Blood Flow Restriction Training In the Upper Extremity Practical Application

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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**

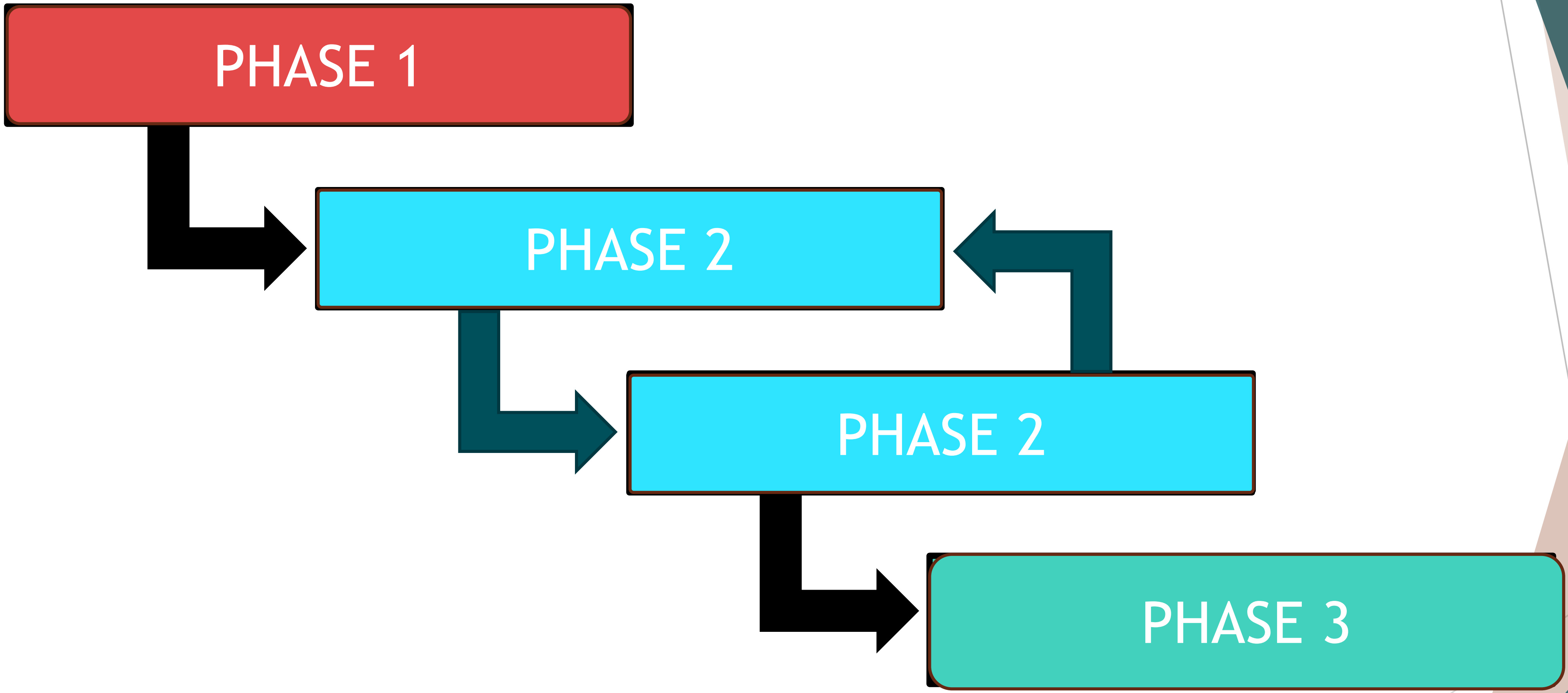
Nakajima 2011[88]

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)



Le Cara 2019

Practical/Clinical Application – Exercise Progression

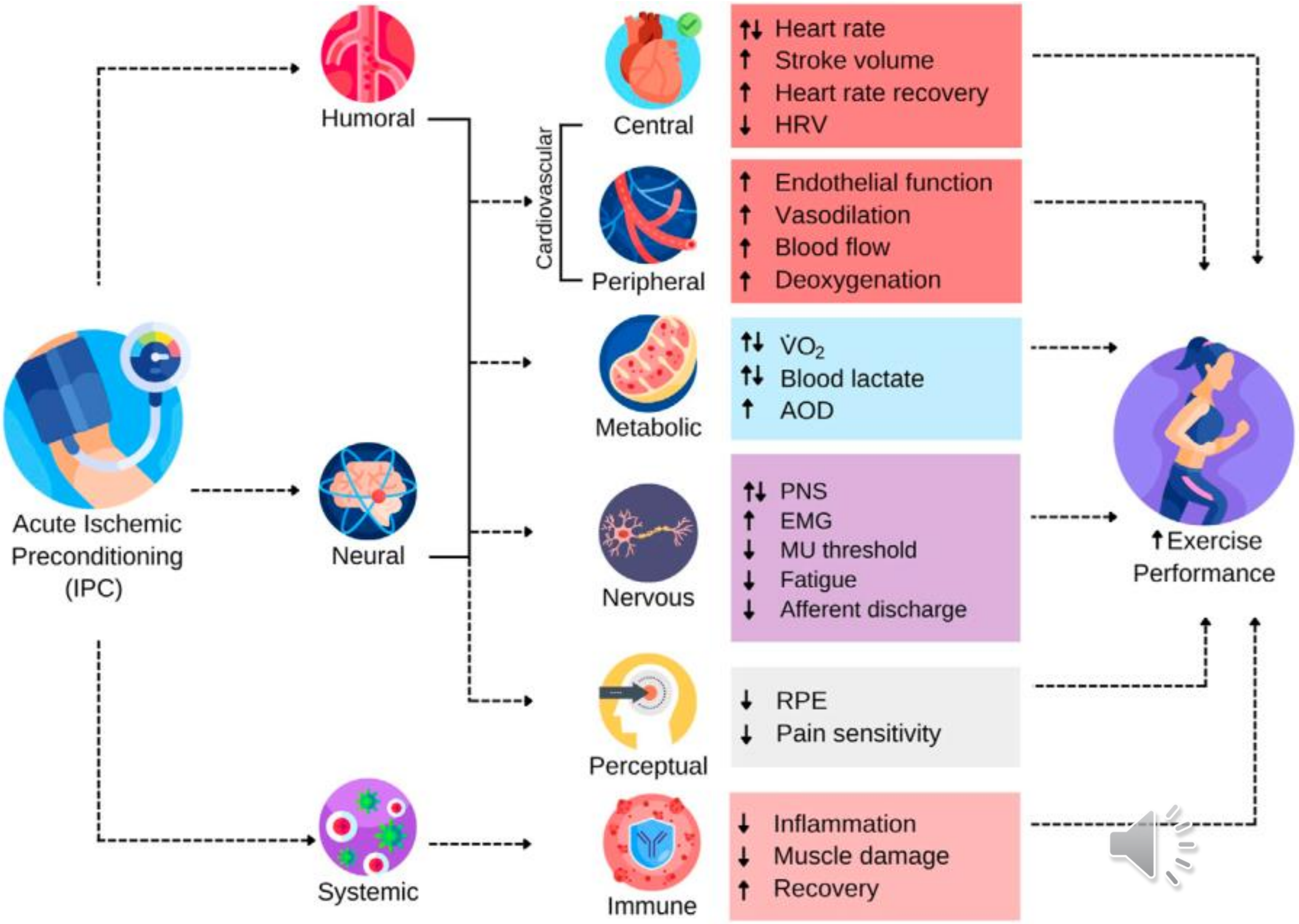
PHASE 1

- Ischemic Pre-conditioning (IPC)
- IPC (NMES)
- IPC (Isometric)
- IPC (NMES +Isometric)

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 $\leq$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 $\leq$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 $\leq$7/10
4. Able to actively exercise

Practical/Clinical Application – Exercise Progression

PHASE 2

BFRT Low Intensity Cardiovascular Conditioning

BFRT Low Load Resistance Training

Le Cara 2019

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

Le Cara 2019

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

Le Cara 2019

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
Duration	• Duration/Exercise: 8 – 20 min
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

PHASE 2

- Cardiovascular Conditioning
- Low Load Resistance Training

Progression Criteria

1. No adverse reactions
2. Completed ALL sets
3. RPE ≤7/10
4. Able to tolerate >70% 1 RM resistance training

OKC → OKC+NMES → OKC+NMES & Aerobic → OKC+NMES & CKC or Aerobic → OKC+NMES, CKC+NMES, & Aerobic

Le Cara 2019

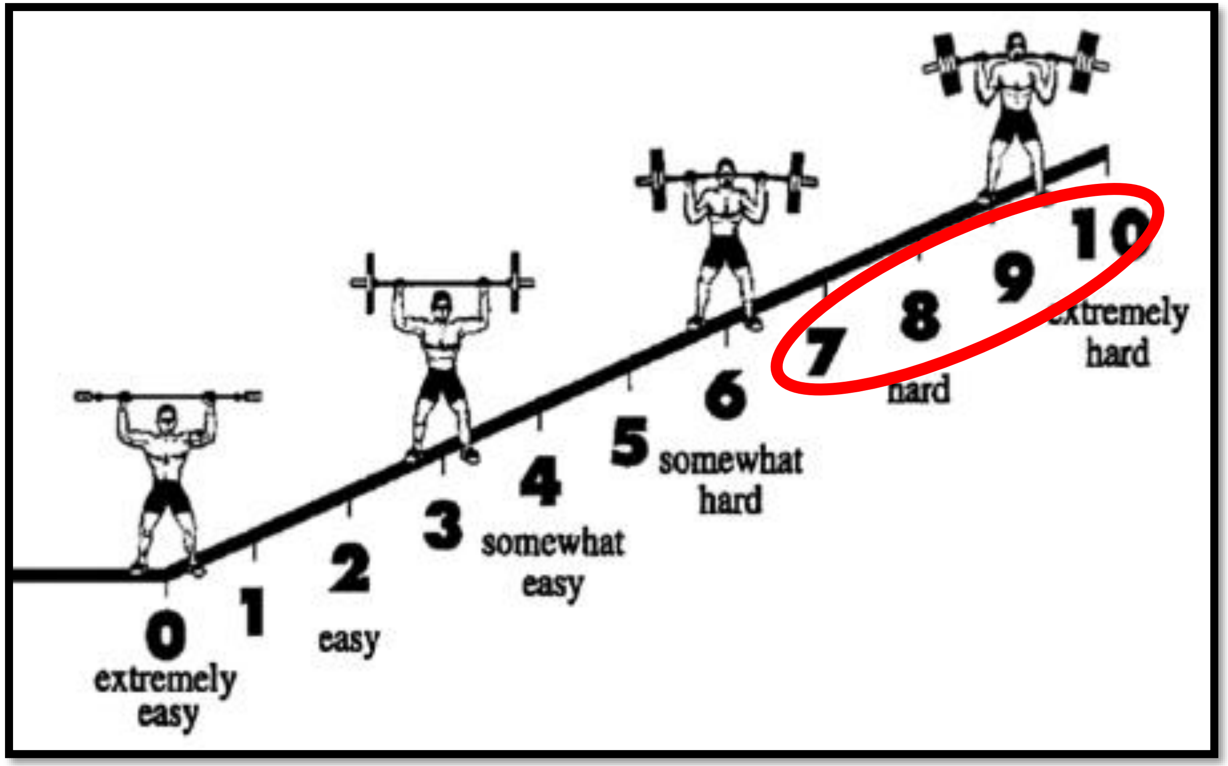
Practical/Clinical Application – Exercise Progression

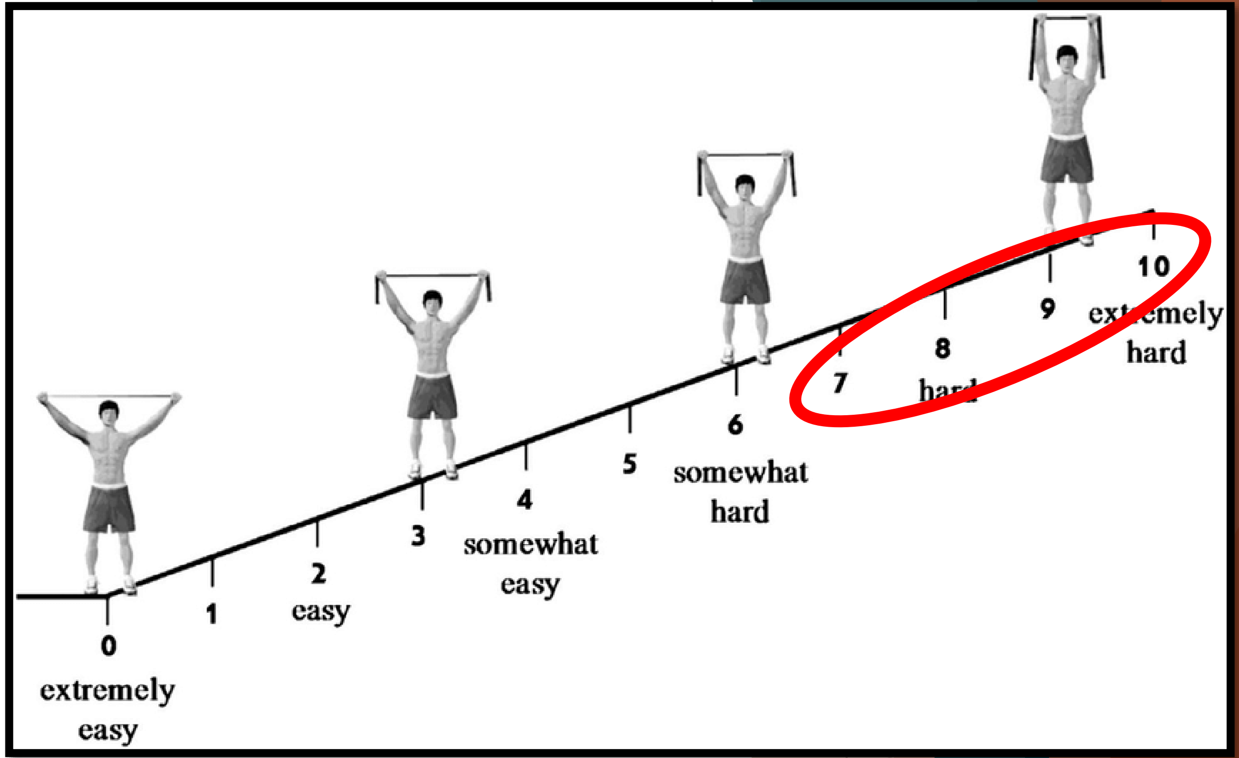
PHASE 3

- BFRT Low Intensity Cardiovascular Conditioning
- Traditional Cardiovascular Conditioning
- BFRT Low Load Resistance Training
- Traditional Resistance Training

Le Cara 2019

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 something 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.

Thera-Band® Band/Tubing Color	Increase from Preceding Color at 100% Elongation	Resistance in Pounds at: 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

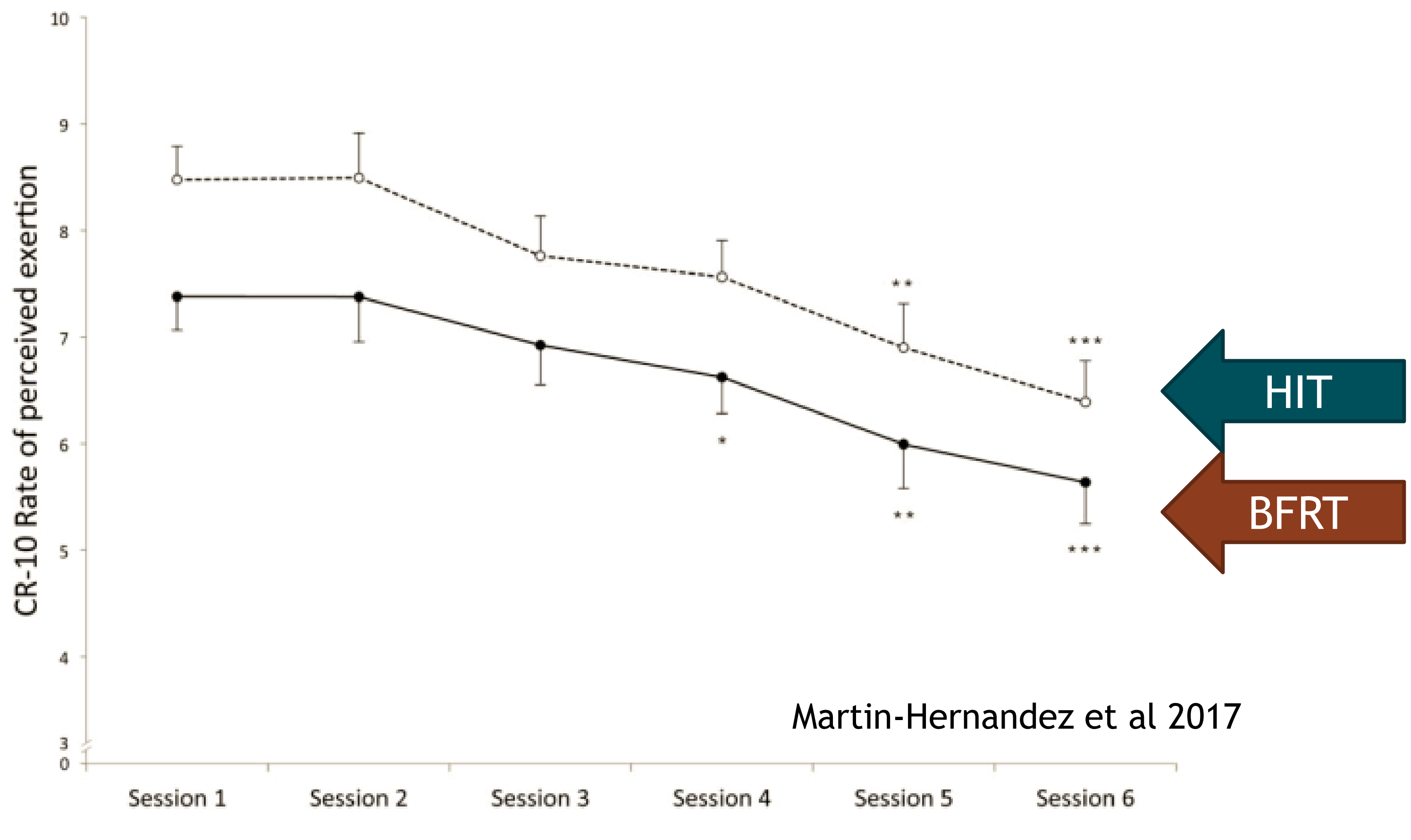


Figure 1. Ratings of perceived exertion (RPE) values after each session of blood flow restriction training (BFF and high-intensity training (HIT). Each session RPE is expressed as the average RPE of all sets. Values are mean *SE*. *, **, *** significantly different from session 1 ($p \leq 0.05$, $p 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

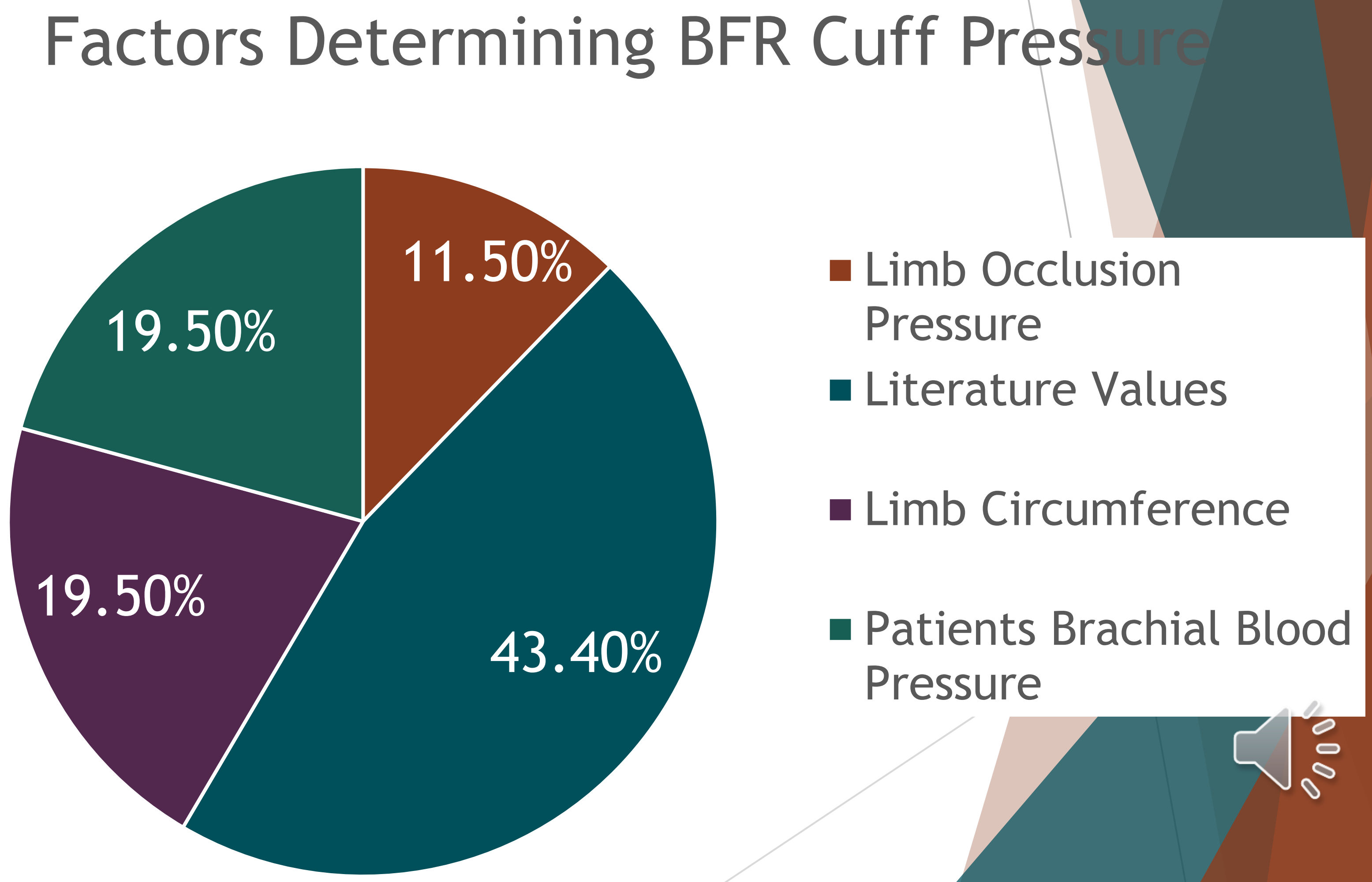
1. NOT superior to Heavy Load Resistance Training
2. Use of non-FDA Regulated Cuffs
3. Poor prescription practices
4. Effects of chronic BFR utilization unknown
5. Methodology of study design (risk of bias & conflicts of interest)

The Limitations of BFR: BFR Cuff Selection

The Limitations of BFR: Poor Prescription

N = 250

- Strength & Conditioning Coaches
- Sports Scientists
- Physiotherapists
- Researchers
- Doctors

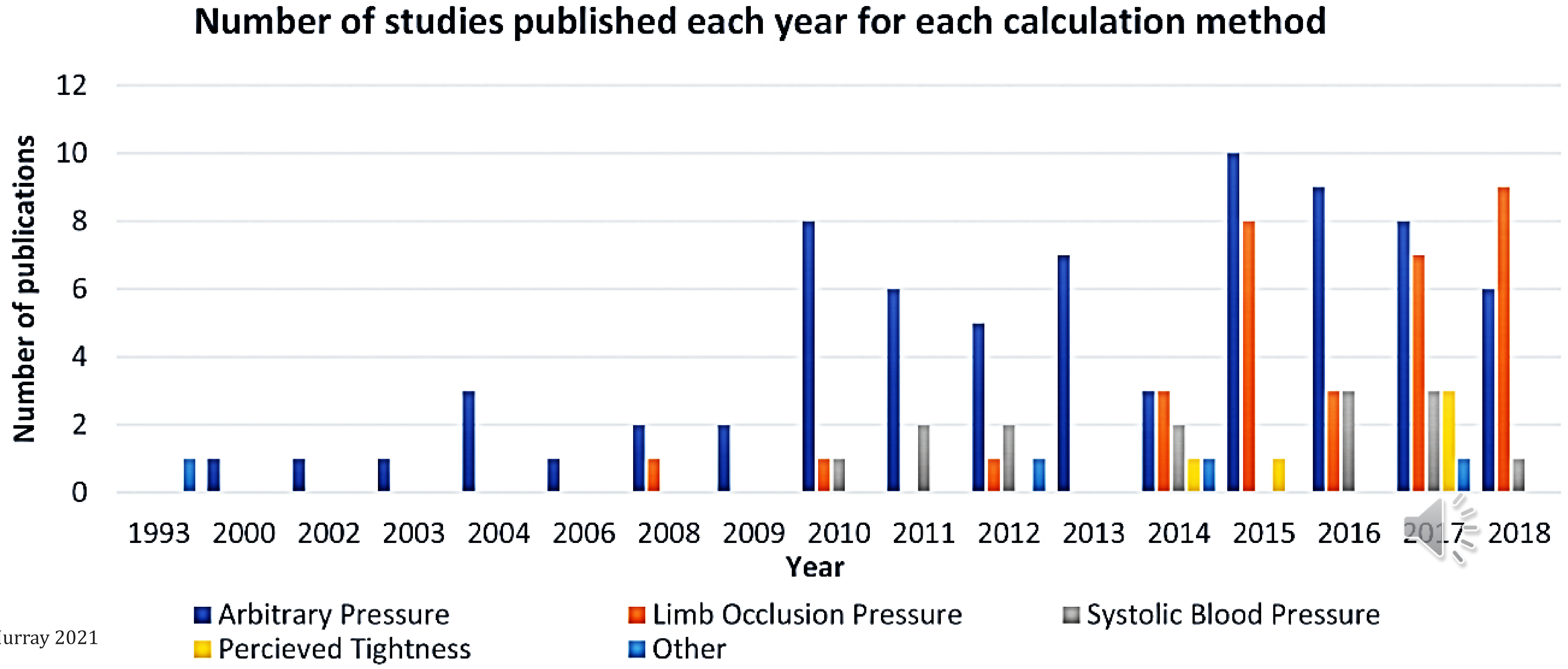


Patterson 2018

Practical Application – Cuff Pressure

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

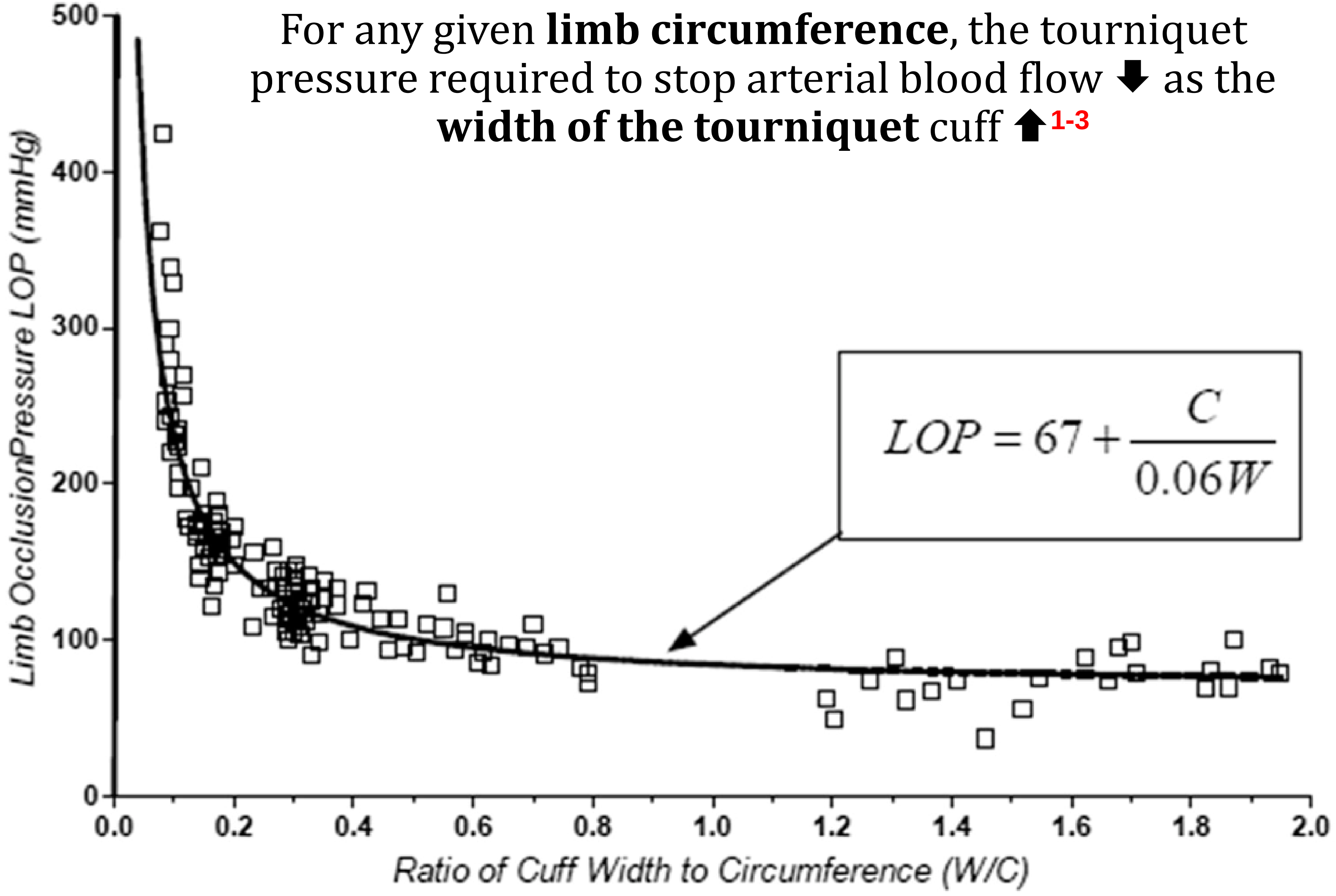
James Murray[a,b], Hunter Bennett[a,b], Terry Boyle[a,c], Marie Williams[a,d] and Kade Davison[a,b]



Murray 2021

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]



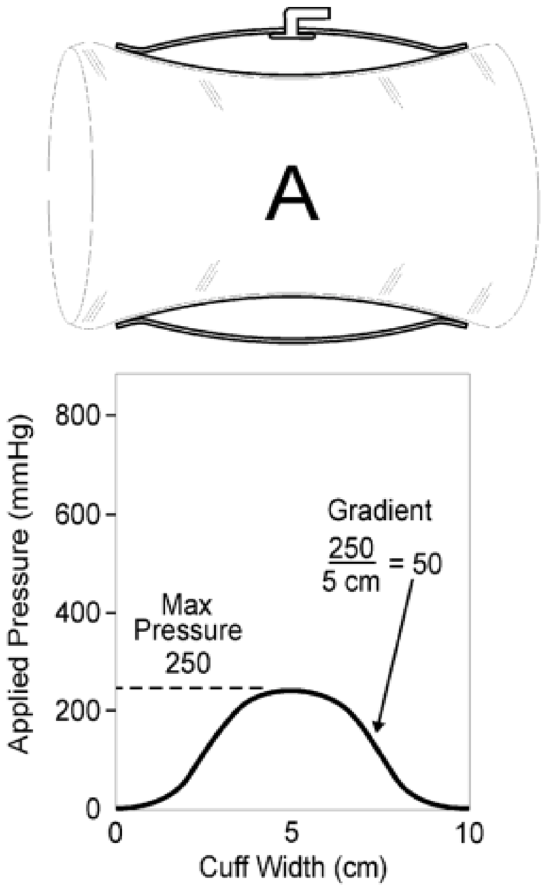
Additional variables that can influence limb occlusion pressures:

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

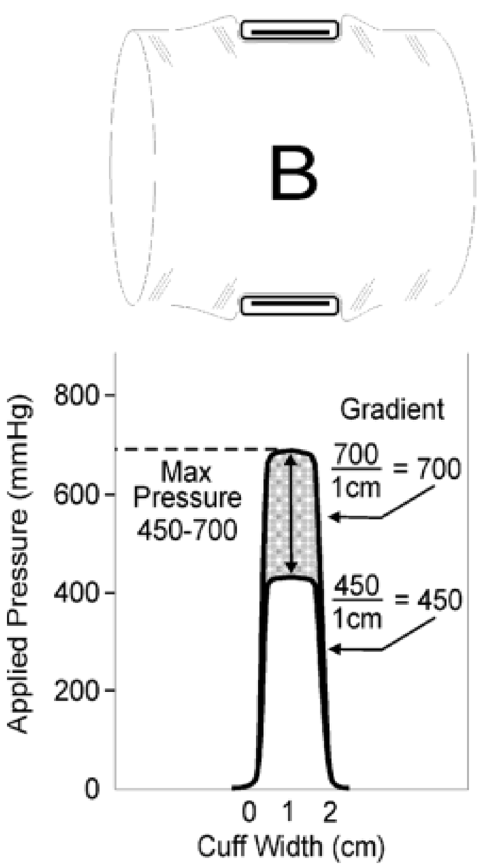
McEwen 2019[1], Graham 1993[2], Weatherholt 2019[3], Leonneke 2015, Hughes 2018[4], Jessee 2016[5], Evin 2020[6] ,Leonneke 2015[7]

Practical/Clinical Application – Cuff Specifications

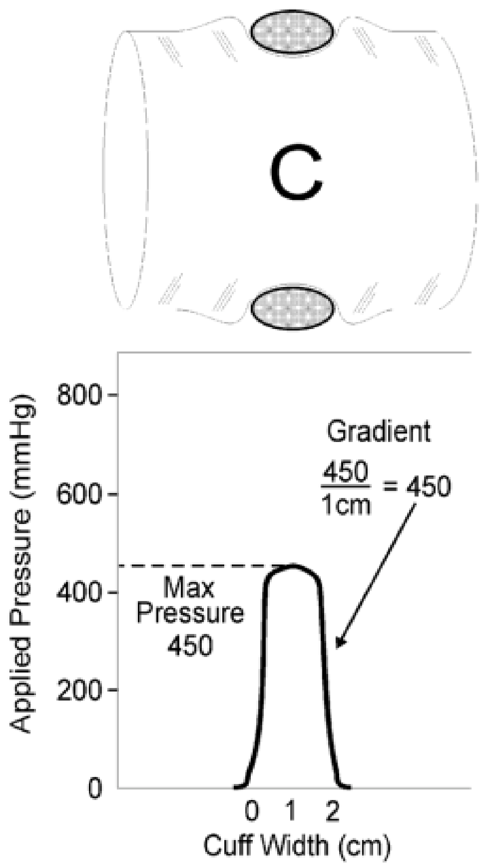
Modern Pneumatic Tourniquet



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

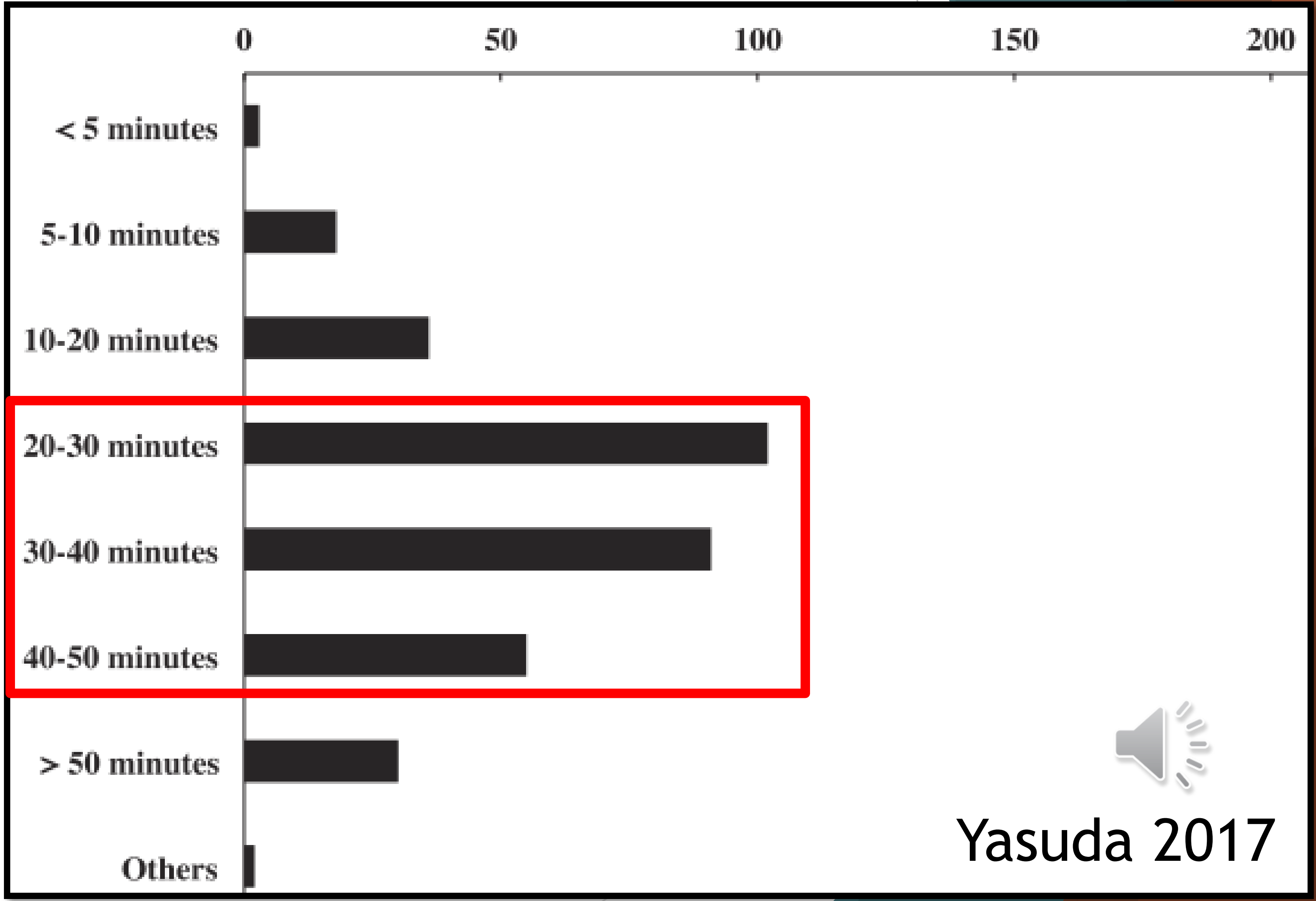
Summary of Cuff Selection

- 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

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

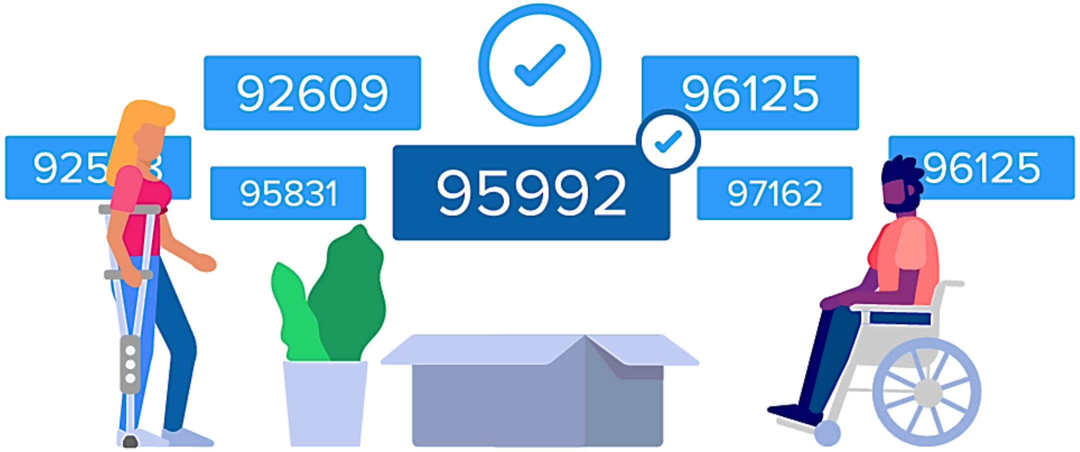
- **BFR Training Scope of Practice**
  - APTA: "BFRT is part of the professional scope of practice for physical therapists."
- **State Legislation**

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

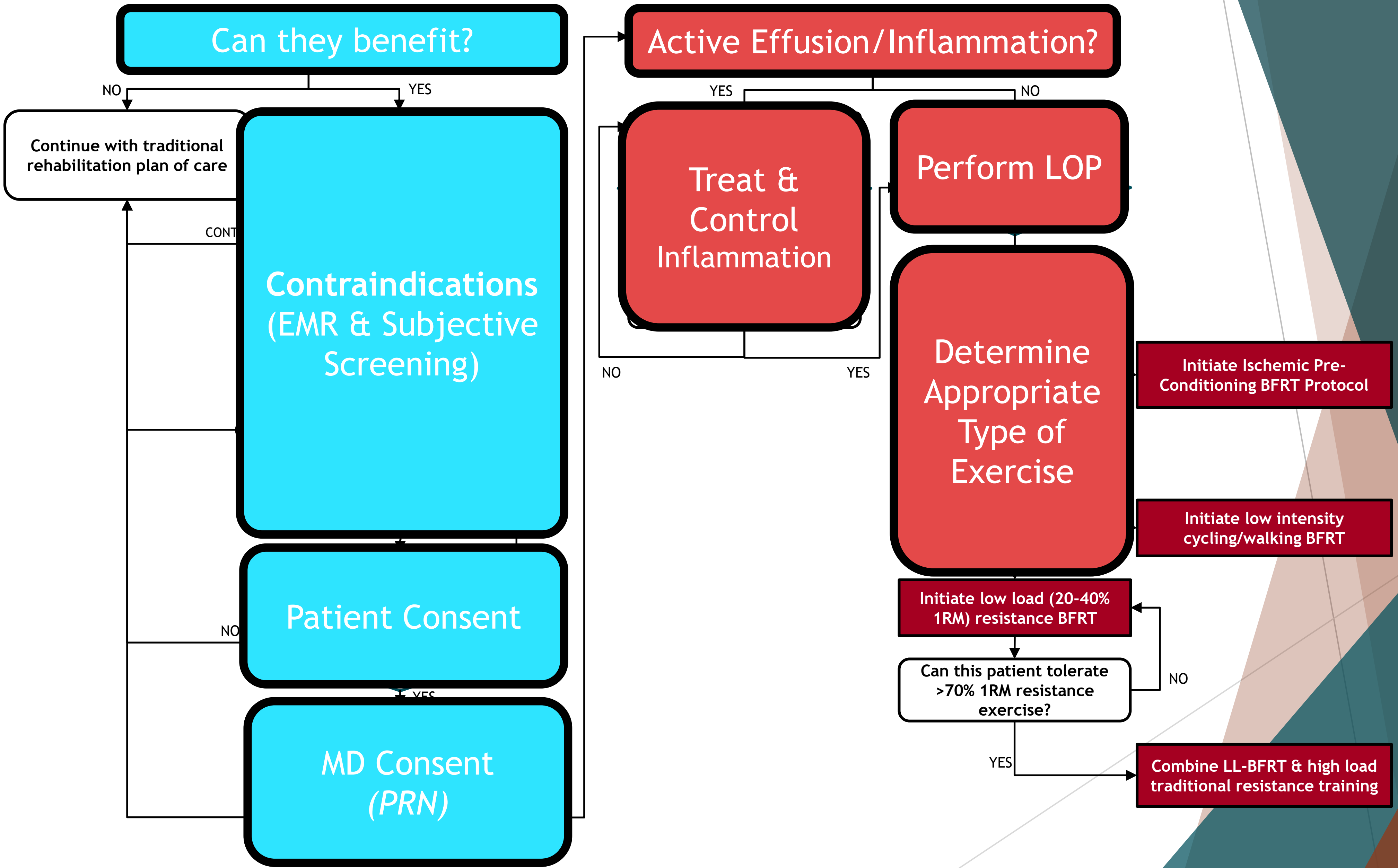
Billing

- 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			
Frequency		PHASE 2	
Exercise Intensity			
Volume	PHASE 1		
Rest[2]		PHASE 3	
Duration			
Tempo			

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

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…

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