[VIEWPOINT]

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Blood Flow Restriction Training in Rehabilitation: A Useful Adjunct or Lucy's Latest Trick?

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In the American cartoonist Charles M. Schulz's comic series *Peanuts*, Lucy first pulled the ball away from Charlie Brown in 1951. Then she continued to torture him for the next 48 years, using variations on the theme. As a physical therapist of a certain age, every time I hear of some new approach promising more for less, I become Charlie Brown: "This has never worked in the past, so why should I believe it will this time? But wouldn't it be great if it were true?" Ever the optimist, my eternally misguided enthusiasm leaves me lying on my back, embarrassed, and vowing, "They won't fool me next time."

Then along comes an intervention claiming that some low-intensity exercise performed while wearing a blood pressure cuff will result in strength gains, improved performance, shorter postexercise recovery, and maybe even pain reduction. "Good grief," indeed. Or will it work this time?

Blood Flow Restriction Training: Early Origins

In the 1960s, scientists noticed improved walking tolerance in people with intermittent claudication after a physical training program.[29] The changes were not explained by increased collateral circulation. Perhaps alternate mechanisms were in play (other than improved blood flow), somehow enhancing muscle function?[11]

This much was the result of scientific investigation. Now we enter the realm of retrospective self-report from an individual whose business depended on the results—your "Spidey-sense" should already be tingling.

Coincidentally and independently, a Japanese high school student noticed that after a period of sustained sitting while attending a religious ceremony, he experienced a feeling of discomfort and swelling similar to that experienced after performing "strenuous calf-raise exercises."[48] For the next 5 years, he self-experimented with variations of occlusion and exercise during weight training. This period included a stint in hospital after a pulmonary embolism induced by self-described reckless tourniquet application.

Later, after opening his own fitness club, the Japanese now former high school student was injured while skiing. He reported that he had fractured both ankles and injured "cartilage and the medial ligament" of his knee. He refused the recommended surgery and hospitalization because of the demands of his business. Instead, he opted for occlusion training combined with isometrics of his casted limb for 2 months. He claimed he had hypertrophy, rather than atrophy, of his casted leg and good functional outcomes.[48] Commercial application of his approach over the ensuing decade saw growing popularity, along with patent applications for equipment and techniques in a number of countries, and "certifications" for practitioners adding to the business model.

By now, the alarm bells should be deafening to those looking for a science-based intervention, free of commercial influence.

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Usually, the story would end here. However, some independent research gives us pause for thought.

Hypertrophy Through Low Load: Plausible Evidence of a Floor Effect

An otherwise healthy, relatively untrained adult can expect muscle hypertrophy with loads as low as 15% to 30% of the 1-repetition maximum when performing exercises to volitional failure (exercise to fatigue),[5,13] although the effects of hypertrophy are more consistently achieved with higher loads and lower repetitions, especially when matching total work (eg, 70% of 1-repetition maximum).[2,13,46]

The patient in pain may present a conundrum: you may not be able to prescribe sufficiently high absolute load to ensure hypertrophy. If you conclude the pain is caused by inadequate muscle strength, then the conundrum is difficult to resolve and might even be intractable. You might also face a similar challenge where strengthening is indicated but loading the joint is not (eg, post surgery or resolving osteochondral defects).

"I really want to start strengthening as soon as possible. Do I really have to wait until the pain settles down? What if pain prevents the patient from loading? What if the pain doesn't settle down?"

Hypertrophy Is Possible With Low Loads and High Repetitions: Enter Blood Flow Restriction Training

Low-load resistance training with the addition of blood flow restriction can achieve equivalent hypertrophy to that of high-load resistance training.[6,17,34] Plausible mechanisms of action, each with some evidence in humans, include locally induced swelling in the muscle cells, improved local neural function (increased fiber recruitment), improved central neural function (increased cortical motor excitability), and increased muscle protein synthesis.[10,19,28]

Blood flow restriction training may also have additional hypertrophy benefits in muscles not directly affected by the blood flow restriction. Measurable improvements in the pectorals (bench press) and gluteus maximus (squatting) are possible with blood flow restriction to the upper[54,55] and lower[1] limbs, respectively. Increased recruitment of the more proximal synergists late in the set, when the occluded muscles are failing, is the most likely mechanism.[12]

Effects on muscle strength are lower with low-load resistance training combined with blood flow restriction than with heavy resistance training, despite similar objective muscle mass gains.[17] This might be due to enhanced fiber recruitment in heavy resistance training.[19] Early research in this area used arbitrary training occlusion pressures for all participants, typically not accounting for exercise position or individual variability.

Limb occlusion pressure will vary depending on the girth of the limb,[33] the cuff used,[40] and body position[16] (eg, lying compared to sitting or standing).[50,52] Limb occlusion pressure is different for different individuals, and even the same individual at different times of the day[18,21,25] (eg, morning versus afternoon, before or after recent exercise or coffee consumption).

Measuring and Adjusting Occlusion Pressure

Failing to individualize limb occlusion pressure might explain inferior strength gains compared with standard heavy resistance training.[16] However, while this is biologically plausible, research in this area is sparse. Cuff width is an important determinant of limb occlusion pressure, and the wider the cuff, the lower the required pressure to occlude the limb.[49] A wider cuff also has the benefit of less local discomfort[24,37] and lower chance of bruising.[38,39]

Clinicians should individually tailor occlusion pressure for safety and best outcomes.[16,32] They should measure limb occlusion pressure in the position in which the exercise will be performed and conduct the exercise as a percentage of this pressure. In the lower limb, 40% to 80% of limb occlusion pressure is effective.[32] Higher occlusion pressure might be desirable, although it is associated with more local discomfort. In the upper limb, lower occlusion pressures (up to 60% of occlusion pressure) can achieve similar results.

Measure limb occlusion pressure by auscultating distal arteries or with a relatively inexpensive handheld Doppler probe, which are valid compared to Doppler ultrasound.[30] More expensive commercially available systems allow for automatic measurement and application of a prescribed limb occlusion pressure, and can be adjusted during the exercise.[39,56]

Blood Flow Restriction Training's Performance and Recovery Enhancement Cousin: Ischemic Preconditioning

In a likely apocryphal story, native South Americans applied tourniquets to their legs immediately before important long-distance runs for performance enhancement.[36] In experiments in the middle of the 20th century, there was a dose-response relationship between measures such as time to exhaustion and the duration and intensity of application of a tourniquet to completely occlude limb perfusion prior to exercise.[41,44] A flurry of investigation followed, which failed to replicate these findings. This field lay fallow for years.[36]

In the mid 1980s, animal experiments documented reductions in cardiac infarction following bouts of ischemic preconditioning.[14,42] Meaningful, albeit conflicting and objectively small, improvements in sporting performance after local (eg, leg during leg exercise) and remote (eg, arm during leg exercise) ischemic preconditioning[20,36,47] prior to cycling,[14] swimming,[23] and running[3] may be possible. Modest gains are acquired with cycles of 3 or 4 bouts of 5 minutes of occlusion and 5 minutes of reperfusion performed a few hours prior to the event.[9,31,47] There is less research examining any benefit of ischemia as an intervention to improve recovery post exercise, and the results are mixed at best.[4]

Routine postexercise application of 3 or 4 bouts of 5-minute occlusion/reperfusion (30-40 minutes in total)[45] is likely not feasible in a team setting. The time can probably be better spent, even with compliant athletes and available equipment.

But Wait, There's More! Have I Told You About Pain Relief?

Researchers noticed that patients with anterior knee pain that was present during single-leg squatting (a reassessment sign often used in people with this condition) had substantially reduced pain immediately after a session of low-load resistance training with the addition of blood flow restriction. Further, this benefit was retained for the duration of their session.[26] There may be a pain-reducing effect in excess of that seen through matched placebo-controlled exercise.[15,27] However, this research is preliminary and must be replicated before one can confidently conclude that it is a true effect.

It Can't All Be Sunshine and Daisies? What's the Risk?

"Reckless" tourniquet application is associated with potentially disastrous side effects, embolism being chief among them.[48] No one should die as a result of strength training. With appropriate patient screening and sensible individualized application, there are remarkably few reported side effects of blood flow restriction training.[17,35,49]

Anecdotally, blood flow restriction training is very common.[53] Likely, many tens of thousands of patients have participated in blood flow restriction training, yet there are very few reports of serious adverse events when precautions have been followed.[8,35,43,51,53] Local discomfort during the exercise (almost ubiquitous) and bruising (unusual, but not rare)[43] are the main adverse effects, although adverse events have been poorly reported.[17]

Far less common, but potentially very serious, are vascular problems. A medical history of vascular compromise or risk of embolism is an absolute contraindication to blood flow restriction training. Three reported cases of rhabdomyolysis[7,22,51] suggest that compromised renal function should be a contraindication.[57] Patients should always be monitored following exercise for excessive muscle soreness.[7]

TABLE — Suggested Clinical Reasoning for the Application of Low-Load Blood Flow Restriction Training*

Parameters	• Description
Indications	• Hypertrophy required and heavy resistance training not clinically indicated
Contraindications	• Vascular compromise, clotting disorders or other elevated risk of embolism, renal compromise, hypertension (systolic blood pressure of 140 mmHg or greater)
Warnings	• Bruising is relatively common (in the upper limb especially). The exercise is very uncomfortable
Applications	• Measure limb occlusion pressure in the body position in which the exercise will be undertaken • Set training pressure (40% to 80% of limb occlusion pressure for leg, 30% to 60% for upper limb). Note that higher pressures are associated with more discomfort but likely superior clinical outcomes • First set: aim for voluntary failure at 30 repetitions at a rate of approximately 1 repetition every 2 to 4 seconds • Second to fourth sets: same weight as first set, 15 repetitions, 30 seconds of recovery between sets. Adjust weight up or down depending on performance in first set: harder if failure wasn't achieved, easier if patient could not reach 30 repetitions • Initially, alternate days; training can ultimately be performed twice daily • Expect to see meaningful results after at least 4 weeks of training • When clinically appropriate, shift to regular resistance training

**The contraindications and warnings are those peculiar to blood flow restriction training, and are in addition to usual care and precautions taken when prescribing resistance training. The exercise parameters suggested are based on the most frequently reported regimens.[17]*

Good Grief, Charlie Brown! Maybe It Is the Miracle We've Been Promised All This Time?

Well, maybe, partially. There are similar muscle mass gains with low-load resistance training plus individually tailored blood flow restriction compared to a similar period of high-intensity strength training. Apply up to 80% of limb occlusion pressure, and prescribe about 75 repetitions in total. Aim for fatigue failure after the first 30 repetitions, followed by 3 more sets of 15 repetitions at the same load (likely around 15% to 30% of 1-repetition maximum). Exercises can be performed on alternate days, and, after a while, even twice daily. Expect hypertrophy changes after at least 4 weeks, but probably closer to 8 weeks (**TABLE**).

Progression to heavy-load resistance training should continue to be your goal—blood flow restriction training is only an interim step. There is less compelling evidence that you can be confident of performance, postexercise recovery, and pain improvements, although this is an area to watch.

It took more than 30 years in practice, but we eventually got a clinical "cheat" that at least works for some select patients. Will there be another one in my lifetime? I seriously doubt it, but I'll try to keep an open mind, if not an empty head.

Key Points

- In patients who cannot tolerate high loads, blood flow restriction training using low loads is associated with similar hypertrophy effects to those of conventional high-load training.
- Training pressures need to be at least 40% of limb occlusion pressure, and can be up to 80% (lower in the arm than in the leg).
- Wider cuffs require lower pressures to occlude and are better tolerated.
- Safe application requires attention to contraindications and tailoring of the pressure to the individual patient, the exercise, and the cuff. ◉

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