BLOOD FLOW RESTRICTION: Scoping Review

MICHAEL JEANFAVRE PT, DPT, OCS, CSCS

1

Objectives

1. Blood Flow Restriction (BFR) Defined
2. Effectiveness of BFR: local & system physiology
3. Mechanisms of BFR
4. Safety & Side Effects
5. Practical/Clinical Application

2

Blood Flow Restriction Defined

OBJECTIVE #1

3

Blood Flow Restriction – Definition & History

- training entails applying a **tourniquet-style cuff** on the proximal aspect of a limb just prior to exercise
- cuff is manually tightened or pneumatically inflated to a pressure that **occludes venous flow yet allows arterial inflow**
- originally **conceived and developed in Japan in the late 1960's** by Yoshiaki Sato and termed KAATSU training
- Prior to 2008 LL-BFR training equipment was scarce outside of Japan
- Thus far, research results regarding the efficacy of LL-BFR have been consistent and promising

VanWye 2017[16]

4

Effectiveness of Blood Flow Restriction

OBJECTIVE #2

5

Effectiveness of Blood Flow Restriction

- exercise + blood-flow restriction (BFR) → hypertrophic adaptations with much lower exercise (<50% 1RM) intensities than previously believed[3,15,24,34,41,43,63,74-80]
- exercise protocols with tourniquet,[81] pressurized cuff,[80] or elastic banding that is applied over the proximal portion of the upper or lower extremities[43]
- Low Intensity BFR Hypertrophy = Moderate/High intensity hypertrophy [20]
  - NOT clear if muscle hypertrophy can be optimized by BFR + ↑ external loads OR if the ceiling for maximal hypertrophy is achieved with low-moderate loads[14]

6

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

11 Included Studies

Loenneke et al. 2012[86]

7

Effectiveness of Blood Flow Restriction – Muscle Adaptation

Table 1 Studies included in the analysis

Citation	Age (years)	Gende	Training status	Exercise mode
Abe et al. (2005c)	<25	M	Rec. active	Squat and knee flexion
Abe et al. (2005b)	<25	M	Athlete	Squat and knee flexion
Abe et al. (2006)	<25	M	Rec. active	Treadmill walking
Abe et al. (2009)	<25	M	Rec. active	Treadmill walking
Abe et al. (2010b)	>50	M/F	Rec. active	Treadmill walking
Abe et al. (2010a)	<25	M	Rec. active	Cycling
Beekley et al. (2005)	<25	M	Rec. Active	Treadmill walking
Fujita et al. (2008)	<25	M	Rec. Active	Knee extension
Kacin and Strazar (2011)	<25	M	Rec. Active	Unilateral knee extension
Madarame et al. (2008)	<25	M	Untrained	Knee extension and knee flexion
Ozaki et al. (2011)	>50	M/F	Untrained	Treadmill walking

Loenneke et al. 2012[86]

8

Effectiveness of Blood Flow Restriction – Muscle Adaptation

Citation	Exercise intensity	Frequency of training	Length of training	Protocol	Measure of hypertrophy
Abe et al. (2005c)	20% 1RM	12× week	2 weeks	3 sets of 15 repetitions; 30 sec rest	MRI
Abe et al. (2005b)	20% 1RM	14× week	8 days	3 sets of 15 repetitions; 30 sec rest	Ultrasound
Abe et al. (2006)	50 M/Min	12× week	3 weeks	52-min walking bouts; 1 min rest	MRI
Abe et al. (2009)	50 M/Min	6× week	3 weeks	52-min walking bouts; 60 sec rest	MRI
Abe et al. (2010b)	67 M/Min	5× week	6 weeks	20 minutes walking	Ultrasound
Abe et al. (2010a)	40% VO_{2max}	3× week	8 weeks	15 minutes cycling	MRI
Beekley et al. (2005)	50 M/Min	12× week	3 weeks	52-min walking bouts; 60 sec rest	MRI
Fujita et al. (2008)	20% 1RM	12× week	6 days	30-15-15-15 repetitions; 30 sec rest	MRI
Kacin and Strazar (2011)	15% MVC	4× week	4 weeks	4 sets to volitional fatigue	MRI
Madarame et al. (2008)	30% 1RM	2× week	10 weeks	30,15,15 repetitions; 30 sec rest	MRI
Ozaki et al. (2011)	45% HRR	4× week	10 weeks	20 minutes walking	MRI

Loenneke et al. 2012[86]

9

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.

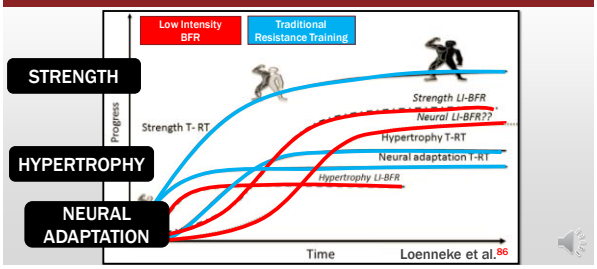
2. LI-BFR 2–3 days/week ➔ greatest ES compared to 4–5 days/week

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

Loenneke et al. 2012[86]

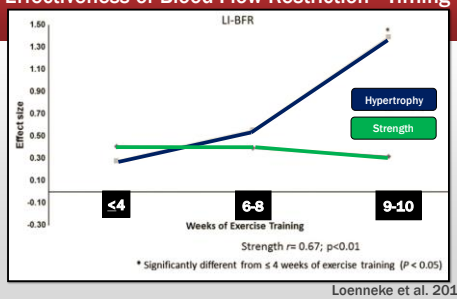
10

Effectiveness of Blood Flow Restriction - Timing



11

Effectiveness of Blood Flow Restriction - Timing

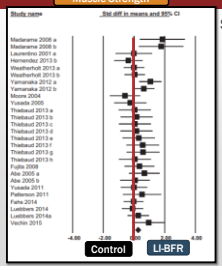


Loenneke et al. 2012[86]

12

Effectiveness of Blood Flow Restriction - Resistance

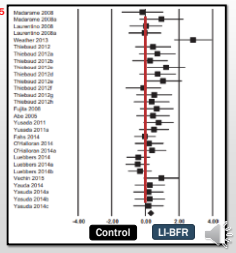
Muscle Strength



Slyzs et al. 2016 [85]

28 Study Meta Analysis

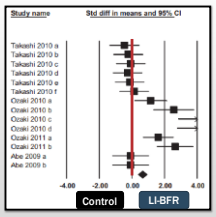
Muscle Hypertrophy



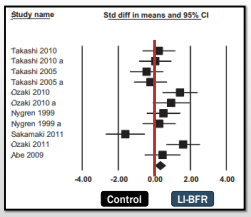
13

Effectiveness of Blood Flow Restriction - Aerobic

Muscle Strength



Muscle Hypertrophy



Slyzs et al. 2016 [85]

14

Following Topics of Interest:

1. Strength & Blood Flow
2. BFR & Post Surgical Populations
3. BFR & Neurologic Diseases
4. BFR & Muscular Diseases

15

BFR Effectiveness – Strength & Blood Flow

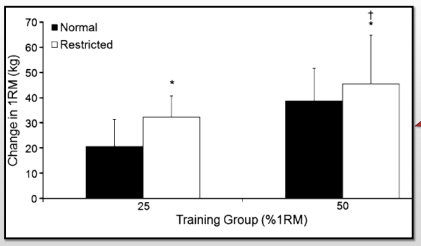
- Subjects: **n = 16 (Female)**
- Exercise: **Unilateral Plantar Flexion**
- Intensity Cohorts: **25% or 50% 1 RM (1 LE BFR, 1 LE no BFR)**
- Duration: **4 weeks, 3x/week, 5-8 min/set**
- Volume: **3 sets to failure (cadence 1.5 sec ↑ & 1.5 sec ↓)**

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[98]

16

BFR Effectiveness – Strength & Blood Flow

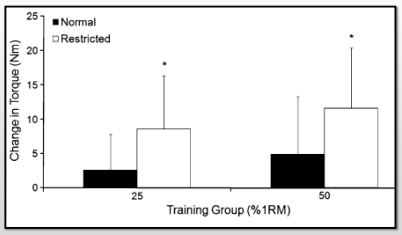


Patterson et al. 2009[98]

26% 1RM

17

BFR Effectiveness – Strength & Blood Flow

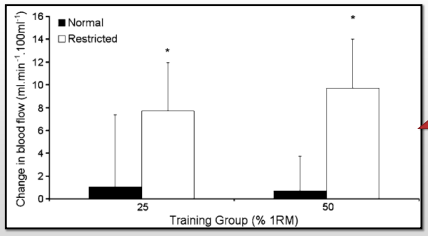


Patterson et al. 2009[98]

106% Iso. MVC

18

BFR Effectiveness – Strength & Blood Flow



Patterson et al. 2009[98]

43% Blood Flow

19

Effectiveness of BFR – Post-Operative: Knee Arthroscopy

Method Variable	Value
Subjects	N = 20 (10 BFR; 10 Controls)
Duration	12 Sessions (2 wk post op) 6 weeks
Frequency	~ 2x/week
Type	Control: Post-Op Protocol BFR: Post-Op Protocol + 1. Leg Press 2. Leg Extension 3. Kick Backs
Volume/Intensity	BFR: - 4 sets x 30/15/15/15 - 30% 1 RM - Set rest: 30 sec - Exercise rest: 1 min

Tennet et al. 2018[103]

Blood Flow Restriction Training After Knee Arthroscopy: A Randomized Controlled Pilot Study

Thigh Girth (cm) Proximal to Superior Patellar Pole (cm)

	P
6-cm proximal	
Occlusion	0.0111*
Control	1
16-cm proximal	
Occlusion	0.0001*
Control	0.1453

20

Effectiveness of BFR – Post-Operative

Peak Torque (N·m)/Body Weight (kg)

	Final Deficit	*P*	% Improvement Involved
Extension corrected			
Occlusion	23.01 (−9.12 to 64.56)	0.0020*	74.594 (42.16-98.88)
Standard	42.44 (14.348 to 119.71)	0.0156*	33.5 (2.99-51.81)
Flexion corrected			
Occlusion	−2.99 (−18.53 to 10.76)	0.0020*	40.20 (26.7-84.6)
Standard	1.79 (−12.2 to 21.89)	0.0469*	16.80 (0.9-119.3)

Tennet et al. 2018[103]

21

Effectiveness of BFR – Post-Operative: Knee Arthroscopy

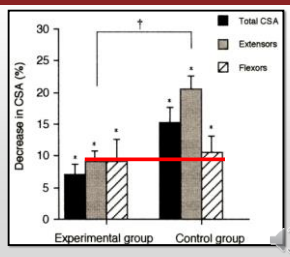
Subjective Outcome	BFR	Control
	P	*P*
KOOS		
Pain	0.0011*	0.0412*
Symptoms	0.0038*	0.0781
ADL	0.0069*	0.0844
QOL	0.0034*	0.0755
Sport	0.0069*	0.412*
VR-12		
PCS	0.0068*	0.0451*
MCS	0.0371*	0.4047
Physical outcome		
SSWV	0.0010*	0.0289*
Stair climb	0.0011*	0.2235
FSST	0.0035*	0.0097*
Sit-Stand	0.0107*	0.0062*

Tennet et al. 2018[103]

22

Effectiveness of BFR – Post-Operative: ACL (1)

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

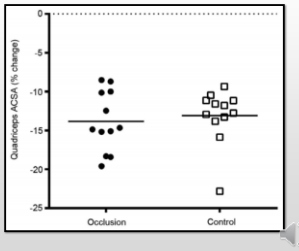


Takarada et al. 2000[112]

23

Effectiveness of BFR – Post-Operative: ACL (2)

Method Variable	Value
Subjects	N = 24 (BFR vs No BFR) M/F: 14/10 Age: 23 y/o
Duration	2 weeks (Day 3–14 post op)
Cuff	BFR: Width: 140 mm Pressure: 130 mmHg (+10/D) Max: 180 mmHg CONTROL: Cuff w/o inflation
Exercise Type	Quad Set (w. towel roll)
Frequency	2x/Day
Volume	5x5 min (5x20 repetitions) Set Rests: 3 min



Iversen et al. 2016[113]

24

Effectiveness of BFR – Post-Operative: ACL (3)

Method Variable	Value
Subjects	N = 44 (BFR vs No BFR) M/F: 14/10 Age: 29 y/o
Duration	16 weeks
Cuff	BFR: 180 mmHg (operative LE only)
Exercise Type	Post Operative ACL Protocol (see Reference for details)
Frequency	6x/week
Intensity	"Relatively Low"

	Before surgery N group	Before surgery R group	16 weeks after surgery N group	16 weeks after surgery R group	p-value
Knee extensor muscle strength					
CC60	86 (14)	84 (13)	55 (17)	76 (16)	<0.001
CC180	90 (9)	84 (14)	65 (13)	77 (13)	0.004
IM60	94 (21)	92 (19)	63 (19)	84 (19)	<0.001
Knee flexor muscle strength					
CC60	90 (16)	96 (21)	72 (15)	81 (14)	0.05
CC180	99 (16)	96 (19)	74 (12)	84 (18)	0.04
IM60	94 (17)	91 (18)	62 (14)	72 (11)	0.02

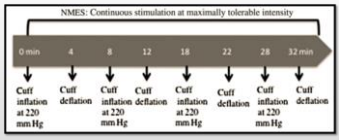
CC60: concentric 60°/sec; CC180: concentric 180°/sec; IM60°

Ohta et al. 2003[114]

25

Effectiveness of BFR – Post-Operative: BFR+NMES

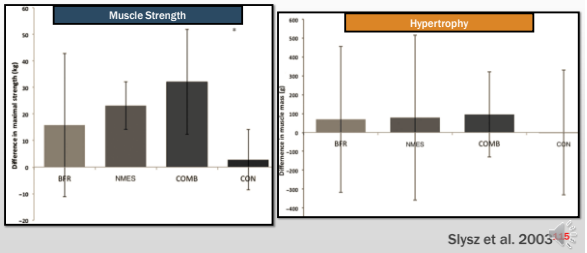
Method Variable	Value
Subjects	N = 20 (M/F: 10/10) Age: 29 y/o
Cohorts	1. Control (CON) | 4. BFR 2. NMES 3. BFR+NMES(COMBO)
Duration	6 weeks
Frequency	4x/week
Cuff	200 mmHg | Width: 10.2 cm 3x4 min inflation
NMES	2 electrodes (5 cm²) Pulse Length: 400 µs Wave Frequency: 50-100 Hz Intensity: Maximally tolerated



Slysz et al. 2003[115]

26

Effectiveness of BFR – Post-Operative: BFR+NMES



Slysz et al. 2003[115]

27

Effectiveness of BFR – Parkinson's Disease

Method Variable	Value
Subjects	N = 1
Duration	10 weeks Phase A: 6 weeks BFR Phase B: 4 weeks no BFR
Time	5x2 min (1 min rest)
Frequency	3x/week
Type	Treadmill Walking
Volume/Intensity	Pace 50m/min 120-160 mmHg

Table 2. *Weekly values for average HR, peak BP and peak RPE.*

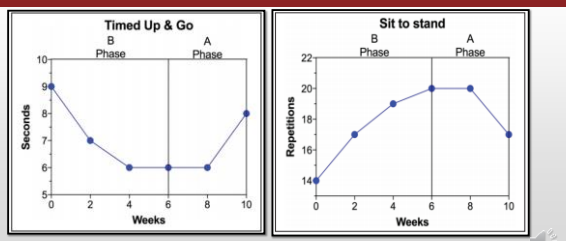
	HR (Mean ± SD)	Peak Weekly BP	Peak RPE
Week 1	68.47 ± 1.71	158/90mmHg	9
Week 2	67.23 ± 1.71	148/78mmHg	7
Week 3	72.99 ± 1.71	142/72mmHg	11
Week 4	69.65 ± 1.71	146/78mmHg	11
Week 5	76.64 ± 1.71	128/74mmHg	10
Week 6	73.27 ± 1.71	150/74mmHg	9

HR, Heart Rate; BP, Blood Pressure; RPE, Rating of Perceived Exertion.

Doris et al. 2018[102]

28

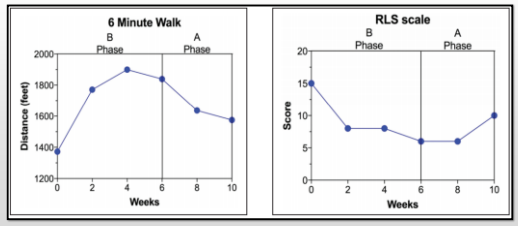
Effectiveness of BFR – Parkinson's Disease



Doris et al. 2018[102]

29

Effectiveness of BFR – Parkinson's Disease



RLS – resting leg syndrome questionnaire

Doris et al. 2018[102]

30

Effectiveness of BFR – Polymyositis & Dermatomyositis

Method Variable	Value
Subjects	N = 13
Duration	12 weeks
Time	25-30 min
Frequency	2x/week
Type	Leg Press & Knee Extension
Volume/Intensity	Frequency: 2x/week Week 1: 4x15 @ 20% 1RM Week 2-4: 4x15 @ 30% 1RM Week 5-12: 5x15 @ 30% 1RM

Variable	*P*-value (pre- to post-test)
SF-36 physical function	0.001*
SF-36 role physical	0.041*
SF-36 bodily pain	0.002*
SF-36 general health	0.003*
SF-36 vitality	0.003*
SF-36 social function	0.017*
SF-36 role emotional	0.014*
SF-36 mental health	0.007*
HAQ	0.001*
VAS patient	0.008*
VAS physician	0.004*

Mattar et al. 2014[101]

31

Effectiveness of BFR – Polymyositis & Dermatomyositis

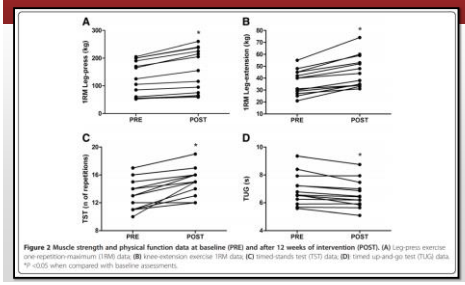


Figure 2 Muscle strength and physical function data at baseline (PRE) and after 12 weeks of intervention (POST). (A) Leg-press exercise one-repetition-maximum (1RM) data; **(B)** knee-extension exercise 1RM data; **(C)** timed-stands test (TST) data; **(D)** timed up-and-go test (TUG) data. *P <0.05 when compared with baseline assessments.

Mattar et al. 2014[101]

32

Effectiveness of Blood Flow Restriction - Conclusion

1. LI-BFR: may ↑ in muscle size & strength effects; used when traditional high-load training may be inappropriate or unattainable.
2. 30% 1RM Adaptations > 20% 1 RM Muscle Adaptations
3. Quantifiable muscular adaptations present quickly; Training >6 weeks seem to offer greater returns in strength adaptation.
4. BFR training has applicability to a range of populations who may seek to progress strength while reducing loads on the associated tissues including muscular, tendinous, connective, and bony.

Slyzs et al.[85]

33

Effectiveness of BFR – Bone Remodeling

Author/Year	Study sample	Intervention type and duration	Conclusion
Beekley et al. (2005)	n = 18 healthy men (21–28 years old).	15-min walk (50 m min^{-1}) on the treadmill, 2 × /day, (4-h interval between sessions) for 3 weeks, 6 days $week^{-1}$	Aerobic training combined with BFR, increased the levels of BAP
Bemben et al. (2007)	n = 9 active men (18–30 years old).	Two sessions of ST with BFR and control (ST without BFR): 20% 1RM for both groups with a 48-h interval in random order	LI training combined with BFR decreased bone metabolism (NTx) during an acute bout
Karabulut et al. (2011)	n = 37 healthy elderly men (58·8 ± 0·6 years old)	ST: 3 × /week for 6 weeks	LISTG showed significant changes in bone ALP concentrations and bone ALP
Kim et al. (2012)	n = 30 healthy untrained men (18–35 years old)	ST: 3 × /week for 3 weeks	HISTG was most effective than LISTG for eliciting bone formation and muscle hypertrophy responses.

Bittar et al. 2018[116]

34

Effectiveness of BFR – Additional & Future Research

Blood Flow Restriction research is **rapidly expanding.**

Patient demographics in which BFR research has been/will be applied:

1. Post-Operative (Clinical Trials)
   - Lower Extremity: *Knee arthroscopy, ACL, Femur Factures, Achilles tendinopathy, Meniscus repair*
   - Upper Extremity: *distal radius fractures, rotator cuff repair*
   - General: *joint arthroplasty, nerve injuries, muscle strains*
2. Myositis[108]
3. Astronauts[110]
4. Geriatric[104, 106, 107, 109]
5. Adolescent[105]

35