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Haute Ecole de Santé
Hochschule für Gesundheit
Blood Flow Restriction Training
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Why blood flow restriction training

If you want muscular strength or hypertrophia → moderate to high load

→Pain

→Blood flow restriction training → same effects with less load → less pain

How

→ Cheap and dirty

→ Cheap

→ Expensive and controlled

→ With resistance training or with other activities (e.g. walking)

Different forms

- → Kaatsu
  - → Patented; developed by Dr. Yoshiaki Sato.
  - → Probably less blood flow restriction due to different cuff width compared to "blood flow restriction" training.
- → Blood flow restriction training
- → Occlusion training
  - → Often used interchangeably with blood flow restriction training, some say that if cuffs too narrow → no occlusion occurs.
- → Hypoxis training
  - → Limiting oxygen availability during exercise
    - → Sometimes done in hypoxic chambers

Kaatsu


http://xbodyconcepts.com/blood-flow-restriction-training/

https://www.kaatsu-deutschland.de/equipment/

https://youtu.be/2fMUpxqJq48

Discussion on BFR Training in Physiotherapy

https://youtu.be/FZWhPx5u9K0

Is it safe?

- Current contraindications
  - History of deep-vein thrombosis
  - Risk of deep-vein thrombosis
  - Pregnancy
  - Varicosis
  - High blood pressure
  - Cardiac disease

→ we would like to use it in persons with pain → these patients often are older and have comorbidities

https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0838.2010.01290.x
https://www.jstage.jst.go.jp/article/ijktr/2/1/2_1_5/_pdf/-char/ja

Is it safe?

- → Blood coagulation
  - → Strenuous exercise → increase activity of coagulation system → venous thrombosis
  - → Vascular occlusion → can cause formation of thrombus → can induce microvascular occlusion even after reperfusion
    - → Muscle damage, cell necrosis
  - → 0.06% out of 300 000 training sessions resulted in an incidence of venous thrombosis, which is lower rate than that reported for the general Asian population (~ 0.2–0.26%) (Nakajima et al 2006)
  - → Problem could be if a patient has asymptomatic VTE (cuff position→VTE occurs more often above the knee than below the knee)
    - → asymptomatic VTE event cannot be detected without costly, time consuming, and potentially unreliable phlebography or sonography
    - → ?wait until six weeks after surgery?

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https://www.jstage.jst.go.jp/article/ijktr/2/1/2_1_5/_pdf/-char/ja

TABLE 1. Possible precautions or contraindications for blood flow restricted (BFR) resistance exercise as related to venous thromboembolism (VTE) risk for post-surgical orthopedic patients. Note that this list is not exhaustive and a given health organization may consider one suggestion a precaution while another may consider it a contraindication. Table presented in alphabetical order.

Abnormal Clotting Times	Lymphectomies
Acid-Base Imbalance/Acidosis	Obesity
Age >40 yr	Open Fracture
Arterial Calcification	Open or Unhealed Soft Tissue Injuries
Atherosclerotic Vessels	Paralysis
Cardiopulmonary Conditions	Peripheral Vascular Disease
Creatine Supplement Use	Pregnancy/Postpartum
Diabetes	Prior Revascularization
Dialysis/Central Venous Access	Renal Compromise
General/Local Infection	Severe Crushing Injuries
High Intracranial Pressure	Sickle Cell Trait/Anemia
Hip, Pelvis, or Femur Fracture	Skin Grafts
History of Venous Thromboembolism	Stroke
Hormonal Contraceptive Use	Temporary Nerve Damage
Hypertension	Thrombophilia
Immobility >48 hr in the Past Month	Tumor/Cancer
Immobilizing Cast	Vascular Grafting
Implanted Medical Device	Varicose Veins

Bond, C. W., Hackney, K. J., Brown, S. L., & Noonan, B. C. **(2018)**. Blood flow restricted resistance exercise as a post-orthopedic surgery rehabilitation modality: a review of venous thromboembolism risk. *Journal of Orthopaedic & Sports Physical Therapy*, (0), 1-29.

Is it safe?

- → Oxydative stress
  - → Strenuous exercise → increase in oxidative stress
  - → Ischemic reperfusion → increased vascular permeability → increased reactive osygen species (ROS)
    - → Not found with moderate vascular restriction (e.g. as proposed by Takarada, ~214 mmHG)

file:///C:/Users/Roger%20Hilfiker/Downloads/Loenneke_et_al-2011-Scandinavian_Journal_of_Medicine_%2526_Science_in_Sports.pdf

Is it safe?

- → Muscle damage
  - → Low intensity blood flow restriction training of the knee extensor (35% MVC) → peak soreness score of 2.8/10 at 24h.
    - → Maximal eccentric contractions → 7-8/10
    - → Isokinetic knee extension → 4-5/10
  - → No increase in creatine kinase or myoglobin found after low-intensity blood flow restriction training.
  - → Conclusion → only minimal muscle damage

file:///C:/Users/Roger%20Hilfiker/Downloads/Loenneke_et_al-2011-Scandinavian_Journal_of_Medicine_%2526_Science_in_Sports.pdf

Is it safe?

- → Nerve conduction velocity
  - → Numbness is sometimes reported
  - → 1.6% out of 30'000 sessions
  - → Transient "problem", no damage

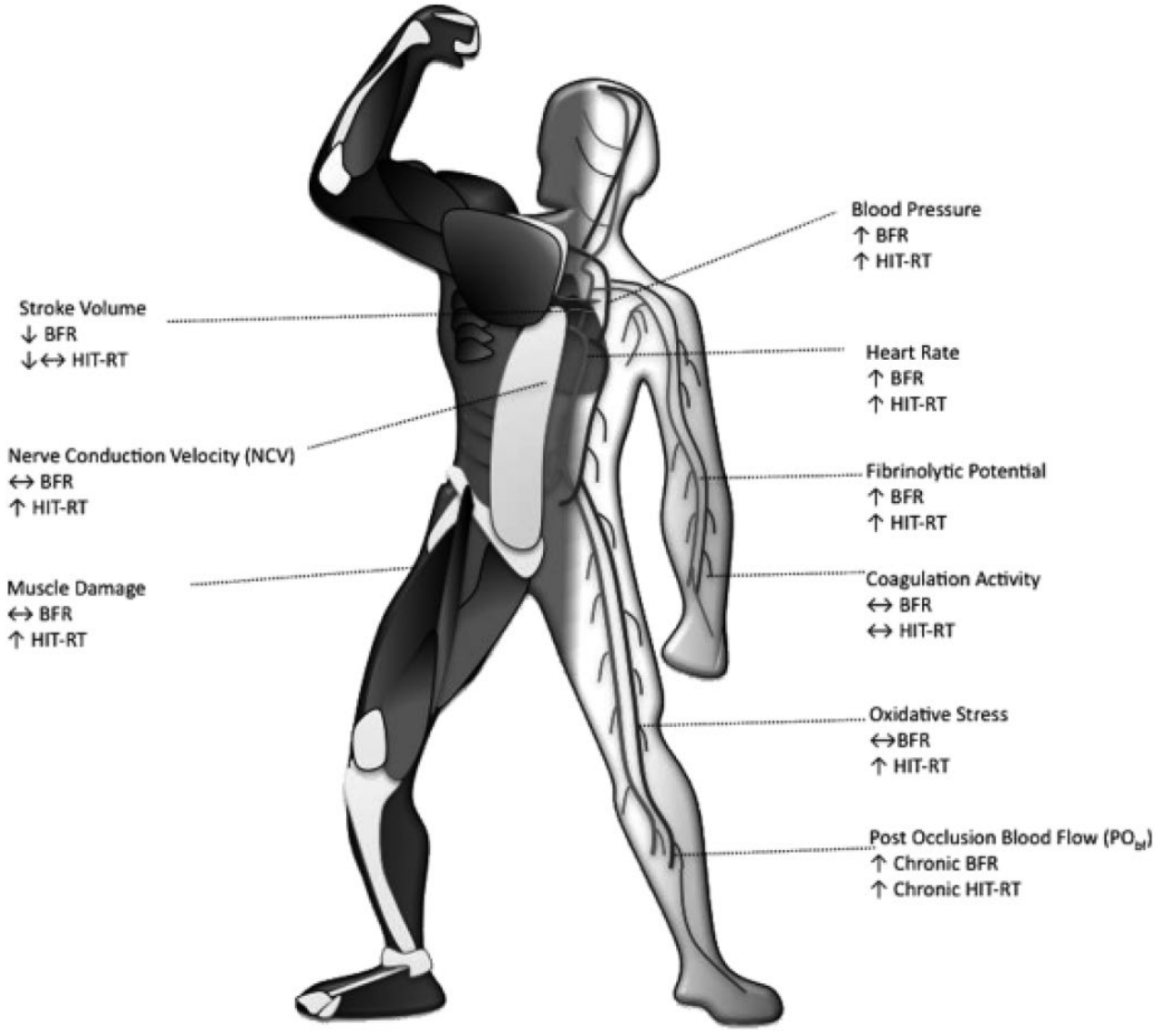
file:///C:/Users/Roger%20Hilfiker/Downloads/Loenneke_et_al-2011-Scandinavian_Journal_of_Medicine_%2526_Science_in_Sports.pdf

Is it safe?

→ Arterial stiffness (in older adults)

→ No changes in arterial stiffness

https://academic.oup.com/biomedgerontology/article/70/8/950/2947617


Blood Pressure
↑ BFR
↑ HIT-RT
Stroke Volume
↓ BFR
↓↔ HIT-RT
Heart Rate
↑ BFR
↑ HIT-RT
Nerve Conduction Velocity (NCV)
↔ BFR
↑ HIT-RT
Fibrinolytic Potential
↑ BFR
↑ HIT-RT
Muscle Damage
↔ BFR
↑ HIT-RT
Coagulation Activity
↔ BFR
↔ HIT-RT
Oxidative Stress
↔BFR
↑ HIT-RT
Post Occlusion Blood Flow (PO_{bf})
↑ Chronic BFR
↑ Chronic HIT-RT

Hypertrophy → early hypertrophy (≤4 weeks) is a consistent finding,
→ whereas significant increases in strength are typically not observed until ≥10 weeks of training

Loenneke, J. P., Wilson, J. M., Marín, P. J., Zourdos, M. C., & Bemben, M. G. (2012). Low intensity blood flow restriction training: a meta-analysis. *European journal of applied physiology*, *112*(5), 1849-1859.

Citation	Age (years)	Gender	Training status	Exercise mode	Exercise intensity	Frequency of training	Length of training	Protocol	Measure of hypertrophy
Abe et al. (2005c)	<25	M	Rec. active	Squat and knee flexion	20% 1RM	12× week	2 weeks	3 sets of 15 repetitions; 30 sec rest	MRI
Abe et al. (2005b)	<25	M	Athlete	Squat and knee flexion	20% 1RM	14× week	8 days	3 sets of 15 repetitions; 30 sec rest	Ultrasound
Abe et al. (2006)	<25	M	Rec. active	Treadmill walking	50 M/Min	12× week	3 weeks	52-min walking bouts; 1 min rest	MRI
Abe et al. (2009)	<25	M	Rec. active	Treadmill walking	50 M/Min	6× week	3 weeks	52-min walking bouts; 60 sec rest	MRI
Abe et al. (2010b)	>50	M/F	Rec. active	Treadmill walking	67 M/Min	5× week	6 weeks	20 minutes walking	Ultrasound
Abe et al. (2010a)	<25	M	Rec. active	Cycling	40% VO_{2max}	3× week	8 weeks	15 minutes cycling	MRI
Beekley et al. (2005)	<25	M	Rec. Active	Treadmill walking	50 M/Min	12× week	3 weeks	52-min walking bouts; 60 sec rest	MRI
Fujita et al. (2008)	<25	M	Rec. Active	Knee extension	20% 1RM	12× week	6 days	30-15-15-15 repetitions; 30 sec rest	MRI
Kacin and Strazar (2011)	<25	M	Rec. Active	Unilateral knee extension	15% MVC	4× week	4 weeks	4 sets to volitional fatigue	MRI
Madarame et al. (2008)	<25	M	Untrained	Knee extension and knee flexion	30% 1RM	2× week	10 weeks	30,15,15 repetitions; 30 sec rest	MRI
Ozaki et al. (2011)	>50	M/F	Untrained	Treadmill walking	45% HRR	4× week	10 weeks	20 minutes walking	MRI

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Muscle Strength

Table 3 Effect size for muscle strength

Overall	LI-BFR			Low intensity		
	Mean (95% CI)	$N = 28$	P	Mean (95% CI)	$N = 20$	P
	0.58* (0.40, 0.76)			−0.00 (−0.18, 0.17)		
Moderators						
Gender						
Male	0.58 (0.29, 0.97)	19	>0.05	0.08 (−0.03, 0.20)	11	<0.05
Female	I.D.			I.D.		
Both	0.58 (0.16, 1.01)	9		−0.20 (−0.37, −0.02)	9	
Training status						
Untrained	1.38 (1.01, 1.76)	6	<0.05	0.32 (0.13, 0.51)	6	<0.05
Recreationally active	0.37 (0.17, 0.57)	21		−0.10 (−0.20, −0.00)	21	
Athletes	I.D.			I.D.		
Days per week						
2–3	1.25 (0.84, 1.67)	6	<0.05	0.27 (0.07, 0.47)	6	<0.05
4–5	0.53 (0.21, 0.86)	10		−0.17 (−0.32, −0.14)	10	
6–7	0.29 (−0.00, 0.58)	12		−0.00 (−0.15, 0.13)	12	
Week of duration						
≤4	0.27 (0.03, 0.52)	13	<0.05	0.00 (−0.03, 0.04)	19	>0.05
5–8	0.49 (0.20, 0.79)	9		−0.05 (−0.11, 0.15)	7	
9–10	1.38 (1.02, 1.75)	6		I.D.		

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Exercise mode						
Isotonic	1.08 (0.69, 1.46)	8	<0.05	0.28 (0.11, 0.44)	8	<0.05
Walking	0.42 (0.16, 0.67)	18		−0.12 (−0.23, −0.02)	18	
Cycling	I.D.			0.28 (0.11, 0.44)		
Exercise intensity						
15–30% MVC/1RM	1.08 (0.69, 1.46)	8	<0.05	0.28 (0.12, 0.44)	8*	<0.05
50–60 (m/min)	0.25 (−0.10, 0.61)	9		−0.05 (−0.20, 0.09)	9	
40–45% HRR/VO_{2max}	0.50 (0.17, 0.83)	11		−0.17 (−0.30, −0.03)	11*	
Repetitions						
60–70	1.37 (0.98, 1.76)	6	<0.05	0.32 (0.13, 0.51)	6	<0.05
Failure	I.D.			I.D.		
14–20 (min)	0.39 (0.17, 0.60)	20		−0.11 (−0.22, −0.01)	20	
Rest period (s)						
0	0.50 (0.19, 0.80)	11	<0.05	−0.17 (−0.30, −0.03)	11	<0.05
30	1.22 (0.83, 1.60)	7		0.30 (0.13, 0.47)	7	
60	0.25 (−0.08, 0.58)	9		−0.05 (−0.20, 0.09)	9	
120	I.D.			I.D.		
Cuff pressure (mmHg)						
140–220	0.50 (0.12, 0.88)	11	>0.05			
160–240	0.67 (0.35, 0.99)	16				
230	I.D.					

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Table 4 Effect size for muscle hypertrophy

Overall	LI-BFR			Low Intensity		
	Mean (95% CI) 0.39* (0.35, 0.43)	N = 31	P	Mean (95% CI) −0.01 (−0.05, 0.03)	N = 29	P
Moderators						
Gender						
Male	0.42 (0.37, 0.47)	25	<0.05	0.00 (−0.02, 0.03)	25	
Female	I.D.			I.D.		
Both	0.26 (0.16, 0.37)	6		I.D.		
Days per week						
2–3	0.48 (0.38, 0.58)	6	<0.05	−0.00 (−0.07, 0.06)	6	>0.05
4–5	0.27 (0.18, 0.37)	7		I.D.		
6–7	0.41 (0.35, 0.47)	18		−0.00 (−0.04, 0.04)	18	
Week of duration						
≤4	0.41 (0.34, 0.47)	19	>0.05	0.00 (−0.03, 0.04)	19	>0.05
5–8	0.39 (0.29, 0.49)	9		−0.05 (−0.11, 0.01)	7	
9–10	I.D.			I.D.		
Exercise mode						
Isotonic	1.08 (0.69, 1.46)	8	<0.05	0.02 (−0.02, 0.06)	13	>0.05
Walking	0.42 (0.16, 0.67)	18		−0.05 (−0.10, −0.05)	12	
Cycling	I.D.			I.D.		

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Muscle Hypertrophy

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Overall	LI-BFR			Low Intensity		
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Exercise intensity						
15–30% MVC/1RM	1.08 (0.69, 1.46)	8	<0.05	0.02 (−0.02, 0.069	13	>0.05
50–60 (m/min)	0.25 (−0.10, 0.61)	9		−0.02 (−0.08, 0.03)	8	
40–45% HRR/VO_{2max}	0.50 (0.17, 0.83)	11		−0.05 (−0.11, 0.00)	8	
Lower strength assessment						
Isokinetic	I.D.		>0.05	I.D.		>0.05
Isotonic	0.33 (0.26, 0.41)	7		−0.03 (−0,10, 0.03)	7	
Isometric	0.37 (0.30, 0.44)	7		0.00 (−0.06, 0.07)	7	
Repetitions						
60–70	I.D.		<0.05	I.D.		>0.05
Failure	I.D.			I.D.		
14–20 (min)	0.36 (0.30, 0.42)	18		−0.03 (−0.07, 0.00)	16	
45 (rep)	0.51 (0.43, 0.60)	8		0.03 (−0.01, 0.09)	8	
Rest period (s)						
0	0.37 (0.28, 0.46)	10	>0.05	−0.05 (−0.10, 0.00)	8	>0.05
30	0.44 (0.36, 0.53)	12		0.00 (−0.03, 0.05)	12	
60	0.35 (0.25, 0.45)	8		−0.02 (−0.08, 0.03)	8	
120	I.D.			I.D.		
Cuff pressure (mmHg)						
140–220	0.37 (0.28, 0.46)	10	>0.05			
160–240	0.41 (0.34, 0.44)	20				
230	I.D.					

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When?

→ Musculoskeletal problems

- → Hughes, L., Paton, B., Rosenblatt, B., Gissane, C., & Patterson, S. D. (2017). Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. Br J Sports Med, 51(13), 1003-1011.

→ ACL Rehabilitation

- → Hughes, L., Rosenblatt, B., Paton, B., & Patterson, S. D. (2018). Blood Flow Restriction Training in Rehabilitation Following Anterior Cruciate Ligament Reconstructive Surgery: A Review. *Techniques in Orthopaedics*, *33*(2), 106-113.

https://tourniquets.wordpress.com/category/blood-flow-restriction/

On limb occlusion pressure https://tourniquets.org/limb-occlusion-pressure-lop/

On personalized blood flow restriction rehabilitation https://tourniquets.org/personalized-blood-flow-restriction-bfr-rehabilitation/

Cuff width

Most frequently used: 10 to 12 cm

Cuffs greater than 15 cm may be more desirable

→ Larger cuff → less problems local, less pressure required to achieve same level of occlusion

Pressure

- → Standard pressure (e.g. 180 mmHG)
- → 1.2 or 1.5 x systolic blood pressure
- → Pressure relative to the patient's thigh circumference
- → Individualised: at rest, cuff pressure slowly increased until flow of blood no longer detected (plethysmography or Doppler US) → 40-80% of that pressure is used for exercise session.
- → Most often used: up to 200mmHG (in operating room for lower-extremity surgery: 300mmHG)
- → Pressure will be up for 5 to 10 minutes per exercise

Pos.	Anzahl	Einheit	Artikelnr.	Bezeichnung	Einzelpreis	Gesamtpreis
1	1	Stück	KA01-001.2	KAATSU Master Paket. Inklusive Kaatsu Valved Air Bands Set. Größe L.	7.140,00 €	7.140,00 €
2	1	Stk.		KAATSU Master Tragekoffer.	65,00 €	65,00 €
3	1	Stück	1002	Versandkostenbeteiligung, inkl. Höherversicherung von zwei Paketen in die Schweiz	65,00 €	65,00 €
4	1	Stk.		Erstellung des Ausfuhrbegleitdokuments	50,00 €	50,00 €
Summe						7.320,00 €

Pos.	Anzahl	Einheit	Artikelnr.	Bezeichnung	Einzelpreis	Gesamtpreis
1	1	Stk.	KA01-002.2	KAATSU Nano Paket. Inklusive Kaatsu Valved Air Bands Set. Größe L.	3.750,00 €	3.750,00 €
2	1	Stück	KA01-028	KAATSU Lederhülle für Nano und Cycle.	33,61 €	33,61 €
3	1	Stück	1002	Versandkostenbeteiligung, inkl. Höherversicherung von zwei Paketen in die Schweiz	65,00 €	65,00 €
4	1	Stk.		Erstellung des Ausfuhrbegleitdokuments	50,00 €	50,00 €
Summe						3.898,61 €

Webseite Kaatsu Deutschland

https://www.kaatsu-deutschland.de/