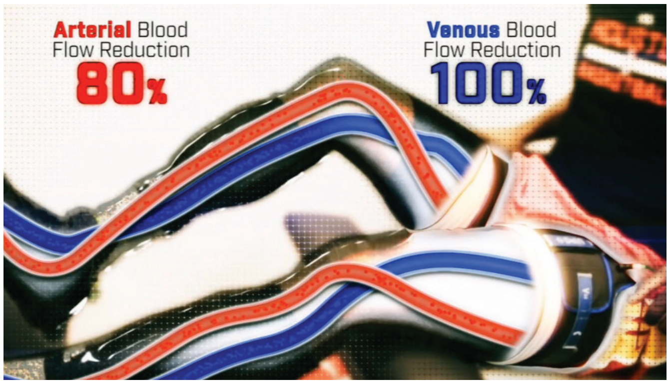
PERSONALIZED BLOOD FLOW RESTRICTION REHABILITATION

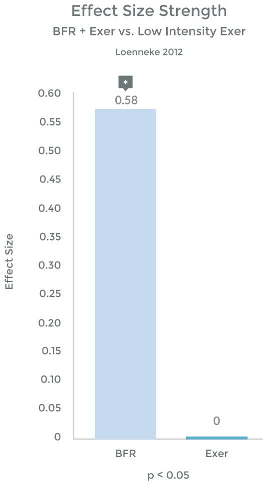
WHAT IS PERSONALIZED BLOOD FLOW RESTRICTION REHABILITATION?

Traditional resistance training guidelines recommend that individuals lift loads greater than 65% of a 1-repetition maximum (1-RM) over a period of 12-16 weeks to obtain strength and hypertrophy gains. (Kraemer et al 2002) Unfortunately, persons recovering from surgery or injury, athletes in a competitive season and the elderly may not be candidates for higher load training. Recently, Personalized Blood Flow Restriction (PBFR) training has become a novel training method for these individuals to obtain similar gains as high intensity training (HIT) utilizing significantly lower loads. BFR utilizes a specialized tourniquet system to reduce vascular inflow and completely occlude venous outflow in the limb. **(Fig. 1)**



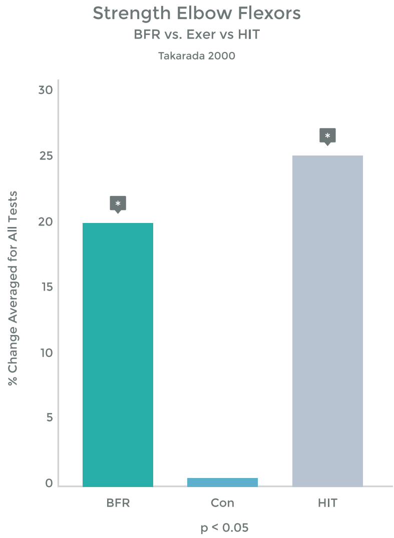
(Fig. 1) Photo credit ESPN Outside the Lines

Through this, individuals create a hypoxic environment within the target muscle group, which allows exercising at light loads that creates a significant strength and hypertrophy effect. The improvements seen with BFR training compared to work matched controls have been well documented within the literature. For instance, a recent meta-analysis comparing the effect size (ES) for strength changes between subjects performing BFR under low load demonstrated a 0.58 ES for the BFR studies compared to a 0.00 ES for the low load-training group. **(Fig.2)**



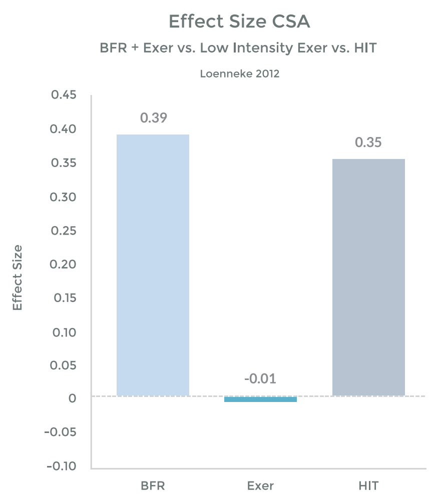
(Fig. 2) Loenneke et al 2012

When comparing low load training, low load training with BFR and HIT for the elbow flexors, only the BFR and HIT groups demonstrated a significant change in strength. **(Fig.3)**



(Fig. 3) Takarada et al 2000

Furthermore, hypertrophy changes are significantly elevated when performing low load training under BFR compared to normoxic low load training. Comparing the ES for hypertrophy between BFR to low load and HIT reveals similar ES only for the BFR and HIT group. **(Fig. 4)**

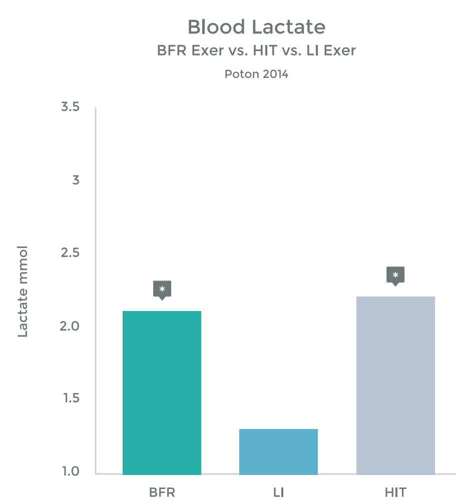


(Fig. 4) Loenneke et al 2012

From this, it appears that to gain strength and hypertrophy when lifting under low loads one would need to consider BFR to obtain a significant effect. A biopsy study in the Journal of Physiology found that the fiber size of both slow twitch and fast twitch fibers increased significantly after 3 weeks of PBFR training (31% and 32% respectively) while the low level exercise without PBFR had no significant change. (Nielson 2012) This may be due to the fact that muscle fibers are activated to significantly higher levels when performing PBFR vs work matched controls. (Yasuda 2014, Fatela 2016) A recent systematic review and meta-analysis concluded "research suggests that low load resistance exercise (20-30% 1RM) and low load aerobic exercise would not be expected to cause considerable increases in muscular quantity or quality under normal circumstances, however when combined with BFR produced an exaggerated response for maximizing muscle strength and hypertrophy" (Slysz et al 2015) A clinical systematic review and meta-analysis conducted in the UK found that BFR had a significantly higher effect size for strength compared to low load exercises and concluded "BFR training can provide a more effective approach to low-load and more tolerable approach to heavy-load rehabilitation". (Hughes 2017)

WHAT IS THE SCIENCE BEHIND IT?

Although the exact mechanism behind BFR training is still not fully understood, several potential mechanisms have been put forward. One prevailing hypothesis is the recruitment of larger fast twitch motor units secondary to the hypoxic state created by the tourniquet. To support this, several papers have demonstrated higher iEMG signal output when performing exercise under vascular occlusion compared to low load training. (Yasuda et al 2009, Wilson et al 2013) As muscle utilizes the anaerobic pathway during resistance training, the metabolic accumulation within the muscle may be a trigger for hypertrophic changes. (Schoenfeld 2013) This can be seen when comparing the accumulation of substances such as lactate in BFR vs low load training. In the BFR group, there is a significant rise in lactate which is a byproduct of anaerobic metabolism and the levels of metabolic stress measured via lactate is similar between BFR and HIT training. **(Fig. 5)**



(Fig. 5) Poton et al 2014

The systemic response from this metabolite accumulation with BFR training includes significant increases in substances such as Growth Hormone (Takarada et al 2000, Pierce et al 2006), Insulin Like Growth Factor,(Abe et al 2005) Myogenic Stem Cells (Nielson et al 2012) and down regulation of substances such as Myostatin. (Laurentino et al 2012)

Additionally, the muscle pump effect seen after BFR training may also play a role in the hypertrophy gains seen. BFR training produces muscle swelling and a plasma volume fluid shift. (Loenneke 2012) This muscle swelling appears to play a role in augmenting muscle size by activation of the protein synthesis pathway via MTORC1. (Schliess et al 2006) In studies that have compared the application of a tourniquet without the addition of exercise, simply causing muscle swelling via the tourniquet, have demonstrated the ability to mitigate atrophy compared to controls. The cellular swelling induced by the tourniquet in the absence of exercise was enough of a signal to induce muscle protein synthesis and has been demonstrated in healthy subjects as well as after anterior cruciate ligament repair. (Kubota et al 2008, Takarada et al 2000)

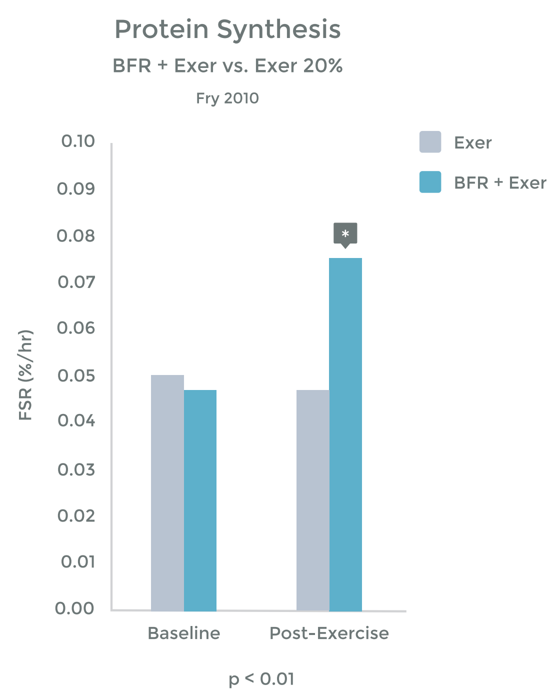
WHY IS IT GOOD FOR REHABBING INJURED ATHLETES?

Rehabilitation strength programs are low load in nature secondary to the constraints placed on the athlete after injury or surgery. The ability to obtain strength and hypertrophy gains while doing low load exercise through the application of BFR make it a very appealing treatment method for the rehabilitation professional. A potentially valuable use of BFR is the ability to combat anabolic resistance within the injured limb during the early phases of injury or after surgery.

Anabolic resistance is defined as the condition in which a limb in a period of disuse, such as after surgery or injury, reduces protein synthesis specifically within that limb. (Glover et al 2008) During this period of disuse, local protein synthesis within the limb has been noted to decrease by approximately 30%, which correlates to a 350-gram loss of muscle tissue and a 30% decline in muscle strength. (Wall et al 2013) Exercising at low load seems to have a minimal impact on protein synthesis, however when combined with BFR there appears to be an augmented protein synthesis response. For instance, Fujita et al demonstrated a 46% rise in protein synthesis 3 hours post training with BFR at low loads. A work matched control group without occlusion demonstrated no change. **(Fig. 6)**

(Fig. 6) Fujita et al 2007

Similarly, Fry et al demonstrated a significant rise in muscle protein synthesis (56%) at 3 hours post training only in the BFR group. **(Fig. 7)**



(Fig. 7) Fry et al 2010

This has been demonstrated in clinical studies comparing low load exercise to the same exercises utilizing BFR. The application of BFR for 2-weeks after ACL surgery reduced atrophy in the quadriceps by greater than half (loss of 20.7% cross sectional area in control compared to 9.4% with BFR) on repeat MRI imaging. (Takarada 2012) A second ACL study examining the effects of BFR compared to standard of care from 2-weeks until 16 weeks found that the BFR group were able to restore quadriceps strength to 91% of the pre-operative level compared to only 64% in the standard of care group. Additionally, post intervention imaging demonstrated a return of quadriceps to 101% of the pre-operative size compared to a loss of 8% in the standard of care group. (Ohta 2003) A DOD retrospective study analyzing the increase in quadriceps strength in trauma patients who had residual weakness after extensive rehabilitation revealed an increase of 42%-81% after 2-weeks of BFR. (Hylden 2015) A second DOD study compared BFR to low load exercise after arthroscopic knee surgery. The BFR group demonstrated significant improvement in strength, hypertrophy and self-reported measures. (Tennent 2017)

In essence, low load exercise combined with BFR may be a tool to combat one of the most problematic conditions occurring in rehabilitation, the loss of muscle in the injured limb during the quiescent period after injury. The rehabilitation professional may be able to manipulate the athlete's protein synthesis into a positive state after injury via BFR.

Pain is also a consistent problem during rehabilitation of patients after injury. Unfortunately, the acute pain many patients endure during rehabilitation may hamper their ability to have sustained relief from pain after rehabilitation. The reduction in pain acutely after a patient performs BFR is one of the most common clinical reports. Researchers at the Aspetar Sports Medicine Center explored this phenomenon when they asked patients with anterior knee pain to perform quadriceps low-level exercise with or without BFR. Immediately after the session, pain provoking tests such as single leg squats, step-downs, and squats were performed. The BFR cohort experienced significantly less pain in all re-testing compared to the standard of care group and the analgesic effects were still sustained at re-testing 45 minutes later. (Korakakis 2017) Researches in Australia repeated the study on anterior knee pain but this time compared low level BFR to heavy resistance quadriceps exercises. After 6 weeks the BFR group experienced a 93% greater reduction in pain with daily activities compared to the heavy lifting group and a 49% greater improvement in knee strength. (Giles 2017)

WHAT ARE SOME OF THE SAFETY CONCERNS PEOPLE HAVE ABOUT BFR TRAINING? HOW DO YOU MITIGATE THEM?

The use of PBFR is widely reported in the literature, and numerous studies have been performed with no reported complications. A recent publication surveyed institutions in Japan that use blood flow restriction training in order to report any observed side effects. Based on the reported side effects in a clinic or rehabilitation setting, the most common risk is temporary bruising at the site of the tourniquet (13%). Transient numbness of the extremity with the tourniquet after cessation of inflation occurred in 1.2% of the population. A dull pain or discomfort due to the tourniquet has also been reported in up to 9% of patients. Other rare side effects, which were all experienced less than 1% of the time, include lightheadedness, a temporary cold feeling of the extremity, venous thrombus, and pulmonary embolism. (Nakajima et al 2006, Ohta 2003)

Tourniquets are medical devices and fall under FDA Class I regulations. In controlled clinical environments clinicians should adhere to published tourniquet safety guidelines to avoid potential injury. One injury concern is the potential for nerve damage under the tourniquet cuff. Utilizing wider cuffs with a variable contoured fit increases the surface area and significantly reduces pressure gradients. The use of cuffs such as these has been demonstrated to significantly reduce potential skin or nerve injury. (Olivercrona et al 2012, Graham et al 1993)

Additionally, the use of 3rd generation tourniquet systems that utilize advanced safety features such as limb occlusion pressure personalized to each athlete can further help minimize complications. (Noordin et al 2009) Previous studies in the literature have shown no increased risk of thrombosis or vascular injury with BFR therapy when compared to other exercise and rehabilitation regimens. Studies measuring clotting factors have not found any increase after BFR. (Madarame et al 2010, Clark et al 2011) Furthermore, fibrinolytic (anti-clotting) factors such as TPA antigen has been demonstrated to increase after tourniquet use and after BFR exercise. (Takano et al 2005, Noordin et al 2009) In totality, BFR appears to be a safe treatment as long as it is performed properly and the clinician is mindful of the safety factors involved with tourniquet use and application. An important factor for clinicians to consider is that the FDA determines full or partial occlusion of blood flow in a patient require the use of a listed medical device. Currently, there is only one BFR system that is device listed with the FDA, the Delfi PTS for BFR. Furthermore, the lowest occlusion pressure to have an effect is the desired outcome of all BFR clinical applications. By using a wider tapered tourniquet cuff, desired occlusion pressures can be obtained at much lower levels than more narrow non-tapered designs. The amount of occlusion needed for each patient varies based on the patients systolic blood pressure, limb circumference, limb density, cuff width and cuff location. Currently there is no formula to determine individual limb occlusion pressure and the use of a Doppler system is the gold standard. The Delfi PTS for BFR includes a built in Doppler system allowing the clinician to provide a personalized blood flow restriction occlusion to each patient.

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