Blood Flow Restriction Training

JORDAN METCALF, PT, DPT

Terms

- **Low Intensity Blood Flow Restriction (LI-BFR)**: resistance training at 15-35% of 1RM with some element of blood flow restriction

- **Traditional resistance training (T-RT or HI-RT)**: High intensity resistance training at >/= 70% of 1RM

History

- KAATSU website https://www.kaatsu-global.com/history-of-kaatsu/
- Dr. Yoshiaki Sato develops principles of KAATSU training in 1973
- Had similar feeling of muscle swelling with sitting on feet as with resistance training, began experimenting.
- Uses KAATSU training bands with isometric exercise to regain strength following an ankle fracture with surprisingly successful results.
- Clinical research started in the 1990's

History

- Blood flow restriction training
  - The use of straps to maintain a constant level of constriction throughout workout
- **Misconception about "occlusion" training**
- First study on BFR published in 1998 by **Dr. Jeremy Loenneke**

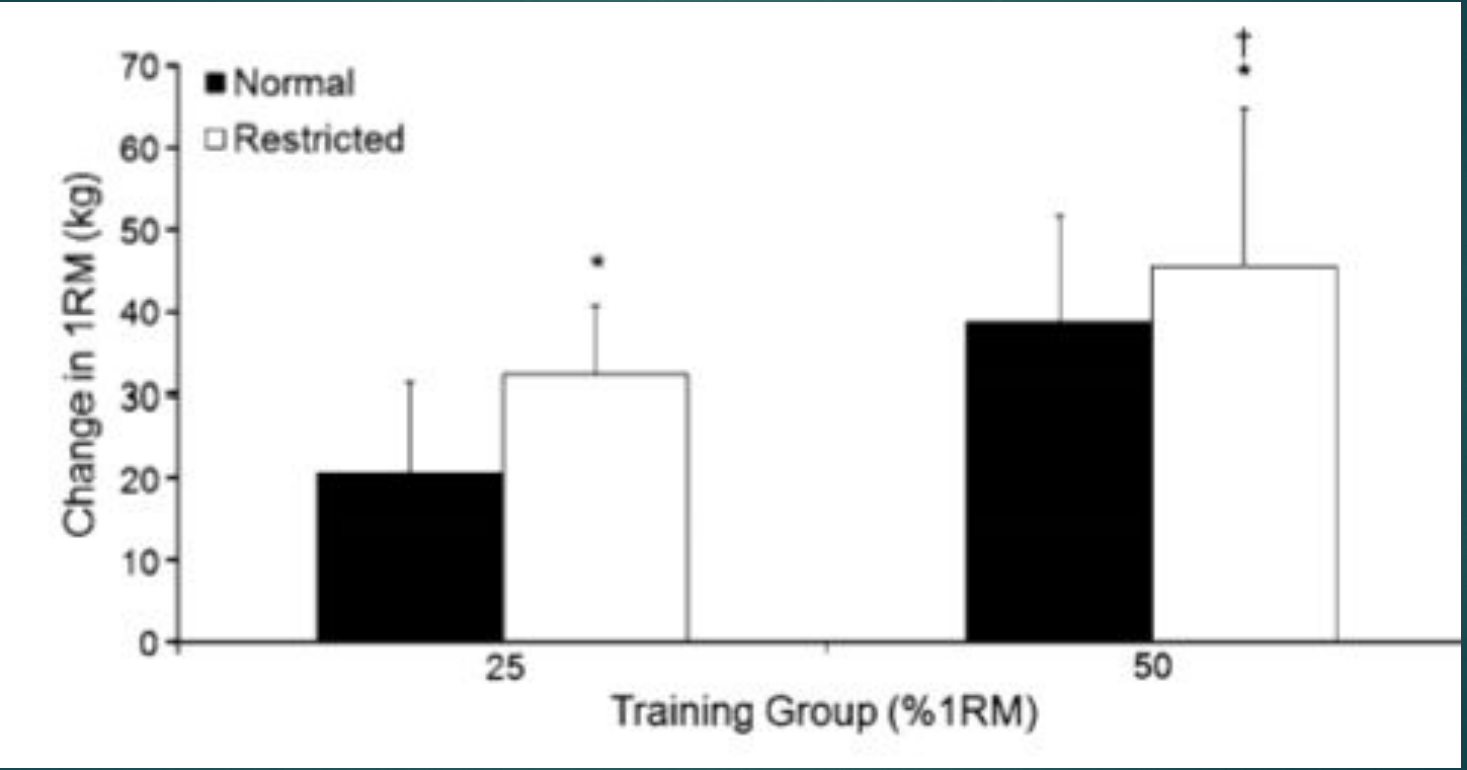
Parameters

- A meta-analysis of studies with varying parameters on the effect of LI-BFR on muscle hypertrophy- Article
  - Exercise type: Isotonic low load resistance training (higher effect size than just walking)
  - **Cuff pressure: 50-80% limb occlusion pressure (LOP)**
  - **Intensity: 15-30% 1RM**
  - **Frequency: 2-3 days/week**
  - **Duration: 14-20 min**
  - Hypertrophy gained before strength, neural adaptation occurs slower with LI-BFR
  - Traditional resistance training still superior, but not always feasible for certain populations.
  - Findings
    - LI-BFR produced increased muscle hypertrophy in early stages, but less overall strength gains than traditional high intensity resistance training, indicating that neural adaptation may take longer with BFR

Current Research

- Patterson SD, Ferguson RA. Increase in calf post-occlusive blood flow and strength following short-term resistance exercise training with blood flow restriction in young women. *Eur J Appl Physiol.* 2010; 108: 1025-1033.
- Study design
  - Controlled trial
  - n = 16 physically active women between 19-26 y/o, that were strength matched based on a 1RM (either 25 or 50% 1RM)
  - Intervention: 4 week training program
    - Single leg plantarflexion against resistance (25 or 50% 1RM depending on the group) to the point of fatigue for 3 sets
  - Blood flow restriction cuff pressure: 110 mmHg
  - Groups
    - Low Load Resistance Training (LLRT) without blood flow restriction
    - Low Load Resistance Training (LLRT) WITH blood flow restriction
- **Findings: Significant difference in change of 1RM and post-occlusive blood flow between control and experimental groups following 4 weeks of resistance training with/without blood flow restriction.**

1RM Change


Normal
Restricted
Change in 1RM (kg)
70
60
50
40
30
20
10
0
25
50
Training Group (%1RM)

MVC Change

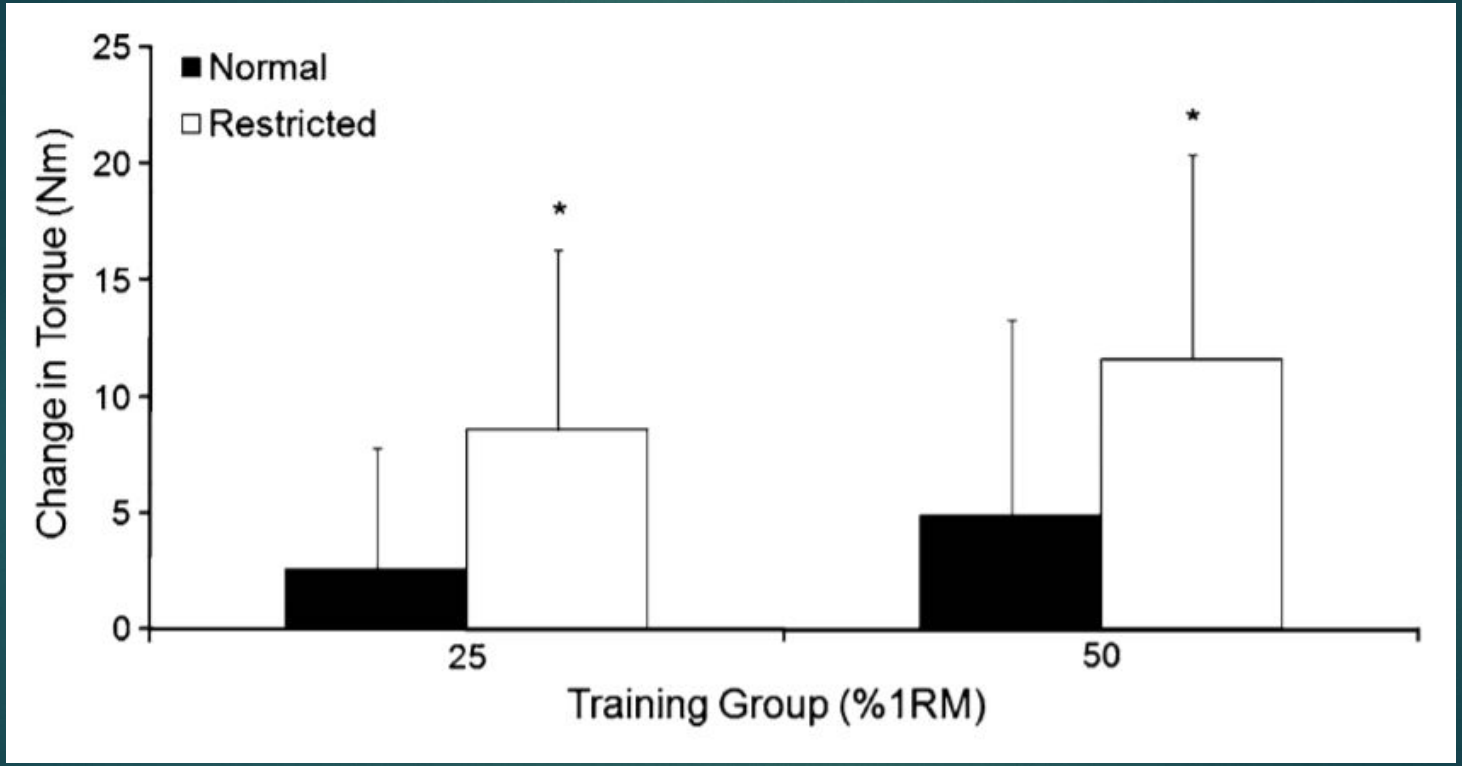
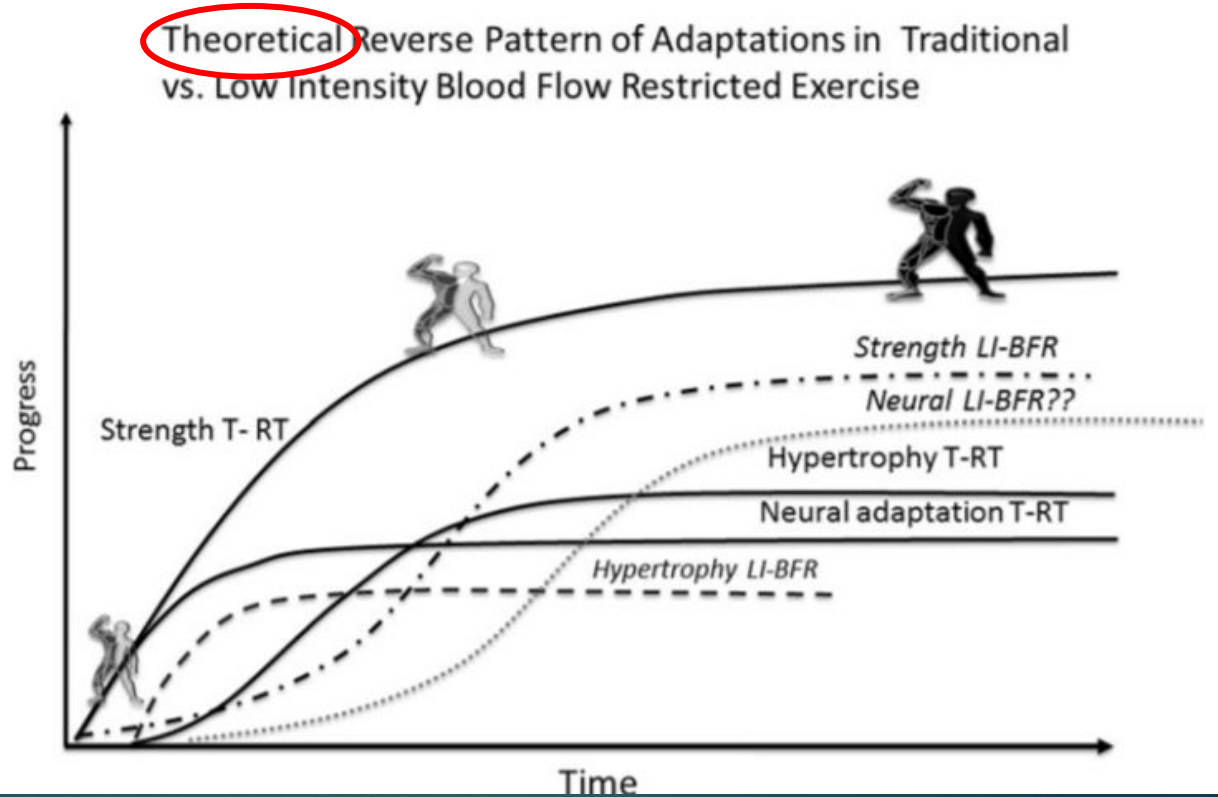

Normal
Restricted
Change in Torque (Nm)
25
20
15
10
5
0
*
*
25
50
Training Group (%1RM)

Fig. 2 Graphical representation of the theoretical interaction between strength, hypertrophy, and neural adaptations during both traditional resistance training (T-RT), and low intensity blood flow restricted exercise (LI-BFR) is shown. During T-RT strength increases at first primarily by changes in muscular hypertrophy followed latter by neural adaptations. For LI-BFR the opposite pattern may occur (adapted from Sale 1988)

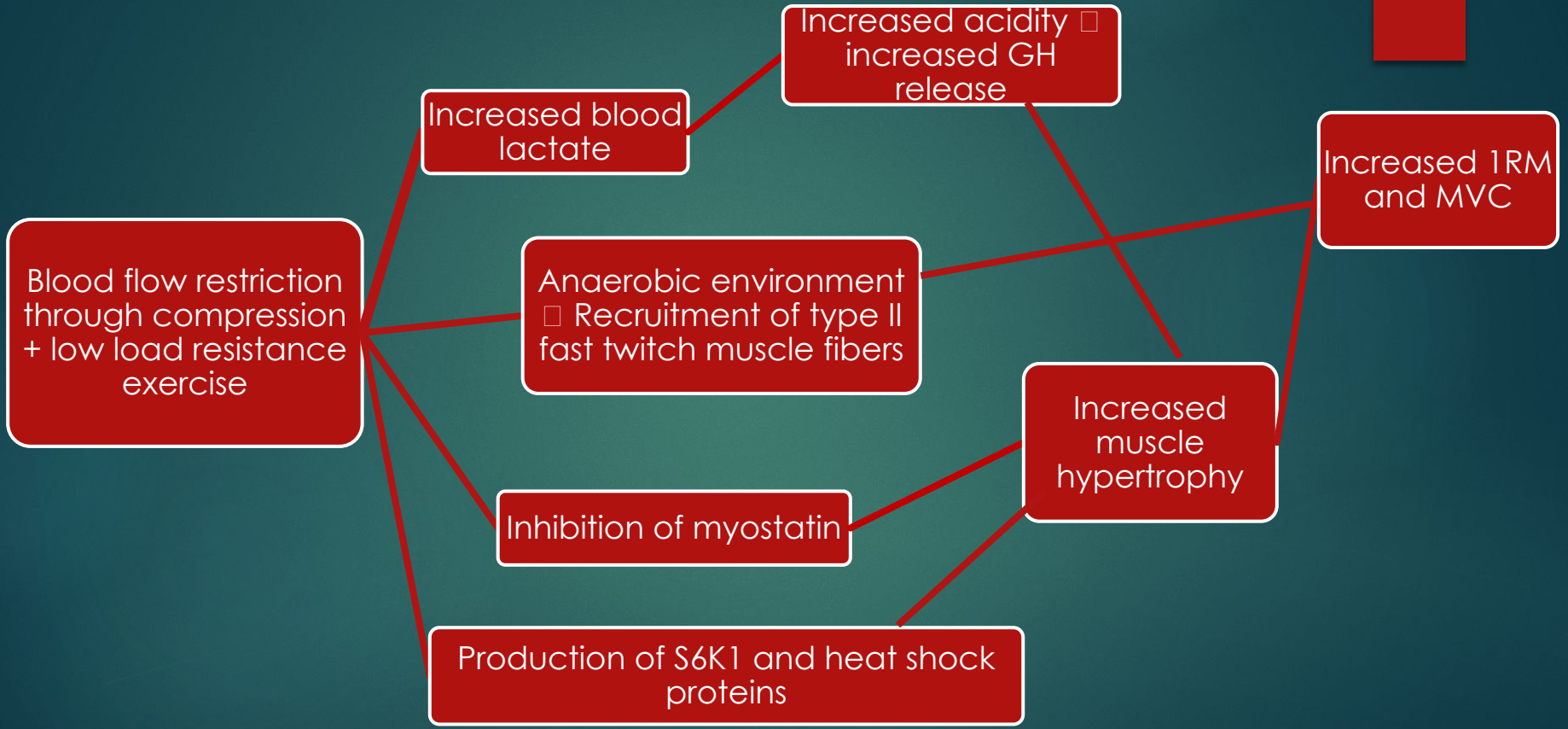


Physiology

- BFR produces more lactate than a roughly equivalent exercise load without BFR and significantly more growth hormone (5)
- BFR recruits fast twitch muscle fibers due to hypoxic environment created (6)
  - There is evidence that supports that fiber type recruitment is no different between LI-BFR and high intensity resistance training. (7)
- BFR causes inhibition of myostatin gene, which is a muscle growth regulator. (9)

Heat shock proteins

Heat shock proteins are released in extreme heat or stress (such as exercising with blood flow restriction) and facilitate various cellular processes and attract amino acids to them to facilitate protein synthesis


Increased acidity increased GH release
Increased blood lactate
Increased 1RM and MVC
Blood flow restriction through compression + low load resistance exercise
Anaerobic environment Recruitment of type II fast twitch muscle fibers
Increased muscle hypertrophy
Inhibition of myostatin
Production of S6K1 and heat shock proteins

Current Research: Strength Gains

- Yasuda T, Ogasawara R, Sakamaki M, Ozaki H, Sato Y, Abe T. Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. *Eur J Appl Physiol* (2011) 111:2525–2533.
  - Design: RCT
  - Methods
    - Subjects: 40 men aged between 22-32 y/o, moderately physically active
    - Groups:
      - Control: no training
      - LI-BFR only: Bench press, 3 days/wk, 30% 1RM for 75 repetitions, graded increase from 100 mmHg to 160 mmHg
      - HI-RT only: Bench press, 3 days/wk, 75% 1RM for 30 repetitions, 1RM reassessed after 3 weeks to adjust load
      - CB-RT (combined): LI-BFR 2x/wk, HI-RT 1x/wk
  - Results: CB-RT produced a higher degree of 1RM and MVC changes when compared to LI-BFR alone, and produced roughly equal increases as HI-RT.
  - **Conclusion: Combination of LI-BFR and HI-RT is more effective than LI-BFR alone, but HI-RT is still the most effective producer of muscle strength gains.**

Current Research: Tendon Healing

- Boesen et al. Effect of growth hormone on aging connective tissue in muscle and tendon: gene expression, morphology, and function following immobilization and rehabilitation. *J Appl Physiol.* 2014 Jan 15;116(2):192-203.
  - 12 elderly (65-75 y/o) men with 2 weeks of immobility of a single limb
    - Experimental group (n=6): 6 week retraining with GH injections
    - Control group (n=6): 6 week retraining with NO GH injection
  - Results
    - Increased tendon stiffness in experimental group with exogenous GH to supplement healing process

Tendon Stiffness...Good or bad???

- Stiffness vs. Elasticity
  - Force transmission economy
  - Running economy

"J" SHAPED FEET

- "J" shaped blades are more commonly used by sprinters.
- This shape allows for a quick return of energy helping you to achieve higher speeds.
- It is more difficult to learn to run on a sprinting specific foot than a jogging foot. This is because you need to put more into this foot in order to get the most out of it and starting off, one may not have the necessary strength to make this kind of foot energy efficient.
- Some J shaped blades include the 1E90 Sprinter by Ottobock and the Cheetah Xtend, Xplore, and Xtreme by Össur.

Tendon Physiology

It sounds confusing- But very easy to understand when you think of tendons as elastic bands. Compliant tendons are like stretchy, thin elastic bands. They stretch a lot even with the slightest pull (force), and will recoil to release energy. But due to their excessive stretch, they will recoil with reduced speed and force such as if you were trying to flick a thin, overstretched elastic band at a mate. Stiff tendons are like thick elastic bands. They stretch less when pulled, and will recoil at faster speed and force like a thick elastic band being flicked across a room.

J Sports Sci Med. 2018 Jun; 17(2): 223–228.
Published online 2018 May 14.
PMCID: PMC5950739
PMID: 29769823

Relationship between Achilles Tendon Stiffness and Ground Contact Time during Drop Jumps

- "However, there is a performance-injury risk trade off in tendon stiffness because the absorption of energy also reduces injury risk of the muscle-tendon system. Witvrouw et al. (2007) concluded that the key point of the prevention and treatment of tendon injuries is to increase the capacity to store elastic energy in the tendon by decreasing its stiffness."

Key points

- Significant correlation between Achilles tendon stiffness and ground contact time.
- Significant correlation between isometric maximum voluntary contraction and ground contact time.
- No correlation between Achilles tendon stiffness and other jumping tests (squat jump and counter movement jump).

The role of tendon microcirculation in Achilles and patellar tendinopathy

Karsten Knobloch

Journal of Orthopaedic Surgery and Research **3**, Article number: 18 (2008) | Cite this article

- "Currently, there is reasonable published evidence that the neovessels are at least part of the pathophysiological process in tendinopathy of the Achilles tendon in its mid-portion area, at the patella tendon and in tendinopathies of the upper extremity such as in tennis elbow or in tendinopathies at the wrist level"

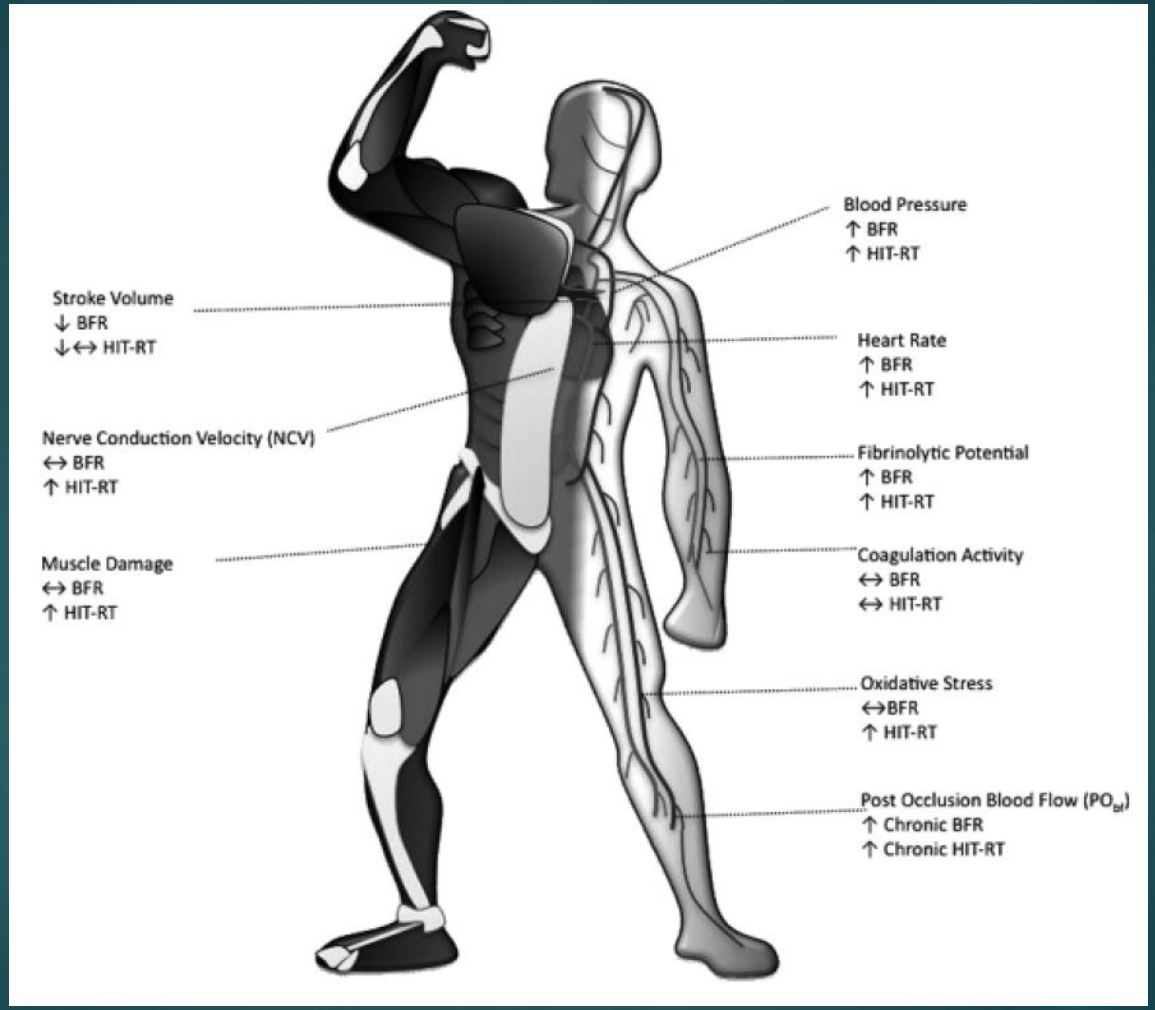
- "Inhibition of angiogenesis is necessary for the development and maintenance of hypo- or avascular tissues."

Effects of Low-Load Resistance Training With Vascular Occlusion on the Mechanical Properties of Muscle and Tendon

- "The Lower Limb Occlusion protocol did not alter the stiffness of tendon-aponeurosis complex in knee extensors, while the High Load protocol increased it significantly. The present study demonstrated that the specific tension and tendon properties were found to remain following low-load resistance training with vascular occlusion, whereas they increased significantly after high-load training
- Importance of combining LLO with traditional resistance training to strengthen tendons to avoid tendinous injuries.

Safety

- Blood flow changes post exercise were comparable to normal resistance training. (11)
- Central cardiovascular effects appear to be comparable to traditional HI-RT, but more research is needed to study long term effects. (11)
- No significant increase in blood coagulation compared to traditional resistance training. (11)
- No injuries or complications with older adult population (12)
- Precautions and contraindications
  - No more than 160 mmHg for arms, and 240 mmHg for legs to avoid occlusion. (10)
  - DVT
  - Fluid shifts (dialysis)
  - Fracture
  - Severe orthostatic hypotension
  - Pregnancy
  - Any pressure disorders (glaucoma, increased ICP, etc.)


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

Current and Future Applications

- Physical Therapy
  - Safe alternative for those who cannot perform traditional resistance training to jumpstart muscle hypertrophy
  - Conditions
    - Post-op ACL
    - Chronic Ankle instability
    - Ankle fx
    - Patellofemoral Disorders/Poor patellar tracking due to quad weakness

Blood Flow Restriction and Concussion

- Hypothesis
  - Subjects performing HIIT with blood flow restriction and cooling will realize greater objective improvements in symptoms compared to subjects training at the same frequency and intensity but without blood flow restriction.
- Variables
  - Control group: HITT on Nustep with no BFR
  - Intervention group: HITT on Nustep with BFR and cooling
- Rationale
  - Blood flow restriction training causes an increased release of growth hormone and other self produced anabolic hormones, which helps facilitate the strengthening of the musculature that supports the head and neck and thereby improve cerebral perfusion.
  - BFR training may also cause a decrease in cortisol which can help normalize sleep.

Summary

- Low intensity blood flow restriction training is more effective than low intensity resistance training alone.
- Traditional high intensity resistance training is still the most effective way to create strength gains, but not all patients are capable of this type of training.
- Blood flow restriction training is safe as long as it is performed within specific parameters and there are no contraindications.

Questions?

References

1. History of KAATSU: The Moment of Discovery. KAATSU Training Website. https://www.kaatsu-global.com/history-of-kaatsu/. Accessed 11/26/17.
2. Patterson SD, Ferguson RA. Increase in calf post-occlusive blood flow and strength following short-term resistance exercise training with blood flow restriction in young women. *Eur J Appl Physiol.* 2010; 108: 1025-1033.
3. Loenneke JP, Wilson JM, Marín PJ, Zourdos MC, Bemben MG. Low intensity blood flow restriction training: a meta-analysis. *Eur J Appl Physiol.* 2011. DOI: 10.1007/s00421-011-2167-x
4. The Science of Vasper. Vasper Website. https://static1.squarespace.com/static/557db6cbe4b02f16630eb0c1/t/59e7bfccd74cffd56e0dee92/1508360157741/ScienceOfVasper_V03.pdf . Accessed 11/26/17.
5. Takarada Y, Nakamura Y, Aruga S, Onda T, Miyazaki S, Ishii N. Rapid increase in plasma growth hormone after low-intensity resistance exercise with vascular occlusion.
6. Moritani T, Sherman WM, Shibata M, Matsumoto T, Shinohara M. Oxygen availability and motor unit activity in humans. *Eur J Appl Physiol*. 1992; 64: 552-556.
7. Takarada Y, Takasawa H, Ishii N. Application of vascular occlusion diminish disuse atrophy of knee extensor muscles. Med Sci Sports Exerc 2000; 32: 2035-2039.
8. Fujita S, Abe T, Frummond MJ, Cadenas, JG, Dreyer HC, Sato Y, Volpi E, Rasussen BB. Blood flow restriction during low-intensity resistance exercise increases S6K1 phosphorylation and muscle protein synthesis J Appl Physiol 2007: 103:903-910
9. McPherron AC Lee SJ. Double muscling in cattle due to mutations in the myostatin gene. Proc Natl Acad Sci USA 1997; 94: 12457- 12461.
10. Yasuda T, Ogasawara R, Sakamaki M, Ozaki H, Sato Y, Abe T. Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. *Eur J Appl Physiol* (2011) 111:2525–2533.
11. Boesen et al. Effect of growth hormone on aging connective tissue in muscle and tendon: gene expression, morphology, and function following immobilization and rehabilitation. J Appl Physiol. 2014 Jan 15;116(2):192-203.
12. Loenneke JP, Wilson JM, Wilson GJ, Pujol TJ, Bemben MG. Potential safety issues with blood flow restriction training. *Scand J Med Sci Sports.* 2011
13. Patterson SD, Ferguson RA. Enhancing Strength and Postocclusive Calf Blood Flow in Older People With Training With Blood-Flow Restriction. *Journal of Aging and Physical Activity.* 2011; 19: 201-213.