Blood Flow Restriction Training for the Upper Extremity

Current Concepts 2024

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Objectives

The Background & Science

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

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Introduction

Defining the problem

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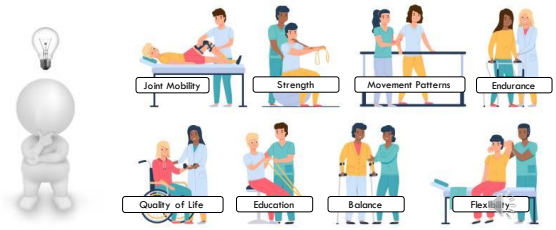
The Situation
What are the **mechanisms** by which we get patients better?



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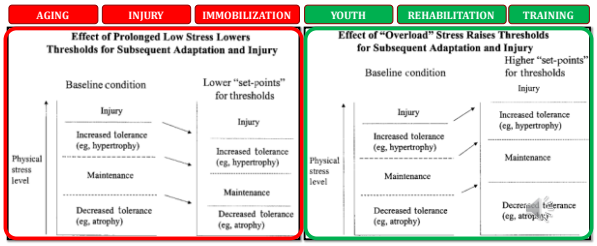
The Situation
Mechanotransduction & The Physical Stress Theory



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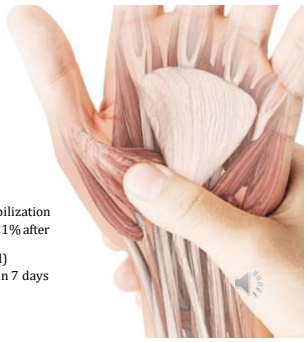
The Problem

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



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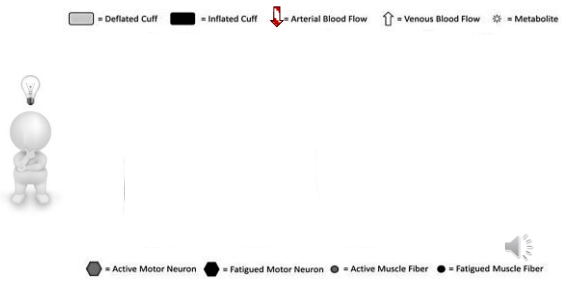
The Solution?



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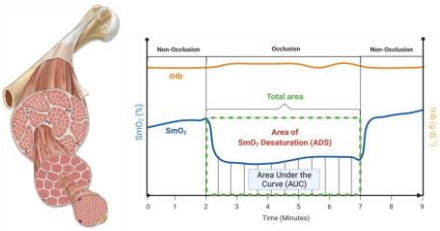
The Solution?



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Defining Blood Flow Restriction Training

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

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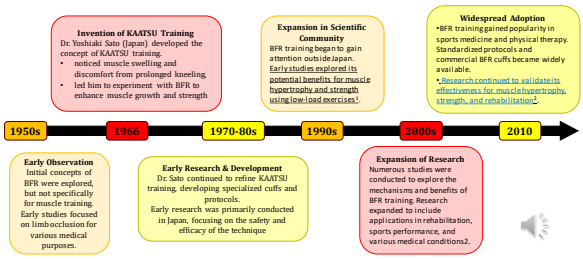
What is the history of BFR?



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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

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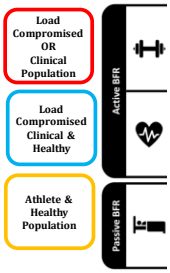
Blood Flow Restriction – Definition

Scott 2023



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Indications of Blood Flow Restriction

Objective #2: **WHY would I consider using BFR? And for WHO?**

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Indications of Blood Flow Restriction: Why?

Cardiovascular System
- ↑ Peak VO2 by 4x (vs control)[1,2]
- ↑ 70% Heart Index[1]
- Improved arterial compliance[2,3]
- 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[2,12]

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)?, Cortisol, IGF-1[5,2]
- ↑ Stimulation of mTOR[5]
- ↑ Testosterone (acute elevation)[14]
- ↑ VEGF (promote angiogenesis & ↑ blood flow & volume to occluded limb

Cahalin 2022a, Tanaka 2018b, Pope 2013c, Abe 2010d, Burgomaster 2003e, Cartee 1985f, Tanaka 2000g, Morintani 1992h, Centner 2020i, Jessee 2018j, Song 2021k, Hughes 2020l, Zhao 2022m, Liu 2021n, Bemben 2022o, Golden 2024p, Franz 2023q, Cetner 2021r, Karanasios 2022s, Kristian 2020t

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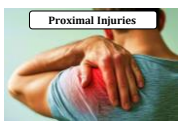
Indications of Blood Flow Restriction: Why?



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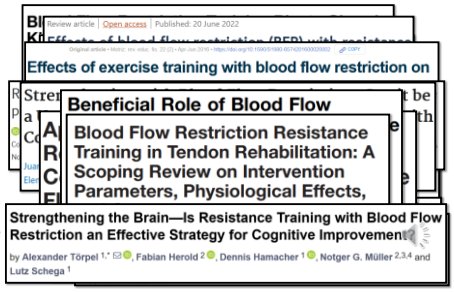
Indications of Blood Flow Restriction: Who?

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



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Effectiveness of Blood Flow Restriction

Objective #3 : **What does the evidence say about the effectiveness of BFR?**

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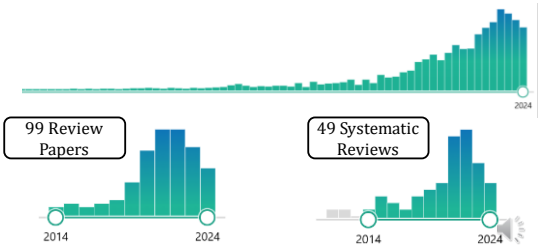
Evidence on Blood Flow Restriction Training



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Evidence on Blood Flow Restriction Training

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Effectiveness of Blood Flow Restriction

Objective #3 : **What does the evidence say about the effectiveness of BFR?**

- Literature Reviews
- Seminal Studies

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Effectiveness of BFR – Muscle Adaptation

Low intensity blood flow restriction training: a meta-analysis

Jeremy P. Loenneke · Jacob M. Wilson · Pedro J. Marín · Michael C. Zourdos · Michael G. Bemben

Loenneke et al. 2012

- **Population:** Healthy (untrained individuals, recreationally active, athletes)
- **Study Count:** 11 studies (study design not specified)
  - Only lower extremity BFR studies included
- **Methods:** Systematic Review and Meta-analysis
- **Outcomes:** Muscle Strength Gain & Muscle Hypertrophy

Cited 91 Times in 10 years

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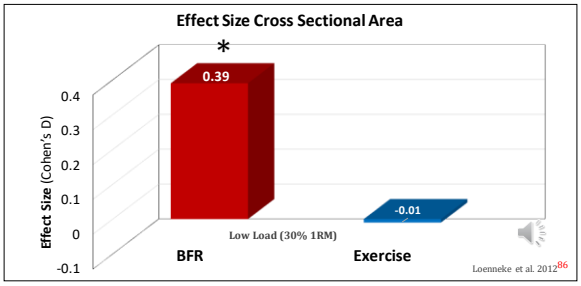
Effectiveness of Blood Flow Restriction – Muscle Adaptation



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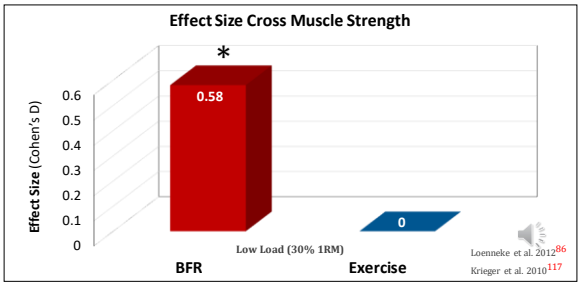
Effectiveness of Blood Flow Restriction – Muscle Adaptation



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Effectiveness of BFR – Muscle Adaptation

Low intensity blood flow restriction training: a meta-analysis

Jeremy P. Loenneke · Jacob M. Wilson · Pedro J. Marín · Michael C. Zourdos · Michael G. Bemben

1. BFR resulted in significantly greater gains in strength and hypertrophy when performed with resistance training than with walking.

2. LI-BFR 2–3 days/week ➔ greatest ES compared to 4–5 days/week

3. Significant correlations were found between ES for strength development & weeks of duration, but not for muscle hypertrophy

Loenneke et al. 2012[86]

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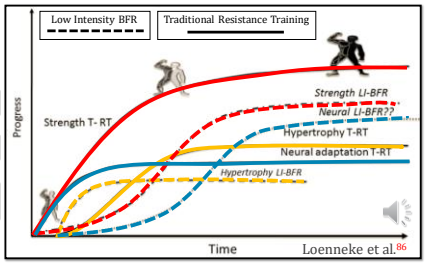
Effectiveness of BFR & Adaptation Timing

Hypertrophy

Strength

Neural Adaptations



Loenneke et al.[86]

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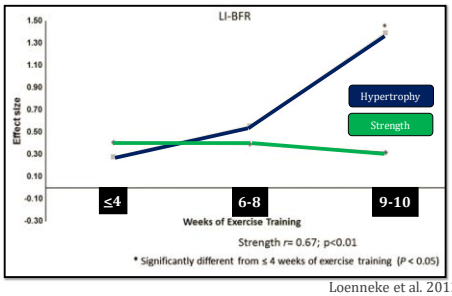
Effectiveness of BFR & Adaptation Timing



Loenneke et al. 2012[86]

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Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis — Hughes 2017

- **Population:** Clinical population
- **Study Count:** 33 studies (15 RCTs & 18 Non-RCTs)
  Knee OA: *n* = 3 | Ligament: *n* = 3 | Myositis: *n* = 1 | Older Adults: *n* = 13
- **Meta-Analysis:** 20 studies (13 did not meet MA criteria)
- **Methods:** Systematic Review and Meta-analysis
- **Outcomes:** Muscle Strength Gain & Muscle Hypertrophy, Pain, Physical Function

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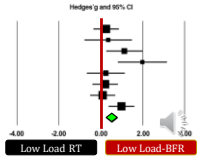
Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis Hughes 2017

Muscle Strength

Study name	Hedges'g	SE	Variance	LL	UL	Z	P
Shimizu et al., 2016	0.269	0.312	0.098	-0.344	0.881	0.860	0.390
Patterson & Ferguson, 2011	0.366	0.578	0.334	-0.767	1.499	0.633	0.527
Ozaki et al., 2011	1.133	0.442	0.195	0.267	1.998	2.565	0.010
Ozaki et al., 2011b	1.986	0.599	0.359	0.812	3.159	3.316	0.001
Yasuda et al., 2015	0.253	0.463	0.215	-0.655	1.162	0.547	0.584
Segal et al., 2015	0.221	0.311	0.097	-0.389	0.832	0.711	0.477
Segal et al., 2015b	0.105	0.307	0.095	-0.497	0.708	0.342	0.732
Ohta et al., 2003	0.995	0.317	0.101	0.373	1.617	3.134	0.002
Total	0.523	0.133	0.018	0.263	0.784	3.939	0.000

Heterogeneity: Q = 13.9 dF = 7.0 I² = 49.8%



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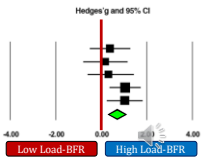
Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis Hughes 2017

Muscle Strength

Study name	Hedges'g	SE	Variance	LL	UL	Z	P
Libardi et al., 2015	0.370	0.456	0.208	-0.523	1.264	0.812	0.417
Thiebaud et al., 2013	0.181	0.507	0.257	-0.813	1.175	0.358	0.721
Vechin et al., 2015	0.310	0.476	0.226	-0.623	1.242	0.650	0.515
Fernandes-Bryk et al., 2016	1.045	0.358	0.128	0.343	1.747	2.918	0.004
Karabulut et al., 2013	1.023	0.408	0.167	0.223	1.824	2.506	0.012
Total	0.674	0.193	0.037	0.296	1.052	3.497	0.000

Heterogeneity: Q = 3.8 dF = 4.0 I² = 0.0%



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Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis Hughes 2017

Conclusions: LL-BFR in a MSK rehabilitation setting & clinical population:

- Is effective at attenuating strength loss & facilitating strength in clinical populations suffering from musculoskeletal (MSK) injuries
- Can ⬆ muscle size & strength adaptations, may act as a surrogate for heavy-load strength rehabilitation training in a broad range of clinical populations
- Is safe when proper screening, individualized pressures, & graded exposure program is applied

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Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis Hughes 2017

Conclusions: LL-BFR in a MSK rehabilitation setting & clinical population:

- Offers added physiological adaptations (beyond the muscle):
  - Stimulation of mTORC1 signalling in muscle protein synthesis in older adults
  - Blood serum ⬆ Bone alkaline phosphatase (BAP) & ⬆ bone turnover ➔ ⬆ bone health
  - ⬆ Carotid arterial compliance, peak oxygen uptake, peak post-occlusive blood flow, & vascular endothelial function, & peripheral nerve circulation (via walking with BFR)

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Effectiveness of BFR – Musculoskeletal Rehab

Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis Hughes 2017

Clinical Recommendations:

- Systematic Progression:
  - (1a) BFR alone during periods of bed rest
  - (1b) BFR with PROM (± NMES)
  - (2) BFR + with low-workload walking exercise
  - (3) BFR combined with low-load resistance exercise
  - (4) LL-BFR training in combination with high-load exercise
- Proper screening (to risk stratify patients)
- Individualized pressures & training parameters
- Longer duration studies (>6 weeks)

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Effectiveness of Blood Flow Restriction – Resistance Training

Review
The efficacy of blood flow restricted exercise: A systematic review & meta-analysis
Joshua Slysz, Jack Stultz, Jamie F. Burr* Slyzs 2016

- **Population:** Healthy adults
- **Study Count:** 47 studies (RCTs & Non-RCTs)
  - Study Genders: 27 Male, 7 Female, 14 Both
- **Subjects:** Healthy Adults (>400 subjects, Age: 34)
- **Meta-Analysis:** 28 studies (19 did not meet MA criteria)
- **Methods:** Systematic Review and Meta-analysis
- **Outcomes:** Muscle Strength Gain & Muscle Hypertrophy

Cardiovascular Training

Resistance Training

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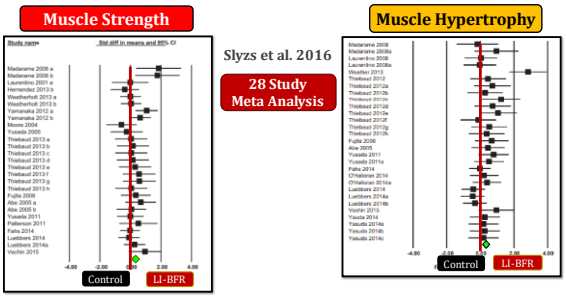
Effectiveness of Blood Flow Restriction – **Resistance Training**



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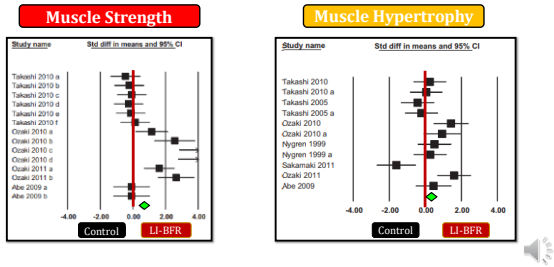
Effectiveness of Blood Flow Restriction – **Aerobic Training**



Slyzs et al. 2016

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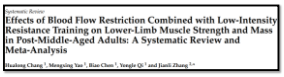
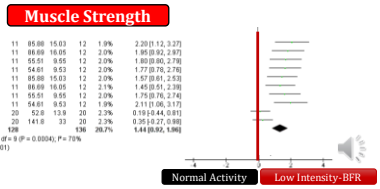
Effectiveness of Blood Flow Restriction – Resistance Training



Population: Healthy adults
Study count: 19
Methods: Systematic Review and Meta-analysis
Outcomes: Muscle Strength Gain & Muscle Hypertrophy



Chang et al. 2023

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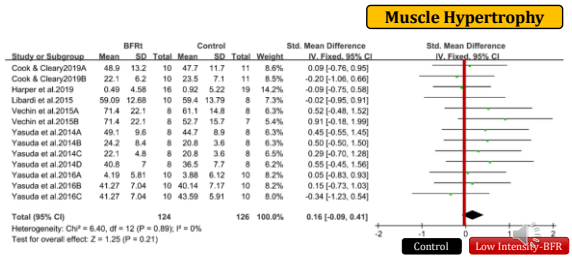
Effectiveness of Blood Flow Restriction – Resistance Training



Chang et al. 2023

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Effectiveness of Blood Flow Restriction – Resistance Training

Chang et al. 2023

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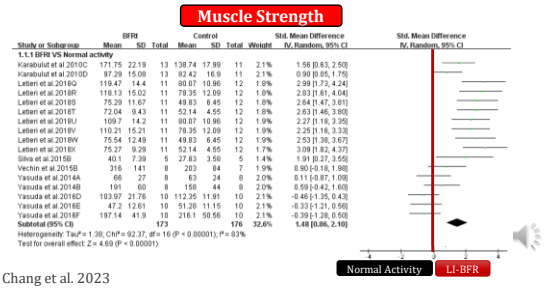
Effectiveness of Blood Flow Restriction – Resistance Training



Chang et al. 2023

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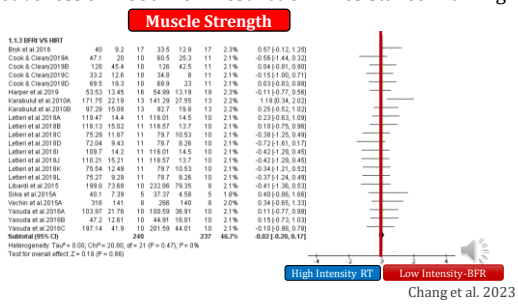
Effectiveness of Blood Flow Restriction – Resistance Training



Chang et al. 2023

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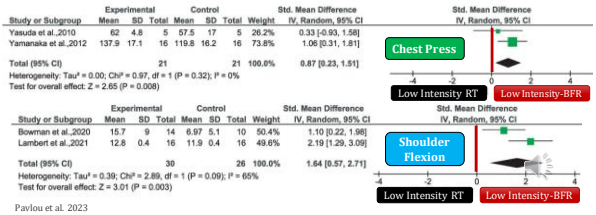
Effectiveness of Blood Flow Restriction

The effects of upper body blood flow restriction training on muscles located proximal to the applied occlusive pressure: A systematic review with meta-analysis

Population: Healthy adults
Study Count: 9
Methods: Systematic Review & Meta-analysis
Outcomes: **Muscle Strength** & Muscle Hypertrophy



Pavlou et al. 2023

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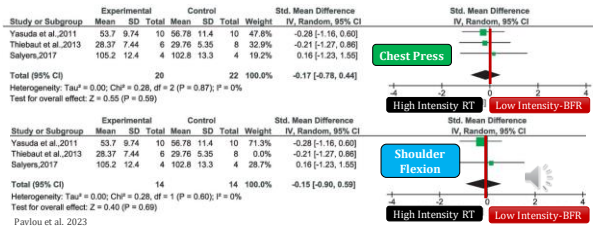

Pavlou et al. 2023

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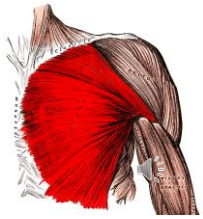
Effectiveness of Blood Flow Restriction

RESEARCH ARTICLE
The effects of upper body blood flow restriction training on muscles located proximal to the applied occlusive pressure: A systematic review with meta-analysis

Population: Healthy adults
Study Count: 9
Methods: Systematic Review & Meta-analysis
Outcomes: Muscle Strength & **Muscle Hypertrophy**

- **No difference** between LL-RT ± BFR was observed in pectoralis major muscle size, thickness, or girth in 3 studies implementing only chest press exercise
- Proximal muscle size adaptations may be plausibly driven **by the total time under occlusion**, a **minimum volume threshold**, the **training period**, or a **systemic effect** (rather than the specific exercise performed)
- **Note:** sensitivity of the muscle size measurement method may have played a role in the findings of our review.
- A significant effect of LL-BFRT was observed only in shoulder lean mass compared to LL-RT **measured by DEXA** in contrast to studies implementing muscle size/thickness measurements using US or tape measure.



Pavlou et al. 2023

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Effectiveness of Blood Flow Restriction – Resistance Training

RESEARCH ARTICLE
The effects of upper body blood flow restriction training on muscles located proximal to the applied occlusive pressure: A systematic review with meta-analysis

Population: Healthy adults
Study Count: 9
Methods: Systematic Review & Meta-analysis
Outcomes: Muscle Strength & Muscle Hypertrophy
Results: LL-BFRT significantly ⬆ bench press & shoulder flexion strength compared to LL-RT.

Risk of Bias

Articles	Brumit 2020	Bowman 2020	Lambert 2021	Yasudo 2011	Yasuda 2010	Yamanaka 2012	Thiebaud 2013	Green 2020	Saylers 2017
PEDro Score	High Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	High Risk	High Risk
GRADE (Quality of Evidence)	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

Pavlou 2023

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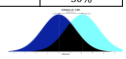
Effectiveness of BFR Upper Extremity

The Effects of Blood Flow Restriction on Upper-Body Musculature Located Distal and Proximal to Applied Pressure
Scott J. Dankel[1] · Matthew R. Jessee[1] · Takashi Abe[2] · Jeremy P. Loenneke[3]

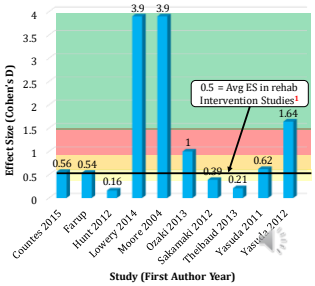
Population: Healthy adults
Study Count: 19
Methods: Systematic Review
Outcomes: Muscle Strength & Muscle Hypertrophy

Effect Size (Cohen's D)	Interpretation	% of CON ⬇ EXP Group Mean
1.4	Very Large	92%
0.8	Large	79%
0.5	Medium	69%
0.2	Small	58%
0.0		50%



Kinney 2020[1]

Change in Biceps Hypertrophy Effect Size



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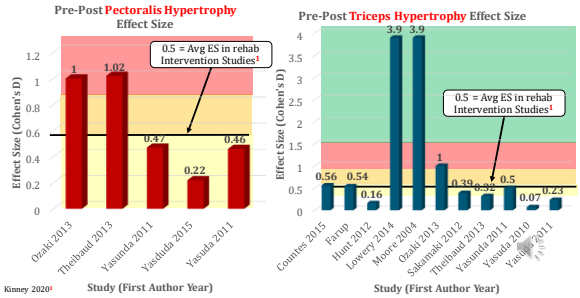
Effectiveness of BFR Upper Extremity



Kinney 2020[1]

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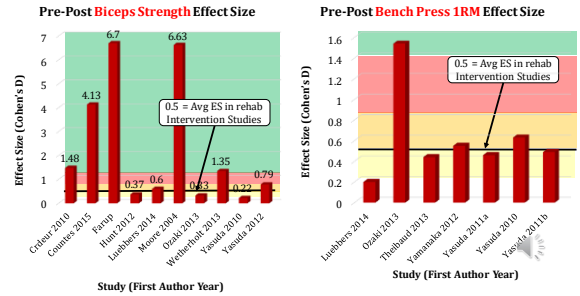
Effectiveness of BFR Upper Extremity



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Effectiveness of BFR Upper Extremity

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

Scott J. Dankel[1] · Matthew B. Jessee[1] · Takashi Abe[2] · Jeremy P. Loenneke[1]

Population: Healthy adults
Study Count: 19
Methods: Systematic Review
Outcomes: Muscle Strength & Muscle Hypertrophy

Conclusions:

- **LL-BFR in the upper body (UB)** produces **similar** muscle adaptation to **high load** resistance training
- ⬆ the adaptations occur in **muscles distal** (i.e., biceps, etc.) and **proximal** (chest & shoulders) to the occlusion
- The positive physiological adaptations of LL-BFR in the UB appear to occur with **relatively low loads (20-30% 1 RM)** & **[low] pressures**

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Effectiveness of BFR Upper Extremity

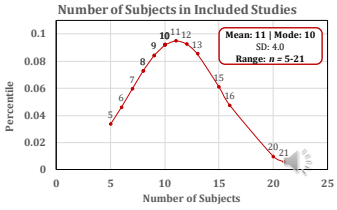
The Effects of Blood Flow Restriction on Upper-Body Musculature Located Distal and Proximal to Applied Pressure

Scott J. Dankel[1] · Matthew B. Jessee[1] · Takashi Abe[2] · Jeremy P. Loenneke[3]

Population: Healthy adults
Study Count: 19
Methods: Systematic Review
Outcomes: Muscle Strength & Muscle Hypertrophy

Limitations:

- Study size (# of subject ➔ under powered)
- Muscle strength & size outcomes measured with various methods (making direction comparison across studies difficult)herefore
- Could not be directly compared with one another.
- No quality appraisal or RoB conducted
- Effect size not reported for control cohorts



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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 **individualized 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 2022[3], Kohlbrenner 2023[5], Corrêa 2021[6], Bemben 2022[7], Franz 2023[8], Cetner 2021[9], Cahalin 2022[10], Liu 2021[11]

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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],

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Effectiveness of Blood Flow Restriction

Objective #3 : **What does the evidence say about the effectiveness of BFR?**

- Literature Reviews
- Seminal Studies

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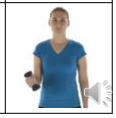
Effectiveness of BFR Upper Extremity

Method Variable	Values

	BFR Group	Control Group
Experimental Limb		
Contralateral Limb		

Bowman 2020

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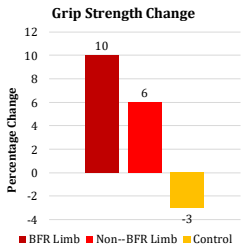
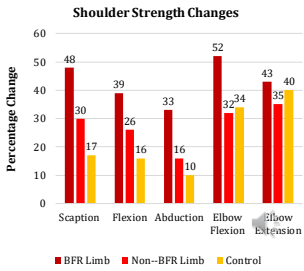
Effectiveness of BFR Upper Extremity





Bowman 2020

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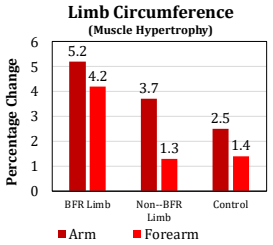
Effectiveness of BFR Upper Extremity



Conclusions:

- This study affirms the effect of low-weight training with BFR on:
- Upper Extremity Strength
- Upper Extremity Hypertrophy*

**Limitation of circumference measures*

On muscles proximal, distal, and contralateral to cuff placement

Bowman 2020

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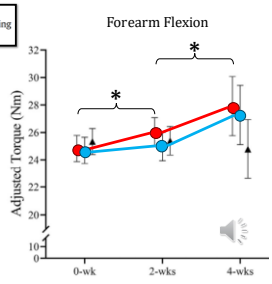
Effectiveness of BFR Upper Extremity

Original Research

Eccentric, but not concentric blood flow restriction resistance training increases muscle strength in the untrained limb

Method Variable	Values



Hill 2020

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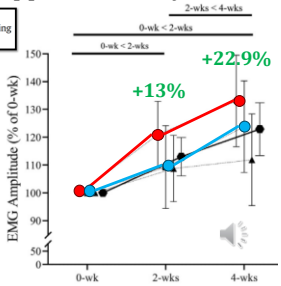
Effectiveness of BFR Upper Extremity

Original Research

Eccentric, but not concentric blood flow restriction resistance training increases muscle strength in the untrained limb

Method Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 36 Healthy Female ECC-BFR: 12 CON-BFR: 12 Control: 12 (Healthy) Age: 22 ± 2 y/o
Freq/Duration	3x/week | 4 weeks
Cuff	KAATSU 30 mm Wide 40% LOP
Exercise Type	Isokinetic 120°/s Wrist Flexion
Outcomes	ECC PT, CON PT, MVIC untrailed arm
Volume	30/15/15/15 (bilateral)



Hill 2020

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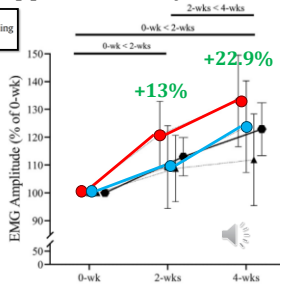
Effectiveness of BFR Upper Extremity

Original Research

Eccentric, but not concentric blood flow restriction resistance training increases muscle strength in the untrained limb

Conclusions:

- This study indicates the LL-Eccentric BFR ⬆ muscle strength
- ⬆ strength were not contraction type specific
- LL ECC-BFR provides a unique alternative to maintain muscle function in an untrained limb that may have application during limb immobilization and rehab practices



Hill 2020

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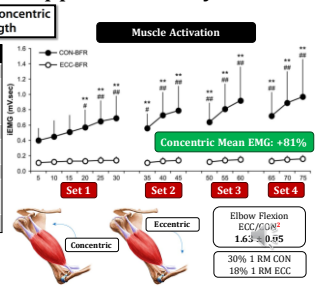
Effectiveness of BFR Upper Extremity

Effects of Blood Flow Restricted Low-Intensity Concentric or Eccentric Training on Muscle Size and Strength

Methods	Values
Study Design	Randomized Control Trial
Subjects	*n* = 10 Healthy Male 1 UE ECC-BFR: 10 1 UE CON-BFR: 10 Age: 22 ± 2 y/o
Freq/Duration	3x/week | 6 weeks
Cuff	KAATSU 30 mm Wide 100 mmHg (⬆10 mmHg/session → 160 mmHg)
Exercise Type	Bicep curls 30% 1 RM (based CON setrength)
Outcomes	EMG during exercise Biceps CSA (MRI) Isometric Elbow Flexion 1 RM (HHD)
Volume	30/15/15/15 (bilateral)



Yasuda 2012, Nuzzo 2023[2]

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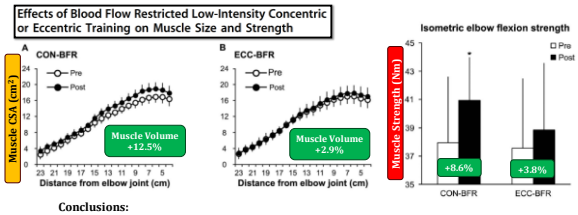
Effectiveness of BFR Upper Extremity

Effects of Blood Flow Restricted Low-Intensity Concentric or Eccentric Training on Muscle Size and Strength



Conclusions:

- CON LL-BFR with elbow flexion exercise @ 30% 1RM ⬆ acute & chronic changes in muscle size
  - Acutely: Cell swelling | Chronically: Muscle hypertrophy
- CON LL-BFR with elbow flexion is sufficient at inducing ⬆ isometric strength

Yasuda 2012

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Effectiveness of BFR Upper Extremity

Rotator cuff strength is not augmented by blood flow restriction training

Jason Brumitt*, Marcey Keefer Hutchison, Dan Kang, Stephen Gerard D. Alterado, Tyler Berg, Bao Phuc Nguyen, Carsten Neumiller, Robert Reynoso, Jacob Stickell

Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 35 Healthy (29 F | 6 M) BFR vs Control Age: 25 ± 1.6 y/o
Freq/Duration	2x/week | 8 weeks
Cuff	80% LOP (ORS Delphi Medical Unit)
Exercise Prescription	**Lower Body:** 30/15/15/15 (2-1-2) | 30% 1RM • Knee EXT & Knee FLX ankle weight **Upper Body:** 3x15 (Tempo 2-1-2) | 30% 1RM • Scaption & Sidelying ER *Note. BFR only applied to lower body exercises*
Outcomes	Muscle strength (HHD) Muscle CSA (US)

Blood Flow Restriction Training for the Rotator Cuff: A Randomized Controlled Trial

Jason Brumitt, Marcey Keefer Hutchison, Dan Kang, Zach Klemmer, Mike Stroud, Edward Cheng, Neil Patrick Cayanan, and Sheldon Shishido

Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 46 Healthy (29 F | 6 M) BFR vs Control Age: 25 ± 2.2 y/o
Freq/Duration	2x/week | 8 weeks
Cuff	50% LOP (ORS Delphi Medical Unit)
Exercise Prescription	BFR: 30/15/15/15 (2-1-2) | 30% 1RM • Sidelying ER
Outcomes	Muscle strength (HHD) Muscle CSA (US)

Brummit 2021, Brummit 2020

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Effectiveness of BFR Upper Extremity

Rotator cuff strength is not augmented by blood flow restriction training

Jason Brumitt*, Marcey Keefer Hutchison, Dan Kang, Stephen Gerard D. Alterado, Tyler Berg, Bao Phuc Nguyen, Carsten Neumiller, Robert Reynoso, Jacob Stickell

Conclusions:

- **Both** groups **significantly ↑ strength** gains in lower extremities & rotator cuff strength
- There was **NO** between group differences in strength
- Neither group increased CSA of rectus femoris

Limitations:

- **No BFR for upper extremity**
- No exercise intensity progression

Blood Flow Restriction Training for the Rotator Cuff: A Randomized Controlled Trial

Jason Brumitt, Marcey Keefer Hutchison, Dan Kang, Zach Klemmer, Mike Stroud, Edward Cheng, Neil Patrick Cayanan, and Sheldon Shishido

Conclusions:

- Sidelying ER @ 30% 1 RM with BFR did **NOT increase** rotator strength nor supraspinatus tendon thickness vs No-BFR

Limitations:

- Single exercise for rotator cuff (targeting muscles proximal to the cuff)

Brummit 2021, Brummit 2020

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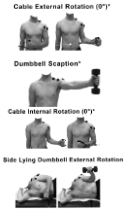
Effectiveness of BFR Upper Extremity

Blood Flow Restriction Training for the Shoulder Lambert 2021

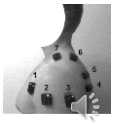
Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 32 Healthy (9 F | 23 M) BFR vs Control Age: 25 ± 1.6 y/o
Freq/Duration	2x/week | 8 weeks
Cuff	50% LOP (ORS Delphi Medical Unit)
Exercise Prescription	30/15/15/Fatigue (2-1-2) | 20% 1RM Isometric • If >75 reps achieved on 2 bouts → +1 lb
Outcomes	Lean Mass (DEXA) Isometric Rotator Cuff Strength (HHD) • Abduction, Scaption, IR & ER @0° & @90° Muscle Endurance (No BFR & BFR) • Standing ER & IR to fatigue, Abduction Muscle EMG

Exercises



EMG Placement

1. Anterior Deltoid
2. Middle Deltoid
3. Posterior Deltoid
4. Teres Minor
5. Infraspinatus
6 & 7. Trapezius



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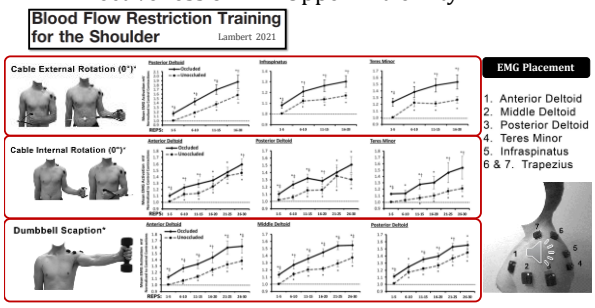
Effectiveness of BFR Upper Extremity



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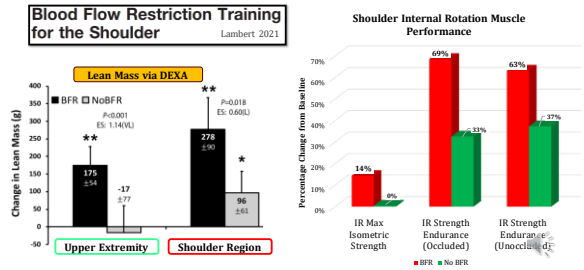
Effectiveness of BFR Upper Extremity



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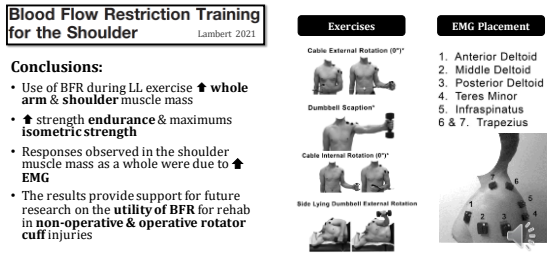
Effectiveness of BFR Upper Extremity



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Effectiveness of BFR Upper Extremity

The effectiveness and safety of blood flow restriction training for the post-operation treatment of distal radius fracture — Fan 2023

Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 35 Post Op Distal Radius Fracture (9 F | 23 M) BFR: *n* = 17 (7 M|10 F; 44 ± 15 y/o) NoBFR: *n* = 18 (10 M|8 F; 47 ± 14 y/o)
Freq/Duration	5x/week | 4 weeks
Cuff	120 mmHg (B Strong©)
Exercise Prescription	4 Week Post Operative Protocol Strength: 30/15/15/15 (20% 1RM) - grip, pinch, isometric wrist ext & flex AROM: shoulder and elbow PROM: wrist & forearm (<4/10 VAS, <50% FROM)
Outcomes	Wrist Function (Cooney modification) Pain Wrist & Forearm Circumference **ROM:** Flx, Ext, Rad Dev, Uln Dev, Pron, Supination **Strength:** Grip, Pinch, Wrist Flexion & Extension D-Dimer Levels Radius Union Scoring System (RUSS)

Exercises

BFR Cuff

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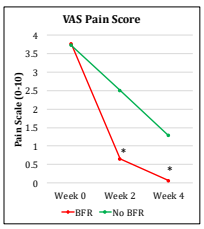
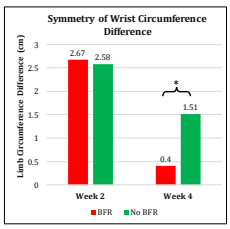
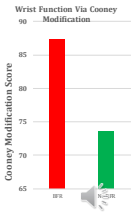
Effectiveness of BFR Upper Extremity

The effectiveness and safety of blood flow restriction training for the post-operation treatment of distal radius fracture — Fan 2023







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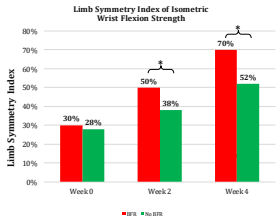
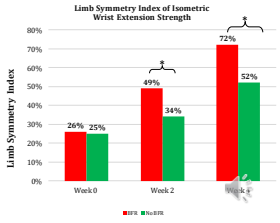
Effectiveness of BFR Upper Extremity

The effectiveness and safety of blood flow restriction training for the post-operation treatment of distal radius fracture — Fan 2023





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Effectiveness of BFR Upper Extremity

The effectiveness and safety of blood flow restriction training for the post-operation treatment of distal radius fracture Fan 2023

Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 35 Post Op Distal Radius Fracture (9 F | 23 M) BFR: *n* = 17 (7 M|10 F; 44 ± 15 y/o) NoBFR: *n* = 18 (10 M|8 F; 47 ± 14 y/o)
Freq/Duration	5x/week | 4 weeks
Cuff	120 mmHg (B Strong©)
Exercise Prescription	4 Week Post Operative Protocol Strength: 30/15/15/15 (20% 1RM) - grip, pinch, isometric wrist ext & flex AROM: shoulder and elbow PROM: wrist & forearm (<4/10 VAS, <50% FROM)
Outcomes	Wrist Function (Cooney modification) Pain Wrist & Forearm Circumference **ROM:** Flx, Ext, Rad Dev, Uln Dev, Pron, Supination **Strength:** Grip, Pinch, Wrist Flexion & Extension D-Dimer Levels Radius Union Scoring System (RUSS)

Conclusions:

- BFR therapy can **significantly** ⬇pain, ⬆ muscle strength, and ⬆ function.
- BFR therapy did **NOT** significantly improve **passive ROM**
- Further research is needed to determine its ability to ⬇ swelling.
- BFR therapy is **safe & effective** for DRF patients after ORIF
- Requires **individualized protocols** and **frequent assessments**.

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Effectiveness of BFR Upper Extremity

BFR Training Improves Patients' Reported Outcomes, Strength, and Range of Motion After Casting for Colles' Fracture Yang 2023

Variable	Values
Study Design	Randomized Control Trial
Subjects	*n* = 28 during plaster cast treatment (9 F | 23 M) BFR: *n* = 17 (7 M|10 F; 44 ± 15 y/o) NoBFR: *n* = 18 (10 M|8 F; 47 ± 14 y/o)
Freq/Duration	**2x/week** | 6 weeks
Cuff	50% LOP (ATS 400TS©) 46 cm wideth
Exercise Prescription	6 Week Post Operative Protocol Strength: 30/15/15/15 (35% 1RM) • If >75 reps on two sessions → ⬆ 1lb 9 Exercises (AROM, AAROM, Strength)
Outcomes	Patient Rated Wrist Evaluation (PRWE) Wrist Range of Motion **Strength:** Grip, Pinch, Muscle Stiffness

Conclusions:

- Individualized BFR therapy can **significantly**
  - ⬆ subjective rating of wrist function (PRWE)
  - ⬆ grip strength
  - ⬆ wrist range of motion (ulnar deviation)
- BFR therapy is **safe & effective** for patients s/p Colles' Fracture

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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]

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Effectiveness of Blood Flow Restriction

Objective #3 : **What does the evidence say about the effectiveness of BFR?**

- Literature Reviews
- Seminal Studies
- *What lessons can we learn from lower extremity BFR studies?*

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BFR Effectiveness – Strength & Blood Flow

- Subjects: **n = 16 (Female)**
- Exercise: **Unilateral Plantar Flexion**
- Intensity Cohorts: **25% or 50% 1 RM (1 LE BFR, 1 LE no BFR)**
- Duration: **4 weeks, 3x/week, 5-8 min/set**
- Volume: **3 sets to failure (cadence 1.5 sec ↑ & 1.5 sec ↓)**

Outcomes:

- Isokinetic Dynamometer
- **Strength: 1 RM**
- **Isometric MVC**
- **Torque @: 0.52, 1.05, 2.09 rad/sec**
- Blood flow: **pre and post (ml/min/100 ml)**

Patterson et al. 2009

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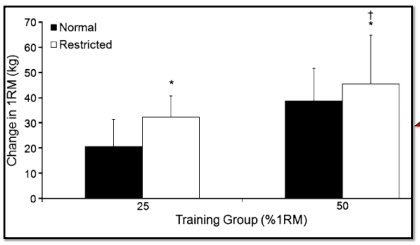
BFR Effectiveness – Strength & Blood Flow



Patterson et al. 2009[98]

26% 1RM

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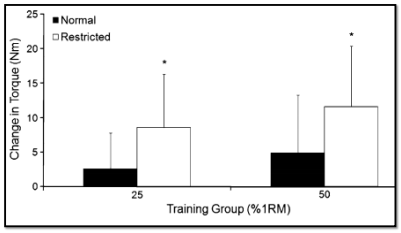
BFR Effectiveness – Strength & Blood Flow



Patterson et al. 2009[98]

106% Iso. MVC

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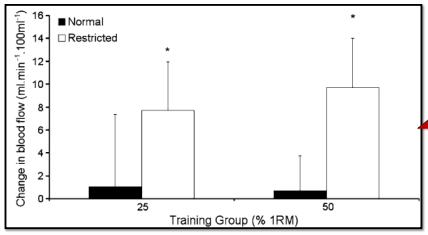
BFR Effectiveness – Strength & Blood Flow



Patterson et al. 2009[98]

43% Blood Flow

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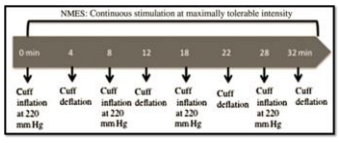
Effectiveness of BFR – Post-Operative: BFR+NMES

Method Variable	Value
Subjects	N = 20 (M/F: 10/10) Age: 29 y/o
Cohorts	1. Control (CON) | 4. BFR 2. NMES 3. BFR+NMES(COMBO)
Duration	6 weeks
Frequency	4x/week
Cuff	220 mmHg | Width: 10.2 cm 3x4 min inflation
NMES	2 electrodes (5 cm^2) Pulse Length: 400 µs Wave Frequency: 50-100 Hz Intensity: Maximally tolerated



Slysz et al. 2003[115]

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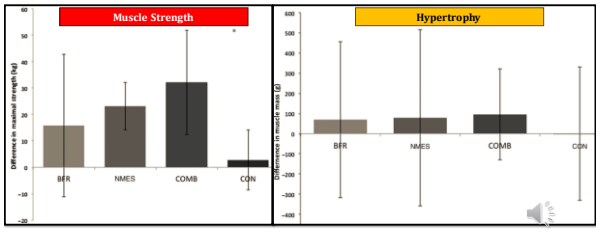
Effectiveness of BFR – Post-Operative: BFR+NMES



Slysz et al. 2003[115]

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Muscle Preservation

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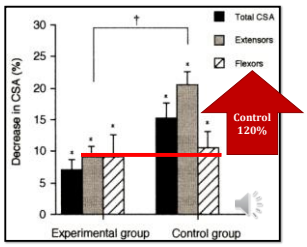
Effectiveness of BFR – Post-Operative: ACL

Method Variable	Value
Subjects	N = 16 (8 BFR; 8 Controls) M/F: 8/8 Age: 23 y/o
Duration	2 weeks (Day 3–14 post op)
Cuff	BFR: Width: 90 mm Pressure: 180 mmHg (+10/D) Max Avg: 238 mmHg (210-260) CONTROL: Cuff w/o inflation
Exercise Type	NONE
Frequency	2x/Day
Volume	5x5 min Set Rests: 3 min

Takarada et al. 2000[112]



122

Effectiveness of BFR: Strength & Hypertrophy

Variable	Methods
Subjects	n = 15 M, Healthy Control: n = 5 Isometric Group: n = 5 No Exercise BFR: n = 5 (200 mmHg)
Duration	2 weeks
Frequency	Isometric Grp: 2x/day BFR: 5x5 min (3 min rest) 2x/D - (occlusion NO EXERCISE)
Type	ALL subjects Immobilized L ankle (casted & crutches) - Isometric Grp: Knee EXT/FLX & Ankle PF
Volume/ Intensity	- BFR: 200 mmHg, 77 mm wide - Isometric Grp: 1x20x5 sec Contraction

Kubota et al. 2008[123]

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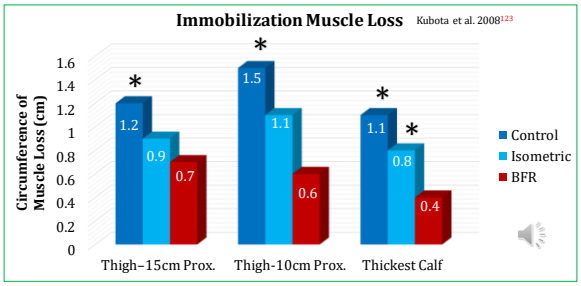
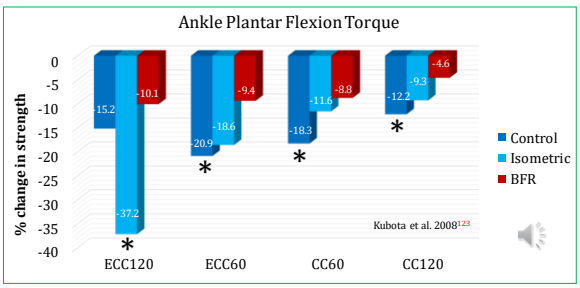
Effectiveness of BFR – Strength & Hypertrophy



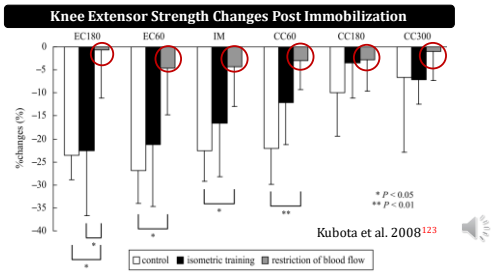
124

Effectiveness of BFR – Strength & Hypertrophy



125

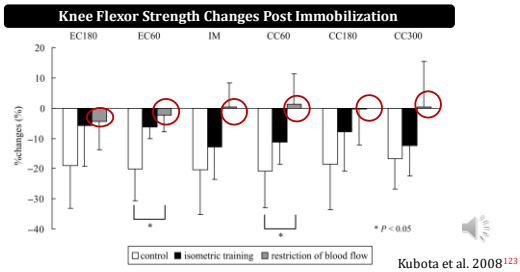
Effectiveness of BFR – Strength & Hypertrophy



Kubota et al. 2008[123]

126

Effectiveness of BFR – Strength & Hypertrophy



Kubota et al. 2008[123]

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So What?!

KEY POINTS

Clinical Application of UE BFR from LE Evidence

- Effect of **Ischemic Preconditioning (IPC)** with immobilization (&/or PROM):
  - Preservation of muscle mass, tendon CSA & stiffness, & bone mineral density
  - Metabolic conditioning (i.e., blood flow & work capacity of the limb via peripheral adaptations of mitochondrial density & function)
  - ↓ **pain** via cannabinoid mechanisms
  - ↑ vascularity & ↑ volumetric blood flow
- Upper extremity **ergometer application** with BFR (± high intensity RT)
- Upper Extremity **BFR with NMES**
- **Early Rehab Multifactorial BFR Program**
  - BFR on the lower extremity
  - Application of Upper Extremity IPC
  - Contralateral LL ECC BFR
  - Implementation of UE LL-BFR as soon as applicable

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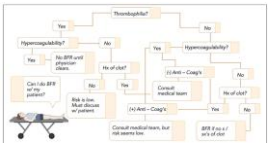
https://andreasphysioblog.com/wp-content/uploads/2022/10/Rolnick2021-Perceived-Barriers-to-Blood-Flow-Restriction-Training.pdf



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Objectives

The Background & Science

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

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Questions, Comments, Feedback, Discussion…

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