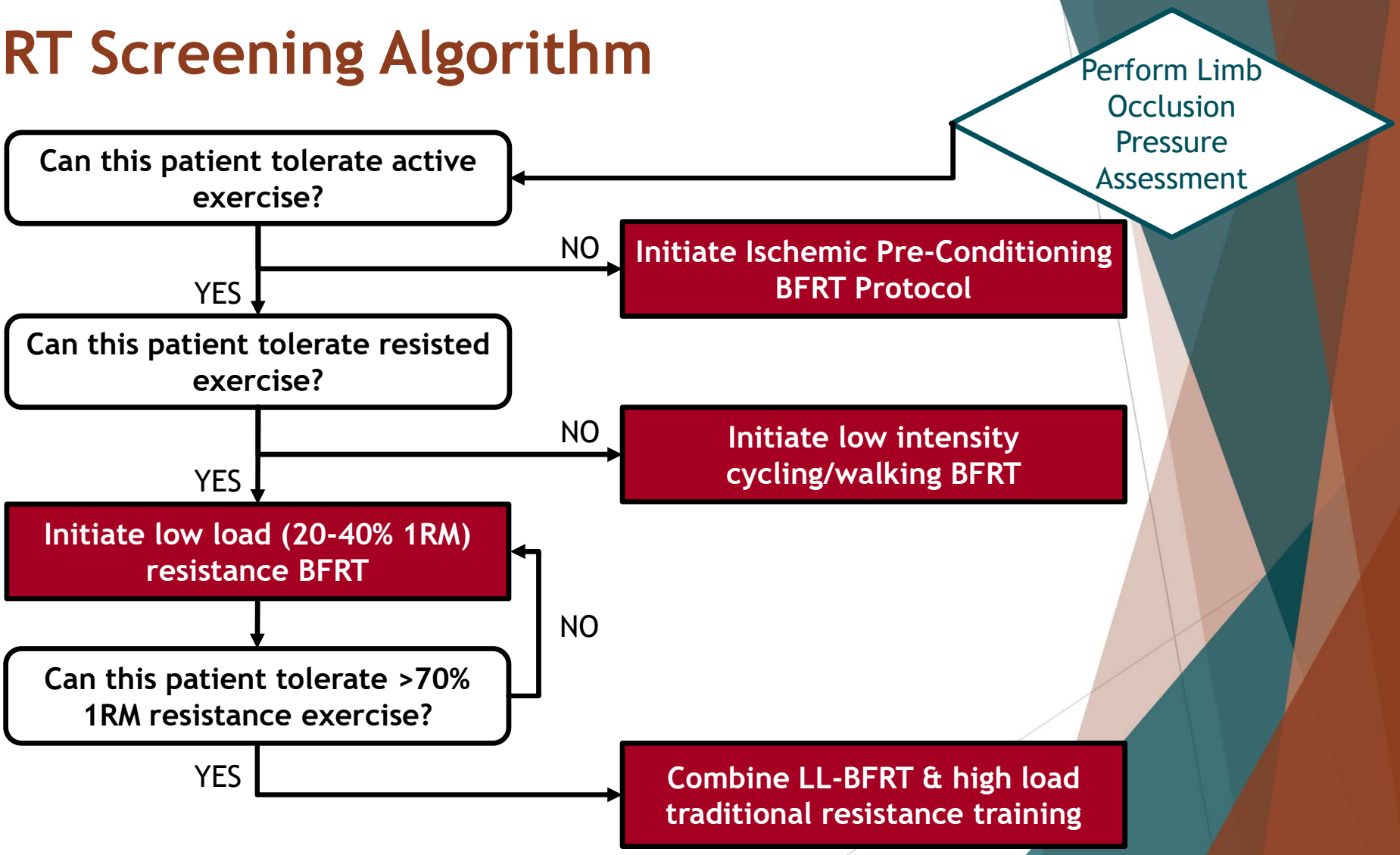
Steps	Description	Images
1	Have the patient lie supine	
2	Place cuff around upper arm	
3	Palpate radial pulse and mark with dry erase marker	
4	Connect sphygmomanometer with valve closed	
5	Place ultrasound (US) gel over marked artery	
6	Turn on doppler (ensure volume is up) and doppler head lightly over US gel	
7	Begin inflating the cuff	
8	The limb occlusion pressure (LOP) is indicated once arterial pulse disappears	

Perform Limb Occlusion Pressure Assessment

BFRT Screening Algorithm

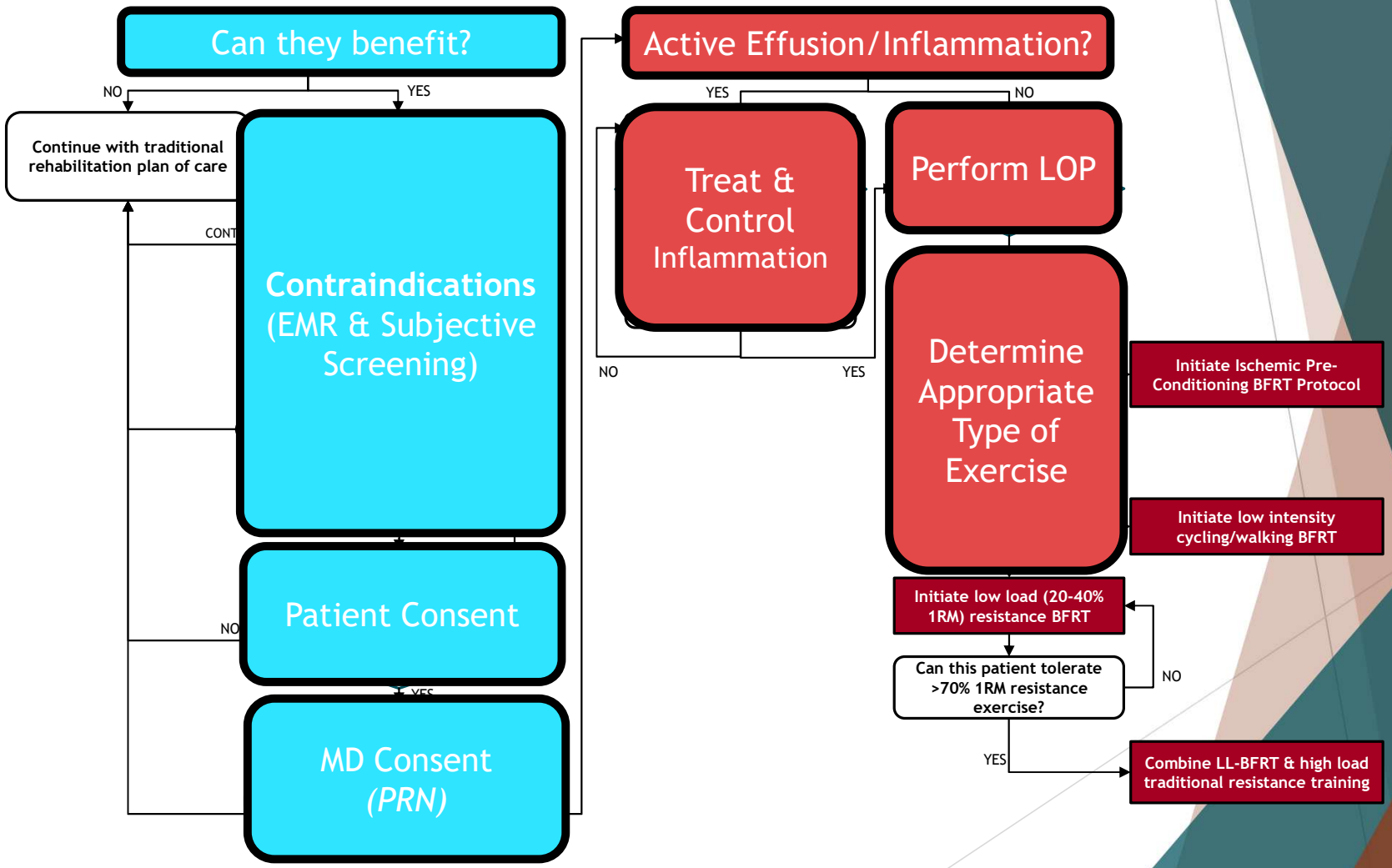


BFRT Screening Algorithm



Summary – BFRT Screening Algorithm

Blood Flow Restriction Training Screening Algorithm



Exercise Prescription of Blood Flow Restriction

Objective #5: **How do I *effectively* apply/use BFR in clinic?**

1. Occlusion parameters
2. Exercise parameters
3. Progression criterion

Optimal Prescription & Progression

1. Occlusion parameters
2. Exercise parameters
3. Progression criterion

The Structured Process of BFR Implementation

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Screening	**Cuff Application**	**Cuff Pressure**	**Exercise Stimulus**	**Exercise Parameters**	**Monitoring & Progression**
Precautions & Contraindications	Location & Cuff Properties	Specific & Individualized Pressures	Type of Exercise	Dosage of Exercise	When & How to Progress

Practical/Clinical Application – Cuff Specifications

Occlusion Variable	Recommended Parameters	Comment

Scott 2014

Practical/Clinical Application – Exercise Specifications[1]

Variable
Type of Exercise
Frequency
Exercise Intensity
Volume
Rest[2]
Duration
Tempo

Scott 2014[1], Heitkamp 2015[2], Loenneke 2012[3], Slyzs 2016[4], Inagaki 2011[5]

The Structured Process of BFR Implementation

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Screening	**Cuff Application**	**Cuff Pressure**	**Exercise Stimulus**	**Exercise Parameters**	**Monitoring & Progression**
Precautions & Contraindications	Location & Cuff Properties	Specific & Individualized Pressures	Type of Exercise	Dosage of Exercise	When & How to Progress

Safety & Side Effects – Basic BFR Principles

Best Practices are as follows:

1. **Confirm No Contraindications** for 'normal exercise' ➔ PAR-Q
2. **Hemodynamically Unstable Patients** (slide 62, 63) should NOT partake in BFR Training
   - Exception: 'expert' clearance has been provided
3. **Thrombotic Diseased Patients** are Contraindicated
   - Believed to be reason why serious complications have been seldom occurred until now
   - Rheomatologic investigations after BFR have shown NO evidence for increased risk of thrombosis[83]
4. Explain **Petechial Hemorrhage Risk –** prior to initiation of training (especially UE)
5. Individualize training to subjects' physical capacity & condition
6. **Build Relationship & Trust** with Patient

Nakajima 2011[88]

Safety & Side Effects – Basic BFR Principles

7. **Pay Attention to Prodromal Symptoms** (syncopy)
   - faintness, dizziness, or light-headedness
8. **Caution:** Older (>65), Bedridden, Postoperative Patients (DVT risk)
9. **AED Available**
10. **SHORT Term and LOW intensity Loads**
    - High Intensity Loads has little effect, but is may be rather dangerous
    - Long duration (UE: >15 min, LE: >30 min) blood flow restriction should be avoided
11. **If unsure about medical condition seek specialist consult**

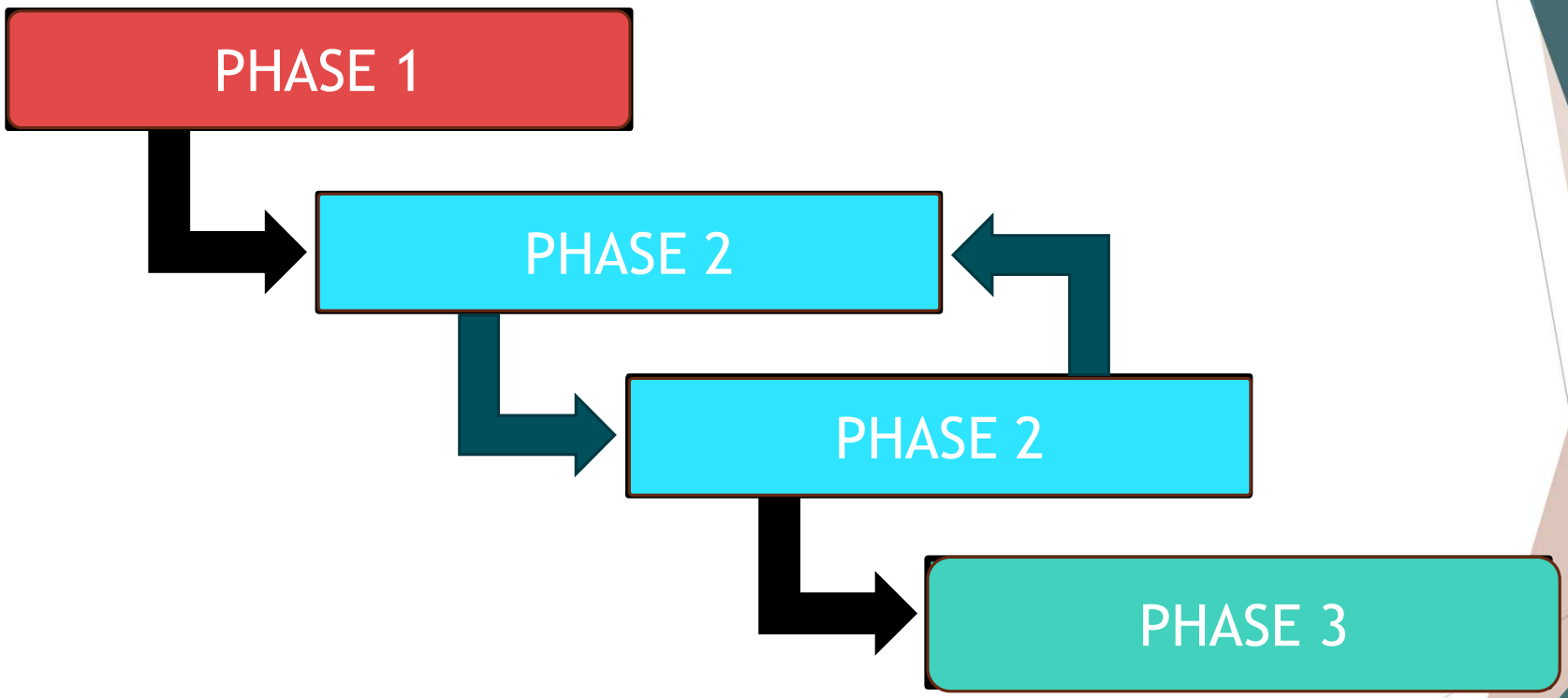
Nakajima 2011

Practical Application – When to deflate?

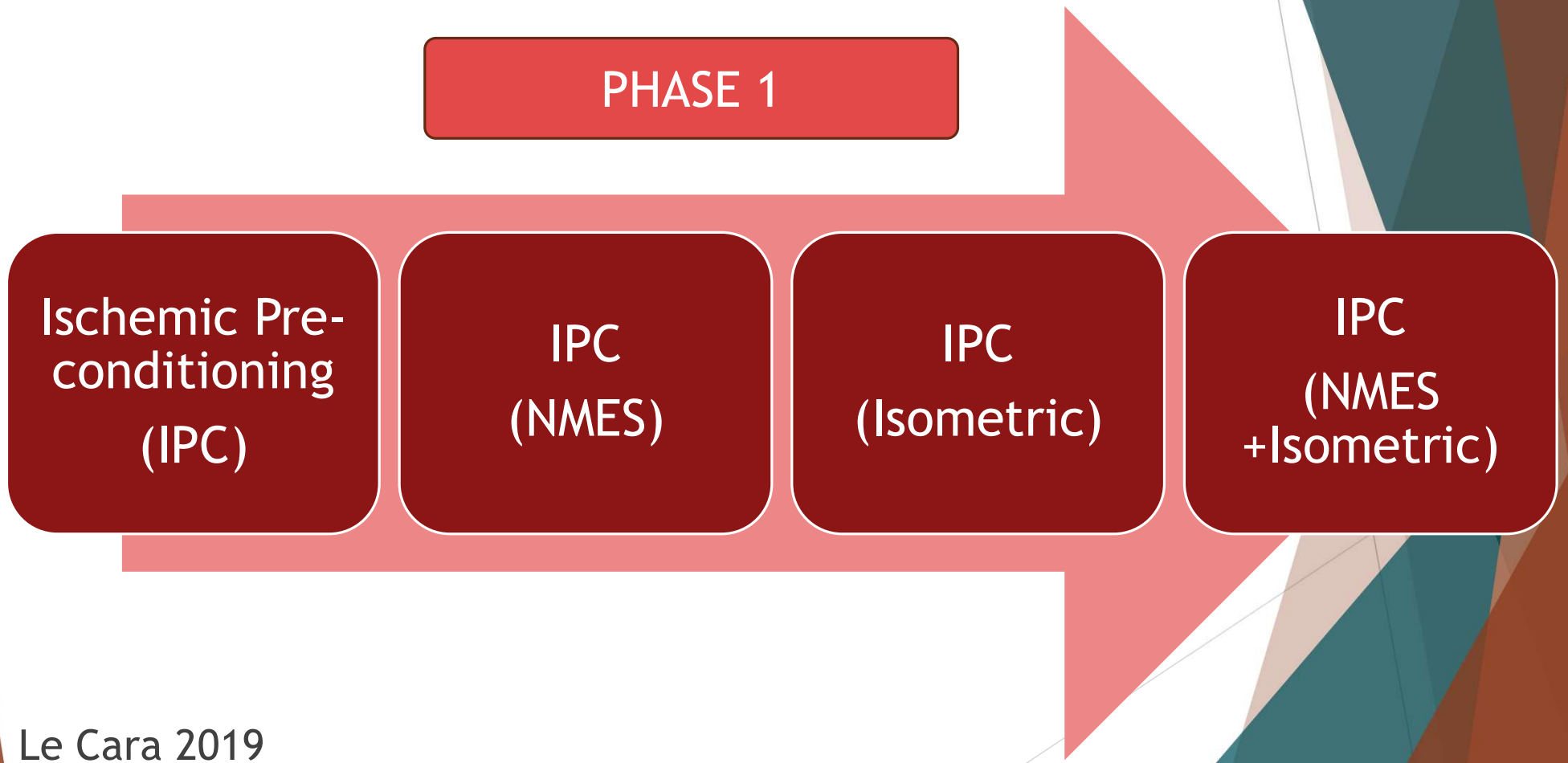
- ❑ Development of ventricular or atrial arrhythmias.
- ❑ Onset of chest pain/discomfort, or other symptoms, suggestive of myocardial ischemia.
- ❑ Dizziness, confusion, deteriorating balance, or other significant neurological symptoms.
- ❑ Paleness or cyanosis.
- ❑ Vomiting, nausea, or feeling generally unwell.
- ❑ ⬇ in SBP from rest < 10 mmHg in the absence of symptoms.
- ❑ SBP ≥ 250 mmHg &/or DBP ≥ 115 mmHg.
- ❑ Exhaustion or fatigue (malaise), sometimes persisting for days, that is out of keeping with the person's usual response to exercise at a given intensity.
- ❑ Swelling and shortness of breath.
- ❑ Skin of the affected limb that is too hot or cold to touch.
- ❑ Increased/excessive pain in the affected limb.
- ❑ Excessive discoloration of the affected limb.
- ❑ Subject requests to stop.

Nascimento 2022

Practical/Clinical Application – Exercise Specifications (cont'd)



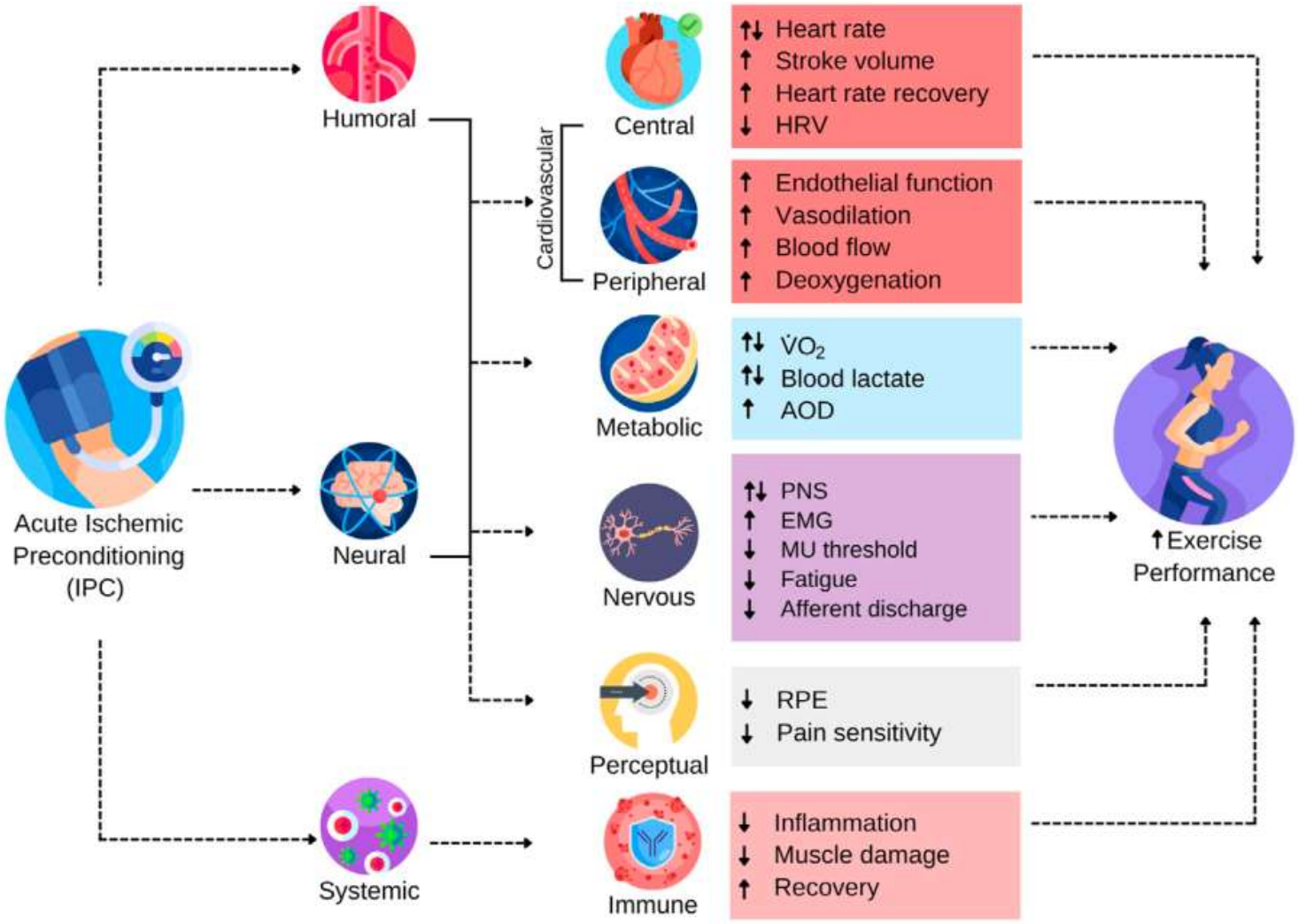
Practical/Clinical Application – Exercise Progression



Le Cara 2019

Ischemic Preconditioning

- The Range of Reported Potential Triggers and Subsequent Responses Contributing to Ergogenic Effects of IPC.[1]
- Arrows indicate directionality of documented changes in the literature
- ⬇ Muscle damage following exercise & ⬆ recovery[2]
- Preservation of lean tissue during immobilization[4]
- Improves maximal performance in highly trained swimmers[3]



O'Brien 2022[1], Franz 2018[2], Jean-St-Michel 2011[3], Kubota 2008[4]

Practical/Clinical Application – Exercise Progression

PHASE 1

Ischemic Pre-conditioning (IPC) → Passive Cell Swelling (Isometric) → IPC (NMES) → IPC (NMES +Isometric)

Progression Criteria

1. No adverse reactions
2. Completed ALL sets
3. RPE ≤7/10
4. Able to actively exercise

Ischemic Preconditioning	
Goals	• Acclimate patient to BFR • Preserve muscle (⬇ disuse atrophy) • Begin capillary growth
Frequency	Perform bilateral 2x/day
Limb Pressure	100% LOP
Prescription	5x5 min Set Rests: 3 min (Soft Tissue & PROM)

Le Cara 2019

Practical/Clinical Application – Exercise Progression

PHASE 1

Ischemic Pre-conditioning (IPC) → Passive Cell Swelling (Isometric) → IPC (NMES) → IPC (NMES +Isometric)

Progression Criteria

1. No adverse reactions
2. Completed ALL sets
3. RPE ≤7/10
4. Able to actively exercise

Ischemic Preconditioning + Isometrics			
Goals	• Preserve muscle (attenuate disuse atrophy) • Improve muscle inhibition & increase motor unit recruitment • Re-establish motor coordination (⬇ co-contraction) • Large stimulus to inhibit Myostatin/TGF-beta • ⬆Lactate to stimulate GH production to aid in collagen synthesis for soft tissue healing		
Frequency	1-2x/day (performed unilateral OR bilaterally)		
Pressure	UE: 40-50% LOP | LE: 60-80% LOP		
Prescription	Long Duration (Connective Tissue)	Short Duration (Muscle Tissue)	Dosage
	Set 1: 6x30 sec Set 2-4: 3x30 sec Intra-set Rest: 1:1 work:rest Inter-set Rest: 30 sec	Set 1: 18x10 sec Set 2-4: 9x10 sec Intra-set Rest: 1:1 work:rest Inter-set Rest: 30 sec	Number of Exercises: 1-3 Intensity: Clinician & Patient Dependent Deflate: 1 min between exercises Isometric Type: Yielding or Overcoming

Practical/Clinical Application – Exercise Progression

PHASE 1

Ischemic Pre-conditioning (IPC) → Passive Cell Swelling (Isometric) → IPC (NMES) → IPC (NMES +Isometric)

Progression Criteria

1. No adverse reactions
2. Completed ALL sets
3. RPE ≤7/10
4. Able to actively exercise

Ischemic Preconditioning + NMES	
Goals	• Preserve muscle (attenuate disuse atrophy) • Large NMES stimulus to inhibit Myostatin/TGF-beta • ⬆Lactate to stimulate GH production to aid in collagen synthesis for soft tissue healing
Frequency	1-2x/day (performed unilateral OR bilaterally) | 3-5 d/week
Limb Pressure	UE: 40-50% LOP | LE: 60-80% LOP
Prescription	5x5 min Rest: 3 min (soft tissue, manual, &/or prom)
NMES[2]	Frequency: 35-50 Hz | Pulse Duration: 400 ms | Work:Rest 3:1

Le Cara 2019
Nussbaum 2017[2]

Practical/Clinical Application – Exercise Progression

PHASE 1

Progression Criteria

1. No adverse reactions
2. Able to complete ALL sets/reps
3. RPE ≤7/10
4. Able to actively exercise

Practical/Clinical Application – Exercise Progression

PHASE 2

BFRT Low Intensity Cardiovascular Conditioning

BFRT Low Load Resistance Training

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Practical/Clinical Application – Exercise Progression

PHASE 2

BFRT Low Intensity Cardiovascular Conditioning

BFRT Low Load Resistance Training

BFRT Low Intensity Cardiovascular Conditioning	
Goals	• Preserve muscle (attenuate disuse atrophy) • Large NMES stimulus to inhibit Myostatin/TGF-beta • ⬆ HR, Peripheral tissue neovascularization, & metabolic function (cellular & mitochondrial) • ⬆ Lactate threshold training to improve VO2max
Frequency	2-5x/week
Limb Pressure	UE: 40-50% LOP | LE: 60-80% LOP
Prescription	• Duration: 5 – 20 min | Intensity: 6-7/10 RPE • Progress Watts/METs as tolerated

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Practical/Clinical Application – Exercise Progression

PHASE 2

BFRT Low Intensity Cardiovascular Conditioning

BFRT Low Load Resistance Training

Goals: BFRT Low Intensity Resistance Training

- Preserve muscle (attenuate disuse atrophy)
- ⬆ Muscle inhibition & ⬆ motor unit recruitment
- Re-establish motor coordination (⬇ co-contraction)
- Large stimulus to inhibit Myostatin/TGF-beta
- ⬆ Lactate to stimulate GH production to aid in collagen synthesis for soft tissue healing
- ⬆ Tolerance to active ROM, internal load, & external resistance

Practical/Clinical Application – Exercise Progression

PHASE 2

BFRT Low Intensity Cardiovascular Conditioning

BFRT Low Load Resistance Training

BFRT Low Intensity Cardiovascular Conditioning	
Frequency	2-5x/week
Pressure	UE: 40-50% LOP | LE: 60-80% LOP
Tempo	• Duration: 5 – 20 min | Intensity: 6-7/10 RPE • Progress Watts/METs as tolerated
Volume	# of Exercises: 3-5 Set 1: 30 reps |Set 2-4: 15 reps (Tempo: 2-1-2-1)

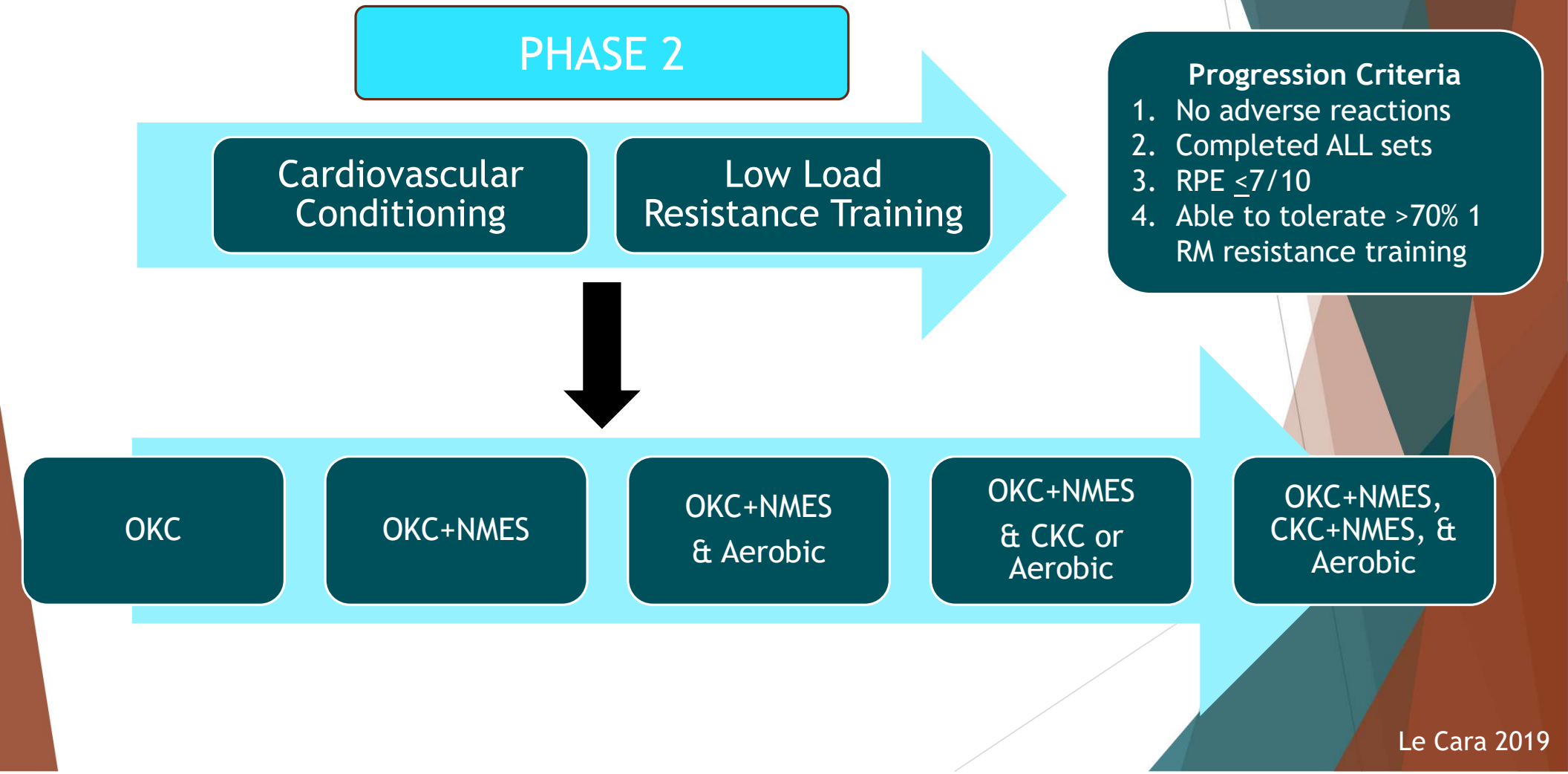
Intensity[2]	• 20-40% 1RM (>7/10 RPE or ≤2 RIR)
	• Progression: Weekly Adjusted Resistance (Maintain >7/10[2])
	  • Smaller Muscles: ⬆ 5-10% | Larger Muscles: ⬆ 10-20%
	  • 2 by 2 Rule (Attempt ≥17 reps on sets 3 & 4)

***Pro Tips*:**

1. Full available ROM
2. Emphasis on Controlled Eccentric
3. Max volitional contraction
4. Manual Pump than, re-inflate after set #2

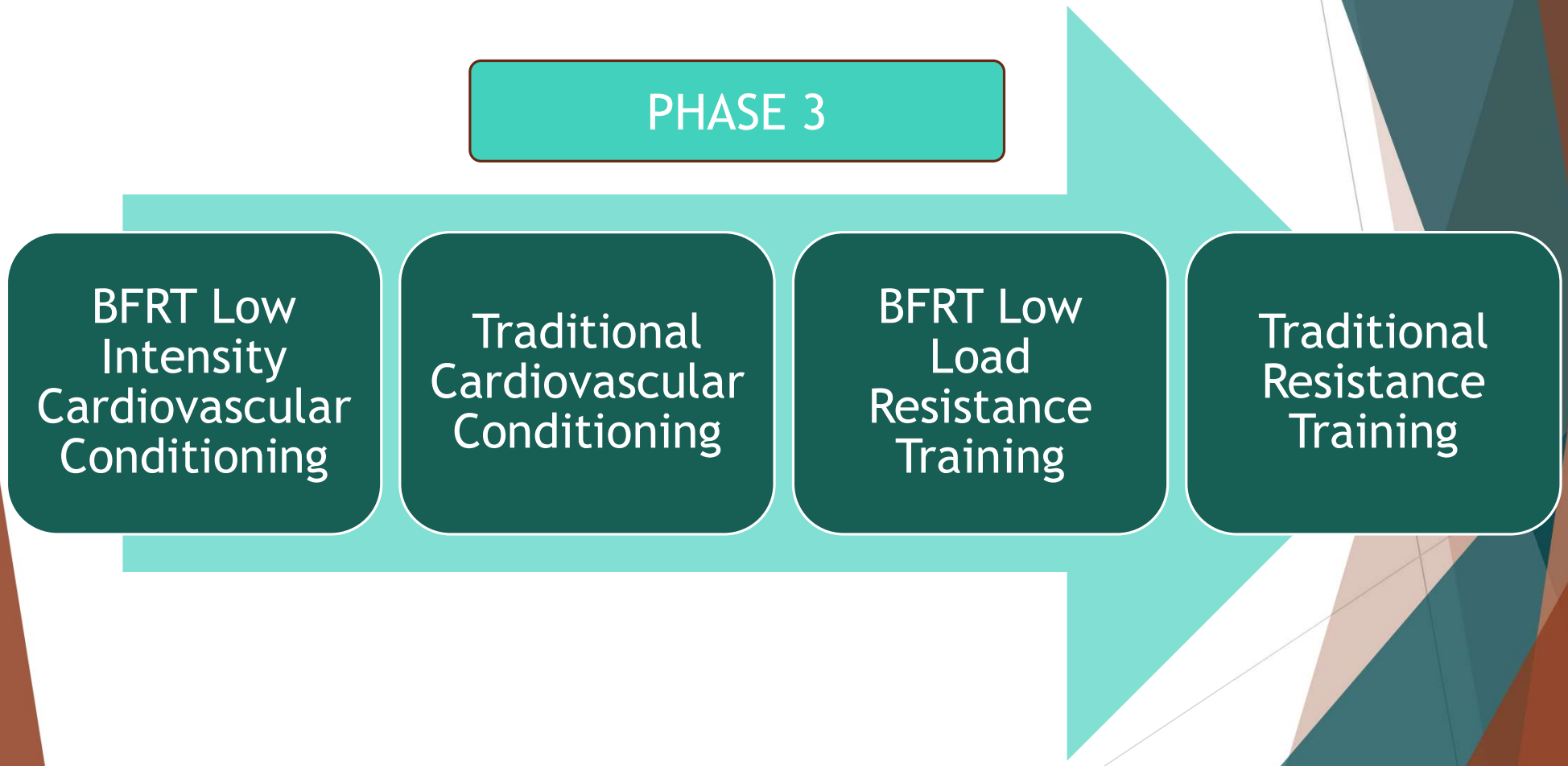
Le Cara 2019
Fiataraone Singh 2019[2]

Practical/Clinical Application – Exercise Progression



Le Cara 2019

Practical/Clinical Application – Exercise Progression



Practical/Clinical Application – Exercise Progression

PHASE 3

SYSTEMATIC REVIEW

Magnitude of Muscle Strength and Mass Adaptations Between High-Load Resistance Training Versus Low-Load Resistance Training Associated with Blood-Flow Restriction: A Systematic Review and Meta-Analysis

Manoel E. Lixandrão[1] · Carlos Ugrinowitsch[1] · Ricardo Berton[1] · Felipe C. Vechin[1] · Miguel S. Conceição[1] · Felipe Damas[1] · Cleiton A. Libardi[2] · Hamilton Roschel[1]

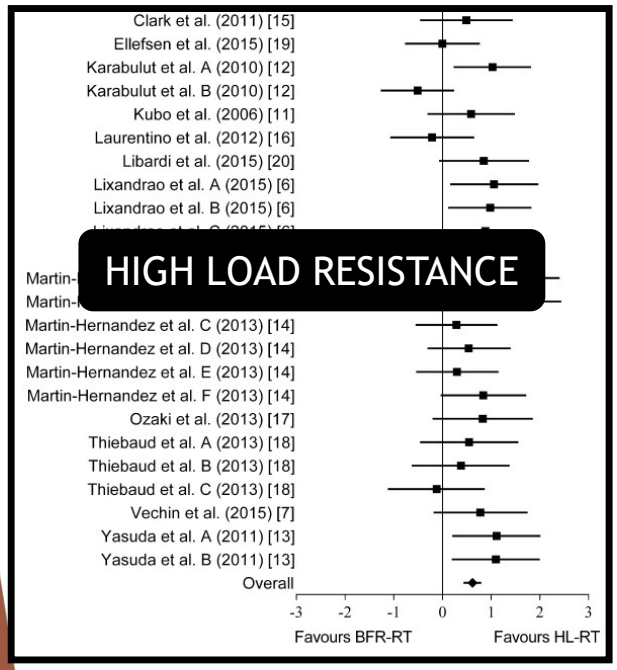
LIxandrao et al 2017

Practical/Clinical Application – Exercise Progression

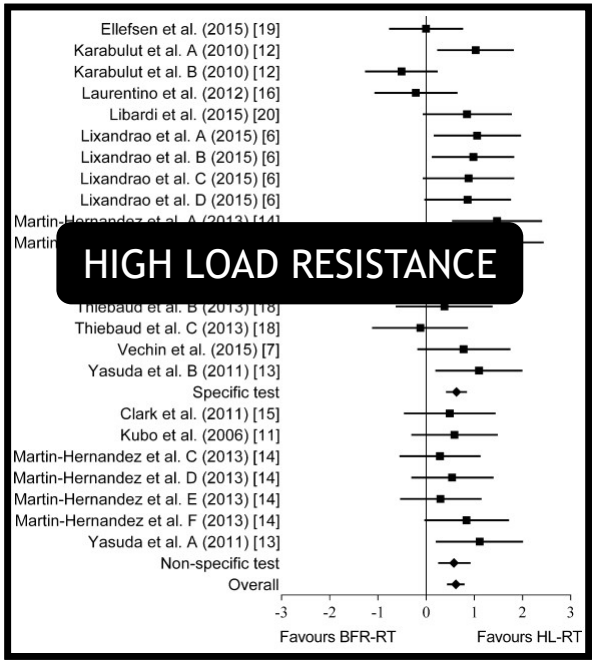
Magnitude of Muscle Strength and Mass Adaptations Between High-Load Resistance Training Versus Low-Load Resistance Training Associated with Blood-Flow Restriction: A Systematic Review and Meta-Analysis

PHASE 3

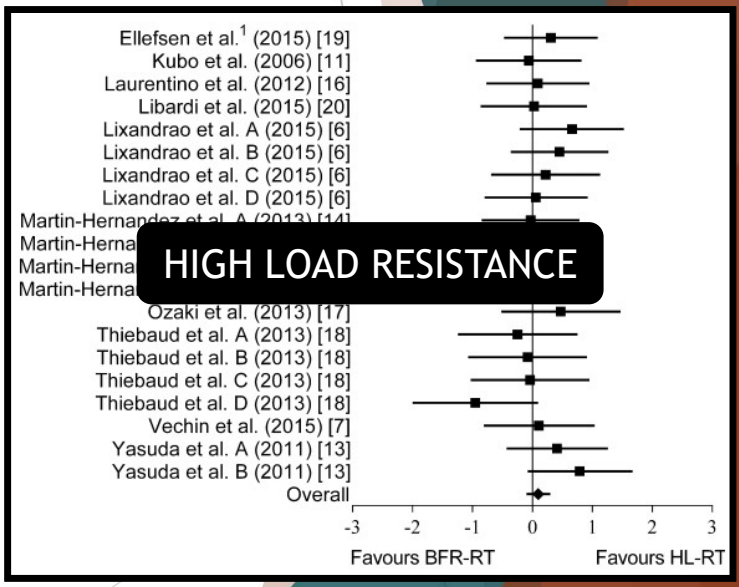
STRENGTH ADAPDATIONS



MUSCLE STRENGTH



HYPERTROPHY



LIxandrao et al 2017

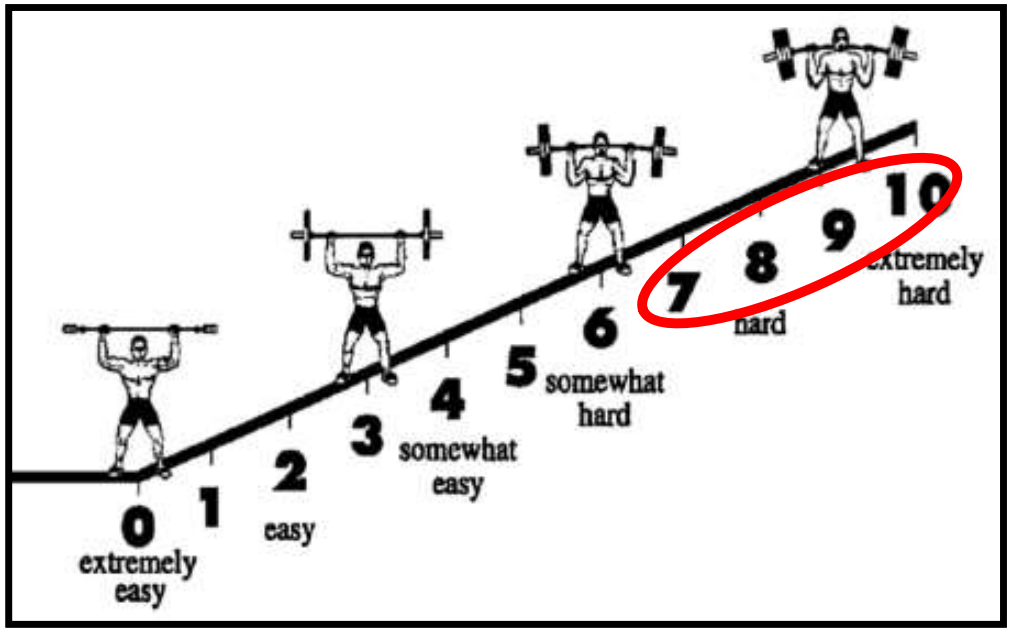
Practical/Clinical Application – Exercise Progression

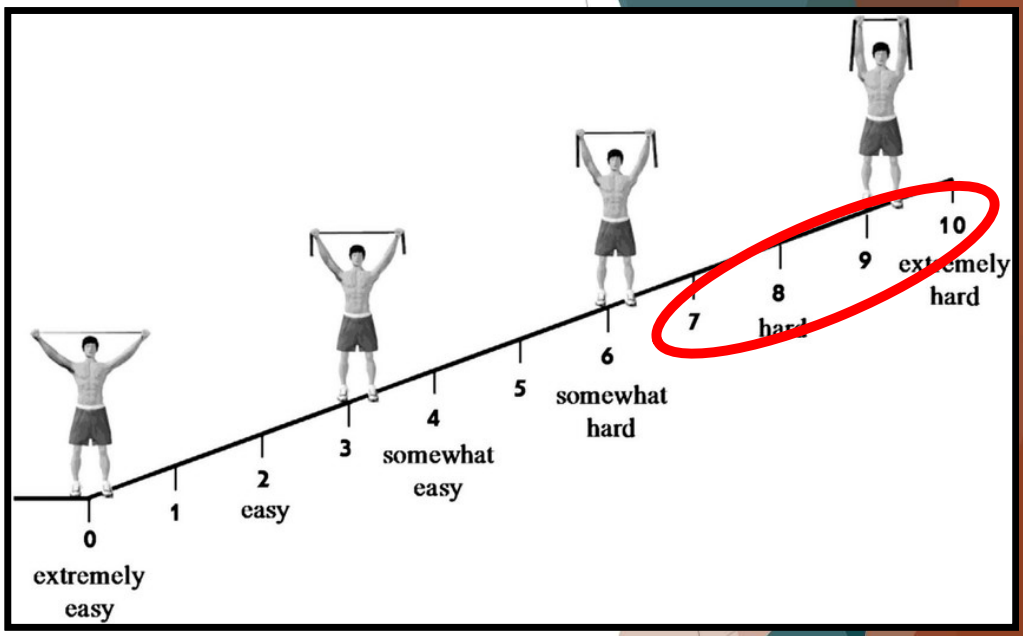
PHASE 3

Magnitude of Muscle Strength and Mass Adaptations Between High-Load Resistance Training Versus Low-Load Resistance Training Associated with Blood-Flow Restriction: A Systematic Review and Meta-Analysis

LIxandrao et al 2017[2018]

Practical/Clinical Application – Exercise Progression





Robertson 2001, Colado 2012, Colado 2014, Morishita 2018

Practical/Clinical Application – Exercise Progression

RPE*	What it feels like	Repetitions in reserve**
10	Your absolute limit	0
9.5	You could maybe add a couple pounds to the bar	0
9	Very close to your max	1
8.5	Where you typically end a set when you're pushing yourself hard	1-2
8	Where you typically end a set when you're feeling strong	2
7	Where you end a set when you're trying to leave some-thing in the tank (or when you just don't have it that day)	3
5-6	Warmup sets	4-6
3-4	General warmup	Too many to count
1-2	Anything more strenuous than watching TV	Infinite

Zourdos 2016

Actual RPE	Assigned RPE range 6–8
1	Increase load by 20%
2	Increase load by 16%
3	Increase load by 12%
4	Increase load by 8%
5	Increase load by 4%
6	Participant choice
7	Participant choice
7.5	Participant choice
8	Participant choice
8.5	Decrease load by 2%
9	Decrease load by 4%
9.5	Decrease load by 6%
10	Decrease load by 8%

Helms 2018

Practical/Clinical Application – Exercise Progression

IF: *patient exceeds target rep by 2 reps on final set on 2 consecutive exercise bouts*

THEN: *progress resistance*

Description of the athlete*	Body area exercise	Estimated load increase†
Smaller, weaker, less trained	Upper body	2.5-5 pounds (1-2 kg)
	Lower body	5-10 pounds (2-4 kg)
Larger, stronger, more trained	Upper body	5-10+ pounds (2-4+ kg)
	Lower body	10-15+ pounds (4-7+ kg)

*The strength and conditioning professional will need to determine which of these two subjective categories applies to a specific athlete.

†These load increases are appropriate for training programs with load-volumes of approximately three sets of 5 to 10 repetitions. Note that the goal repetitions per set remain constant as the loads are increased.

		Resistance in Pounds at:	
Thera-Band® Band/Tubing Color	Increase from Preceding Color at 100% Elongation	100% Elongation	200% Elongation
Thera-Band Tan	-	2.4	3.4
Thera-Band Yellow	25%	3.0	4.3
Thera-Band Red	25%	3.7	5.5
Thera-Band Green	25%	4.6	6.7
Thera-Band Blue	25%	5.8	8.6
Thera-Band Black	25%	7.3	10.2
Thera-Band Silver	40%	10.2	15.3
Thera-Band Gold	40%	14.2	21.3

BEGINNER → ADVANCED

Represents typical values. All products not available in all colors.

Baechle 2008

Practical/Clinical Application – Exercise Progression

Number of Repetitions Performed	Percent of 1-Repetition Maximum	Multiply Weight Lifted By:
1	100	1.00
2	95	1.05
3	93	1.08
4	90	1.11
5	87	1.15
6	85	1.18
7	83	1.20
8	80	1.25
9	77	1.30
10	75	1.33
11	70	1.43
12	67	1.49
15	65	1.54

Haff 2015

Practical/Clinical Application – RPE Adaptation

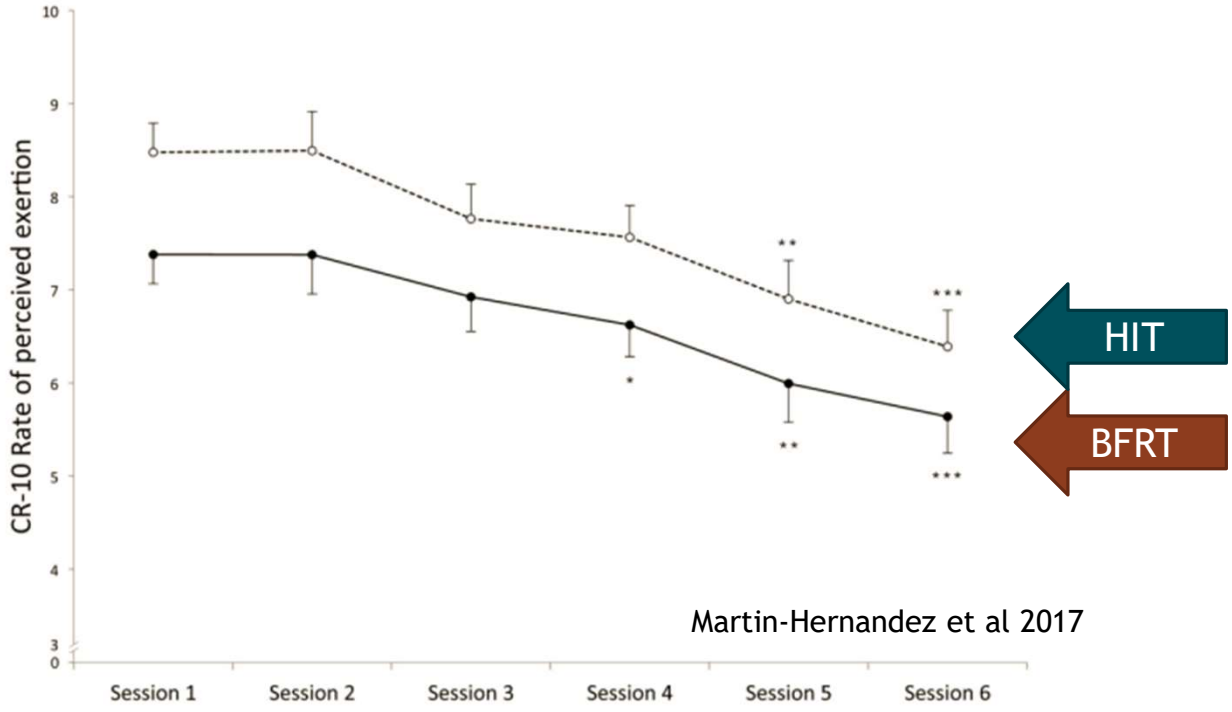


Figure 1. Ratings of perceived exertion (RPE) values after each session of blood flow restriction training (BFR and high-intensity training (HIT). Each session RPE is expressed as the average RPE of all sets. Values are mean *SE*. *, **, *** significantly different from session 1 ($p \leq 0.05$, $p < 0.01$, $p < 0.001$, respectively).

High Intensity Training:
- Sets: 3
- Reps: 8
- Intensity: 85% 1RM
- Leg Extension

BFR Training (BFRT):
- Sets: 4
- Reps: 30/15/15/15
- Intensity: 20% 1RM
- Leg Extension

Conclusion:
- BFRT induces a marked RPE to training, vs HIT
- may not limit the application of BFRT to highly motivated individuals

Practical/Clinical Application

Clinical Outcomes
- Circumference of thickest portion of limb segment
- Force production (i.e. strength)
- Work Capacity (i.e., total work via fatigue assessments)
- Rate of force development (i.e., isometric strength)
- Biofeedback / Surface EMG
- Serial imaging
- Patient specific physical performance measure
- Functional Outcome Measures

The Limitations of BFR

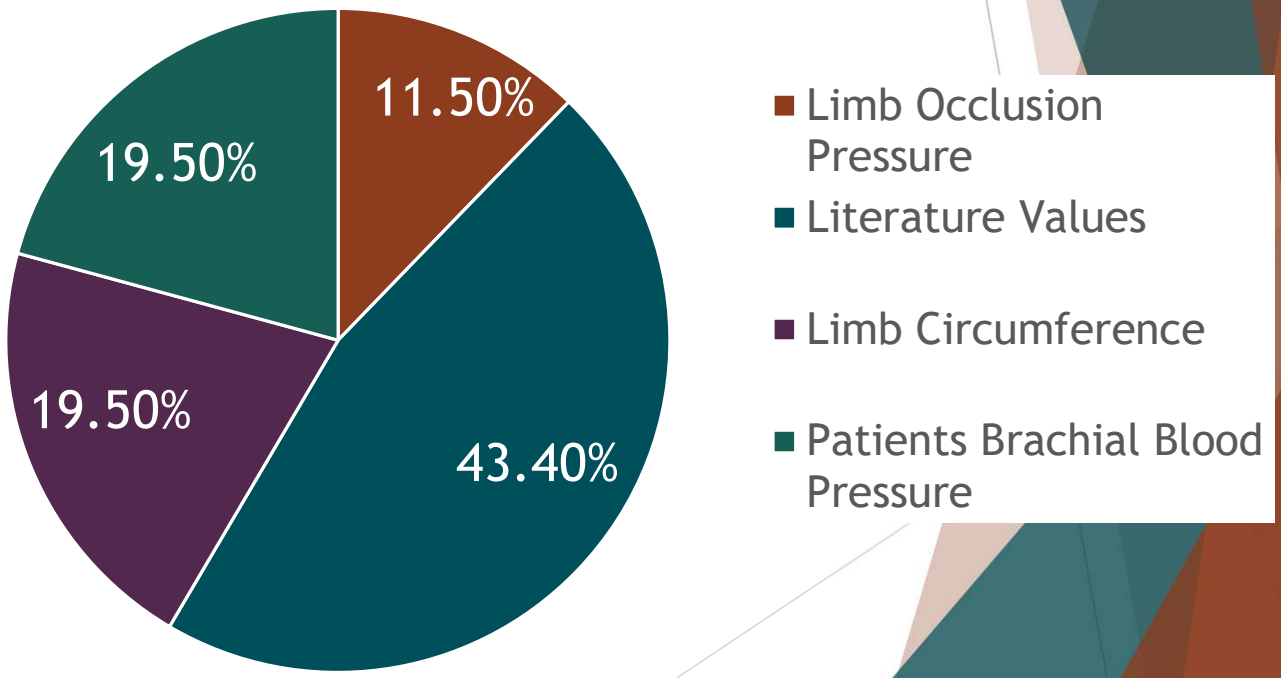
Limitations of BFR

1. NOT superior to Heavy Load Resistance Training
2. Use of non-FDA Regulated Cuffs
3. Poor prescription practices
4. Effects of chronic BFR utilization unknown
5. Methodology of study design (risk of bias & conflicts of interest)

The Limitations of BFR: BFR Cuff Selection

The Limitations of BFR: Poor Prescription

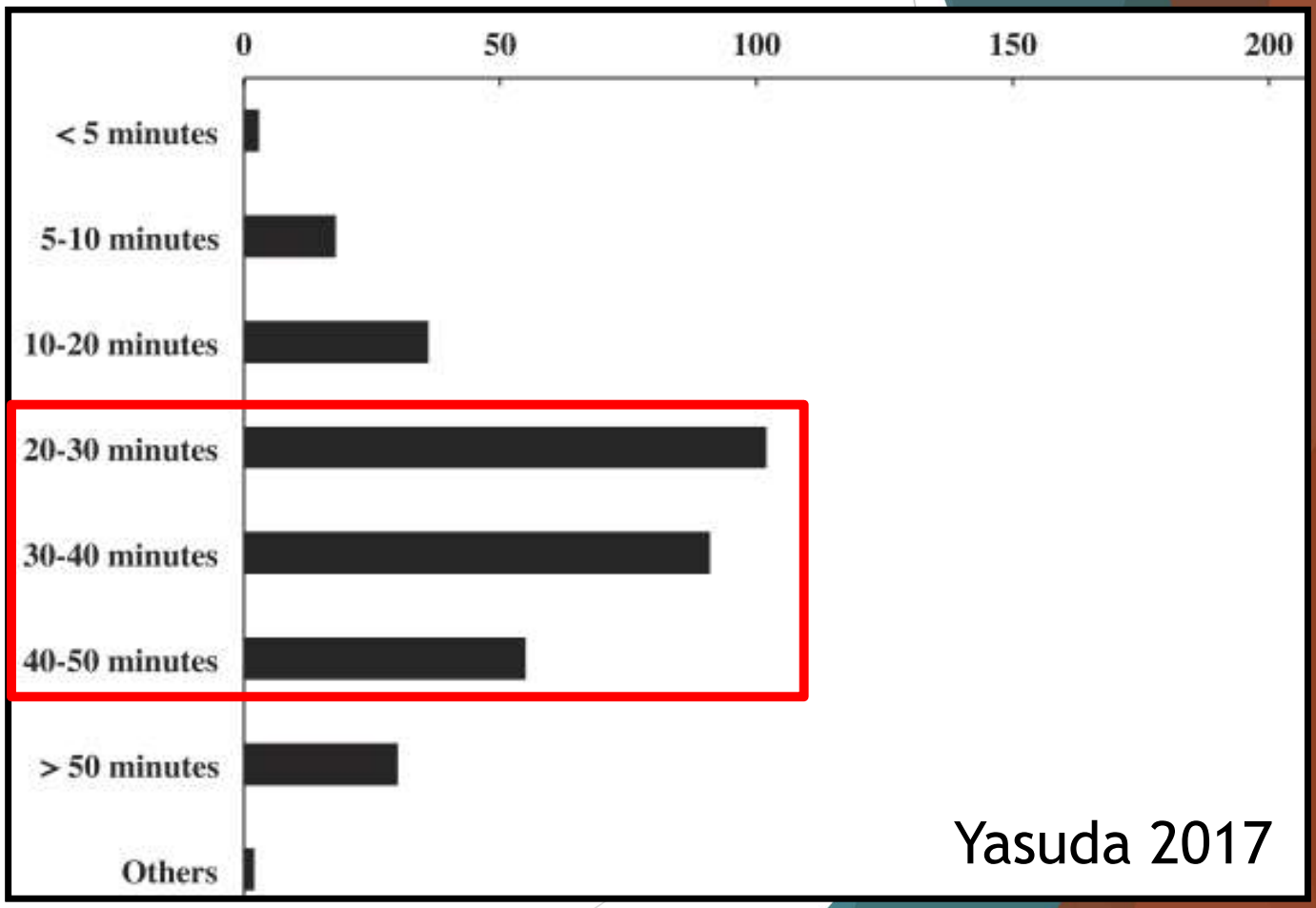
N = 250
- Strength & Conditioning Coaches
- Sports Scientists
- Physiotherapists
- Researchers
- Doctors



Patterson 2018

Limitations of BFR: Poor Prescription

- Occlusion pressure, intensity of training, number of sets and duration of a training unit remain unclear (Heitkamp 2015)



Yasuda 2017

Limitations of BFR (cont'd)

4. Effects of chronic BFR utilization unknown
5. Methodology of study design

   (risk of bias & conflicts of interest)

BFR Legislation & Logistics

Blood Flow Restriction Training & Scope of Practice

- **APTA Positional Statement:** What to Know About Blood Flow Restriction Training 2018[3]
  - "**BFRT is part of the professional scope of practice for physical therapists.**"
- The Scope of Practice of Physical Therapy has 3 components[3]
  - **Professional:** the unique body of knowledge, supported by educational preparation, based on a body of evidence, and linked to existing or emerging practice frameworks
  - **Jurisdiction (legal):** is established by a state's practice act governing the specific physical therapist's license, and the rules adopted pursuant to that act
  - **Personal:** consists of activities for which an individual physical therapist is educated and trained and their competence to perform
- **BFR became part of OT & PT scope of practice in 2018**[4] & CEU Credit available for[3]
  - OT, PT, ATC
- **Licensed medical healthcare providers able to purchase medical grade pneumatic tourniquet system**[1]
  - Physician (MD, DO)
  - Athletic Trainers
  - Physical Therapists/Occupational Therapists
  - Chiropractors

Owens Recovery Science[1], MedBridge, APTA website[3], CAOperformanceandtherapy.com[4]

Practical Implications – Legislation

- **BFR Training Scope of Practice**
  - APTA: "BFRT is part of the professional scope of practice for physical therapists."
- **State Legislation**
  1. Check State's Practice Act
     - May be silent in regard to BFRT
  2. Check State's Laws for Confirmation
- CAPTA Practice Act Silent on BFR & No laws prohibiting use of BFRT

Blood Flow Restriction Training & Billing

CPT Code Number	Title
97110	Therapeutic Exercise
97112	Neuromuscular Re-education
97116	Gait Training
97530	Therapeutic Activities
9140	Manual Therapy

8-Minute Rule Quick Reference

1 Unit	8–22 Minutes
2 Units	23–37 Minutes
3 Units	38–52 Minutes
4 Units	53–67 Minutes
5 Units	68–82 Minutes
6 Units	83–97 Minutes

Practical Implications – Legislation & Billing

FDA Regulation

- Pneumatic Tourniquets are Class 1 - FDA regulated products
- Ensure that product is registered and approved by the FDA when practicing in the United States

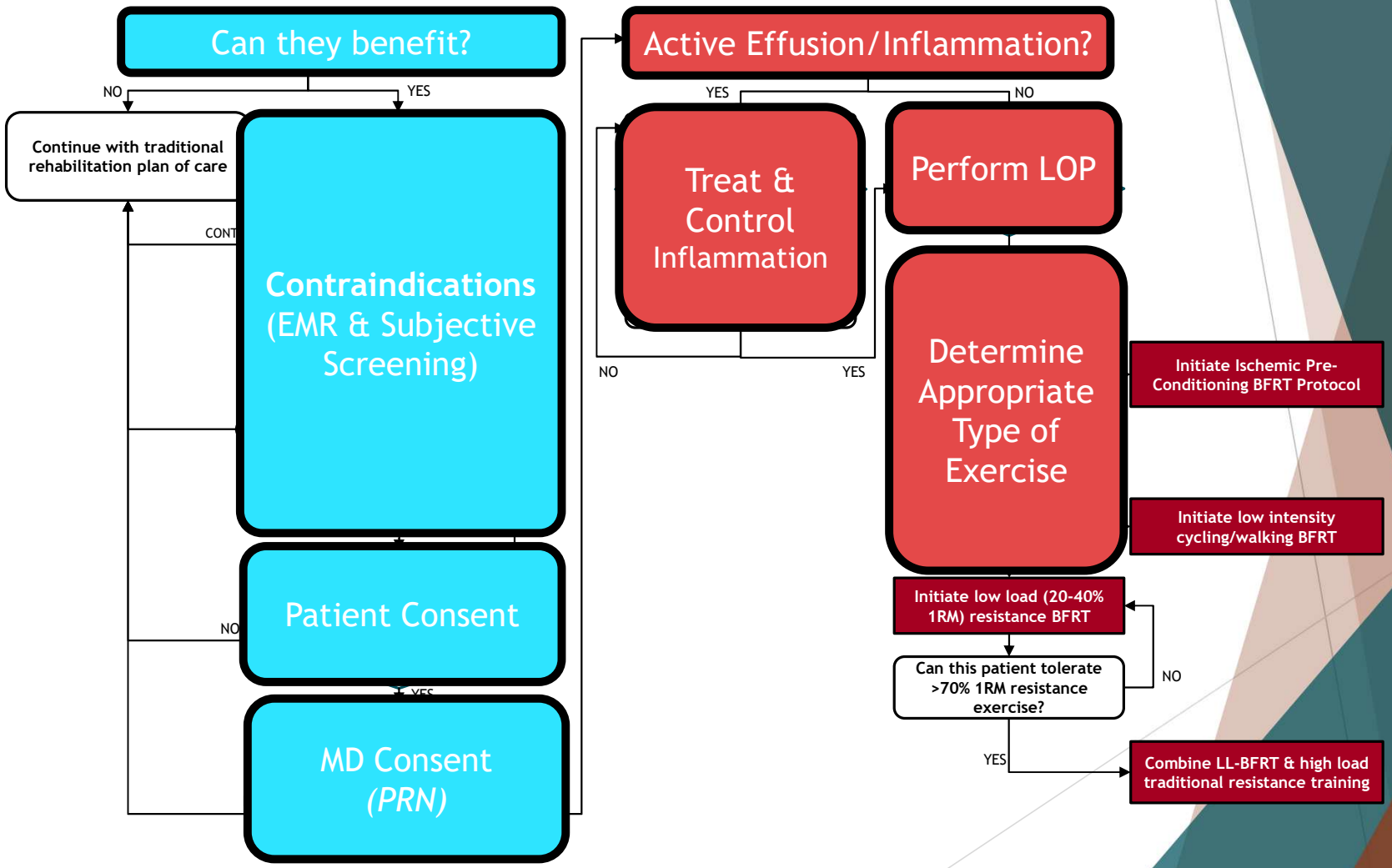
Billing

- Billed under the standard physical therapy codes depending on the activity that the patient is performing

Summary & Conclusion

1. Summary Slides
2. Review Objectives
3. Lab

Blood Flow Restriction Training Screening Algorithm



Practical/Clinical Application – Exercise Specifications[1]

Variable	Passive Exercise	Aerobic Exercise	Resistance Exercise
Type of Exercise	PHASE 1	PHASE 2	
Frequency			
Exercise Intensity			
Volume		PHASE 3	
Rest[2]			
Duration			
Tempo			

Scott 2014[1], Heitkamp 2015[2], Loenneke 2012[3], Slyzs 2016[4], Inagaki 2011[5]

Objectives

The audience will be able to:

- Describe an **algorithmic decision making process to identifying appropriate patients** for blood flow restriction training (BFRT)
- Utilize best **evidence screening process** to stratify patients' risk of adverse response(s) to BFRT
- **Perform a limb occlusion pressure (LOP)** using the ultrasound doppler for the upper and lower extremity
- Determine the **optimal occlusion and exercise parameters** for BFRT
- Verbalize **evidence and criterion-based clinical progression** of BFRT

Objectives

The Background & Science

1. What is blood flow restriction training (BFR)?
2. How does it *actually* produce said adaptations? *(Pre-material)*
3. Why would I consider using BFR? AND Who can benefit from BFR?
4. What does the evidence say about the effectiveness of BFR? *(Pre-material)*
5. How do I safely apply BFR in the clinical setting?
    1. Is it *truly* safe? And for who?
    2. What are the risks & side effects?
    3. How do I know if my patient is appropriate?
6. Practical/Clinical Application

Questions, Comments, Feedback, Discussion…

Lab

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