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Blood Flow Restriction Training in Tendinopathy Rehabilitation: An Underutilised Alternative to Traditional Heavy-load Resistance Training for Enhancing Outcomes

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ABSTRACT

Tendinopathy is a chronic tendon disease which can cause significant pain and functional limitations for individuals and collectively places a tremendous burden on society. Resistance training has long been considered the treatment of choice in the rehabilitation of chronic tendinopathies, with both eccentric and heavy slow resistance training demonstrating positive clinical effects. The application of progressive tendon loads during rehabilitation is essential to not compromise tendon healing, with the precise dosage parameters of resistance training and external loading a critical consideration. Blood-flow restriction training (BFRT) has become an increasingly popular method of resistance training in recent years and has been shown to be an effective method for enhancing muscle strength and hypertrophy in healthy populations and in musculoskeletal rehabilitation. Traditional resistance training for tendinopathy requires the application of heavy training loads, whereas BFRT utilises significantly lower loads and training intensities, which may be more appropriate for certain clinical populations. Despite evidence confirming the positive muscular adaptations derived from BFRT and the clinical benefits found for other musculoskeletal conditions, BFRT has received a dearth of attention in tendon rehabilitation. Therefore, the purpose of this narrative review was threefold: firstly, to give an overview and analysis of the mechanisms and outcomes of BFRT in both healthy populations and in musculoskeletal rehabilitation. Secondly, to give an overview of the evidence to date on the effects of BFRT on healthy tendon properties and clinical outcomes when applied to tendon pathology. Finally, a discussion on the clinical utility of BFRT and its potential applications within tendinopathy rehabilitation, including as a compliment to traditional heavy-load training, will be presented.

Introduction

Blood-flow restriction training (BFRT), which may also be referred to as Kaatsu, occlusion or hypoxic training, has become an increasingly popular method of resistance training in recent years (Patterson et al., 2019). BFRT involves the application of straps or pneumatic cuffs around an upper or lower limb extremity, with cuff pressure aiming to partially restrict arterial blood flow, while also occluding venous outflow while the cuff pressure remains intact (Lorenz et al., 2021; Hughes et al., 2018). BFRT has been shown to be an effective resistance training method for enhancing muscle strength and hypertrophy in healthy populations and in the rehabilitation of musculoskeletal pathologies and following orthopaedic surgery (Barber-Westin et al., 2019; Hughes et al., 2017; Nitzsche et al., 2021; Lowery et al., 2014). Traditional resistance training requires the application of heavy training loads and intensity of 70-100% of 1 repetition maximum (1-RM), whereas low-load BFRT (LL-BFRT) utilises significantly lower loads and training intensities of between 20-40% of 1-RM, which may be more appropriate for some clinical populations unable to train with heavy resistance (Krzysztofik et al., 2019; Kataoka et al., 2022; Hill et al., 2020; Centner et al., 2019; Shiromaru et al., 2019). A plethora of physiological benefits induced by BFRT have been highlighted, included beneficial adaptations to the musculoskeletal, cardiovascular, and endocrine systems with psychosocial benefits also reported such as mood and performance improvement (Miller et al., 2021; Karabulut et al., 2021; Karabulut et al., 2013; Neto et al., 2016; Silva et al., 2018; da Silva et al., 2019; Okita et al., 2019; Bowman et al., 2019; Freitas et al., 2021).

Tendinopathy is a chronic tendon pathology which can cause significant pain and functional limitations for individuals, and which collectively places a tremendous burden on society and healthcare systems (Dean et al., 2017; Hopkins et al., 2016). In tendinopathy, morphological changes in tendons are seen with ultrasonography, including increased tendon thickness, neovascularization, collagen disruption, and fibril disorganization, resulting from repetitive tendon microtrauma (Magnusson et al., 2019; Millar et al., 2021). Athletes typically experience higher tendinopathy prevalence and incidence due to repetitive jumping, landing, running and change of direction movements (Zwerver, Bredeweg, and van den Akker-Scheek, 2011). Collectively, tendinopathies have been shown to represent up to 30% of all musculoskeletal conditions requiring primary care intervention, with lower limb tendinopathies such as Achilles and patellar tendinopathy occurring frequently in recreational and elite athletes (Canosa-Carro et al., 2022; Skjong et al., 2012; Lian et al., 2005). Resistance training has been regarded as the treatment of choice in the rehabilitation of chronic tendinopathies in recent years, with both eccentric and heavy slow resistance training (HSRT) demonstrating positive clinical effects, with improvements in pain, function, and tendon structure (Beyer et al., 2015; Kongsgaard et al., 2009). The application of progressive tendon loads during rehabilitation is considered essential to avoid compromising the tendon healing process, with the exercise dosage parameters of resistance training considered critical for optimal tendon response (Bohm et al., 2015). Training parameters such as high time under tension with traditional heavy loads during the early tendinopathy rehabilitation could compromise tendon healing and may be considered counterproductive (Couppe et al., 2015; Loenneke et al., 2012). Whilst traditional eccentric or HSRT in tendinopathy utilises heavy loads of up to 70% of 1-RM, BFRT is typically prescribed with lower intensity and loads in the range of 20-40% of 1RM, which may be more tolerable for those patients not able to tolerate high training loads, while still preventing muscle atrophy and promoting hypertrophy and strength increases (Krzysztofik et al., 2019; Kataoka et al., 2022; Hill et al., 2020; Centner et al., 2019; Shiromaru et al., 2019). Interventional studies have found superior or similar clinical outcomes with LL-BFRT compared to conventional high-load resistance training (HL-RT) for various other musculoskeletal disorders such as osteoarthritis (Hughes et al., 2017). Recent evidence suggests that LL-BFRT may be a superior method for augmenting muscular adaptations in early musculoskeletal rehabilitation, which has been found to be comparably effective for inducing muscular hypertrophy and only minimally inferior for increasing muscular strength compared to HL-RT (Lixandrao et al., 2018). The mechanisms of action of BFRT in muscular adaptation are not fully elucidated but are thought to be related to increased inflammation and metabolic stress which augments plasma growth hormone and blood lactate levels (Teixeira et al., 2018; Pearson and Hussain, 2015). Due to a paucity of research, it is unclear what effects BFRT may have on tendons, but the induced ischemic muscular milieu may facilitate adaptations in morphological and mechanical tendon properties through enhanced collagen metabolism and tendon remodelling (Klein et al., 2001; Boesen et al., 2013). Despite these potential beneficial physiological mechanisms of BFRT on tendon healing, BFRT has received a paucity of attention in tendon rehabilitation, despite the clinical benefits found for other musculoskeletal conditions and the knowledge of resistance training being the most evidence-based treatment available for tendinopathies. Therefore, the purpose of this narrative review was threefold: firstly, to give an overview and critical analysis of the mechanisms and outcomes of BFRT in both healthy populations and in musculoskeletal rehabilitation. Secondly, to give an overview of the evidence to date on the effects of BFRT on healthy tendon properties and clinical outcomes when applied to tendon pathology. Finally, a discussion on the clinical utility of BFRT and its potential applications within tendinopathy rehabilitation, including as a compliment to traditional heavy-load training will be presented.

BFRT application overview

The application of BFRT involves several key considerations, including cuff and training parameters and safety considerations. The recommended training loads for increasing strength and hypertrophy with BFRT are typically between 20-40% of 1-RM (Counts et al., 2016; Lixandrao et al., 2015). The most applied and recommend training protocol throughout the BFRT literature, is four sets of 75 (30,15,15,15) repetitions, with sets often performed to either muscular failure or to completion of the set number of repetitions (Madarame et al., 2008; Rossow et al., 2012; Loenneke et al., 2016; May et al., 2017; Loenneke et al., 2012; Fahs et al., 2015; Ogasawara et al., 2013). Despite variances existing in inter-set rest times throughout the literature, rest times are typically short, with cuff restriction maintained during rest, with common recommendations of between 30-60 seconds (Loenneke et al., 2012; Loenneke et al., 2016; Ladlow et al., 2018; Patterson et al., 2018). There have also been wide variances in training frequency reported throughout the literature, ranging from twice daily to once per week

(Scott et al., 2015; Laurentino et al., 2008; Nielsen et al., 2012; Ohta et al., 2003). However, current recommendations for a training frequency of 2-4 times per week, mirror those of traditional resistance training for strength and hypertrophy increases (Kraemer and Ratamess, 2004; Fleck; 2011, Schoenfeld et al., 2017; 2019). Despite variances in the duration of BFRT interventions, three weeks or longer is typically advocated as a prerequisite for adequate strength and hypertrophy adaptations to occur (Martin-Hernandez et al., 2013; Luebbers et al., 2014; Kang et al., 2015). Considerations of cuff application in BFRT are also important, with key variables of cuff pressure, width and material requiring attention (Abe et al., 2019; Hughes et al. 2018). Arterial occlusion pressure is the amount of pressure required to cease blood-flow within the targeted limb, which varies between individuals subject to characteristics such as body size and health status (Loenneke et al., 2012; McEwen and Hughes, 2020; de Queiros et al. 2021). There are wide variances in occlusion pressures throughout studies, with many suggesting an individualised approach should be taken to account for individual characteristics, with recommended pressures typically ranging between 40-80% arterial occlusion (Brandner et al., 2015; 2015; Loenneke et al., 2012; Kubota et al., 2011; Cook et al., 2007; Jesse et al., 2017; Jesse et al., 2018; Mattocks et al., 2017; Hunt et al., 2016). The width of BFRT cuffs is another important consideration, as cuff width will affect the pressure required to achieve arterial occlusion, with variances in size between 3-18cm common in studies (Jessee et al., 2016; Rossow et al., 2012; Mouser et al., 2017; Kacin and Strazar 2011; Ellefsen et al., 2015). Various cuff sizes are recommended and considered appropriate, provided that arterial occlusion pressure is appropriately applied, with wider cuffs requiring lower pressures (Patterson et al., 2019). BFRT cuff material can also vary, with elastic and nylon cuff materials most common in the literature (Loenneke et al., 2013). Like cuff width, cuff material is not considered to impact on BFRT outcomes, provided occlusion pressure is appropriately measured and applied (Fahs et al., 2015; Kim et al., 2017). Attention must be paid to safety considerations during BFRT, due to the modality causing multiple systemic responses, including cardiovascular, central vascular and peripheral vascular responses (Credeur et al., 2010; Staunton et al., 2015; Hunt et al., 2012; Hunt et al., 2013). Although BFRT has been shown to have a comparable safety profile to traditional resistance training in musculoskeletal rehabilitation (Minniti et al., 2019), clinicians should remain vigilant for signs of adverse responses, such as deep vein thrombosis or venous thromboembolism (Warmington et al., 2016; Raskob et al., 2014). An overview of the recommended training parameters for BFRT is presented in Table 1 (Patterson et al., 2019). A full discussion on the methodology, application, and safety of BFRT interventions is beyond the scope of this review and readers are directed to a recent position stand which comprehensively covers these considerations in BFRT (Patterson et al., 2019).

Table 1: Model of exercise prescription with BFRT (Patterson et al., 2019)

Training parameter	Guidelines
Frequency	2–3 times a week (>3 weeks) or 1–2 times per day (1–3 weeks)
Load	20–40% 1RM
Restriction time	5–10 min per exercise (reperfusion between exercises)
Type	Small and large muscle groups (arms and legs/uni or bilateral)
Sets	2–4
Cuff	5 (small), 10 or 12 (medium), 17 or 18 cm (large)
Repetitions	(75 reps) – 30 _ 15 _ 15 _ 15, or sets to failure
Pressure	40–80% AOP
Rest between sets	30–60 s
Restriction form	Continuous or intermittent
Execution speed	1–2 s (concentric and eccentric)
Execution	Until concentric failure or when planned rep scheme is completed

BFRT mechanisms

Although the exact mechanisms of effect of BFRT remain to be elucidated, several mechanisms have been theorized for the beneficial adaptations and responses elicited by BFRT, particularly in relation to increases in muscular strength and hypertrophy. The hypoxic microenvironment induced by BFRT is thought to lead to an influx and accumulation of metabolites and increased anabolic signalling and hormonal responses due to the augmented muscular fatigue and activation compared to standard training at a similar intensity (Pearson and Hussain, 2015; Rossi et al., 2018; Jessee et al., 2018). Muscular adaptations in response to BFRT may be related to increased inflammation and metabolic stress which augments plasma growth hormone and blood lactate levels (Loenneke et al., 2012; Rossi et al., 2018). The exact role played by metabolites in response to BFRT has been debated in the literature, with some suggesting that accumulation of metabolites such as lactate and hydrogen ions combined with a decrease in intramuscular pH and phosphocreatine, stimulates afferent fibres and causes neuromuscular fatigue much earlier than traditional resistance training (Rossi et al., 2018; Jessee et al., 2018; Okita et al., 2018). Several studies have found that LL-BFRT can significantly increase blood lactate levels to a higher level than controls and at a comparable level to HL-RT (de Oliveira et al., 2016; Shimizu et al., 2016; Neto et al., 2016). The increased presence of metabolites following BFRT is associated with a contemporaneous increase in growth hormone, inflammatory cytokines and myokines, further activating muscle satellite cells (Pearson and Hussain 2015; Rossi et al., 2018; Jessee et al., 2018). In response to the hypoxic environment and reduced oxygen availability, there is an increase in reactive oxygen species such as nitric oxide and a proliferation of vascular endothelial growth factor, which stimulates angiogenesis in a similar manner to traditional resistance training (Reis et al., 2019; Jessee et al., 2018). A further response to decreased oxygen availability and subsequent increase in muscular fatigue, is a decrease in force production resulting in increased motor unit recruitment (Patterson et al., 2019). Other purported endocrine system responses to BFRT which may impact on muscular adaptations include increases in free testosterone (Cook et al., 2014), serum growth hormone (Shimizu et al., 2016), insulin-like growth factor-1 (IGF-1), (Karabulut et al., 2013), growth and differentiation associated serum protein-1 (GASP-1) and changes in gene activity including decreases in myostatin mRNA gene expression (Laurentino et al., 2011; Drummond et al., 2008; Fry et al., 2010; Sieland et al., 2021). This section on mechanisms has largely focused on the potential mechanisms of action for muscular adaptations with BFRT, as the increases in muscular strength and hypertrophy are of relevance in the rehabilitation setting and may directly correlate to tendon adaptations, which are discussed in a later section. However, various other systemic and physiological systems responses have been shown with BFRT including positive effects on cardiopulmonary function (Moriggi et al., 2015), vascular stiffness and compliance (Renzi et al., 2010; Iida et al., 2011; Ozaki et al., 2016; Sugawara et al., 2015), bone function (Karabulut et al., 2011), psychological function (Lixandrao et al., 2019; Silva et al., 2018; da Silva et al., 2019; Mattocks et al., 2019), musculoskeletal function (Bowman et al., 2019), neural function (Centner et al., 2020), and anaerobic and aerobic exercise capacity (Mendonca et al., 2015; Abe et al., 2010; Tanaka et al., 2018). A full discussion of the potential mechanisms involved in BFRT are beyond the scope of this review, and readers are directed to other reviews for a more focused analysis of BFRT mechanisms (Pearson and Hussain, 2015).

BFRT general outcomes

The application of LL-BFRT has shown improvements in strength, muscle function and hypertrophy in a variety of populations, including healthy young adults, older adults, high-level athletes, and patients with various medical conditions. A systematic review which included nine studies on high level athletes only, found that LL-BFRT led to significant improvements in strength, muscle size, and markers of sports performance such as sprint, agility and jump measures compared to controls (Wortman et al., 2021). At the opposite end of the population spectrum, systematic reviews have found that LL-BFRT can increase strength and function in older and often sedentary adults compared to controls and reduce the risk of falls and musculoskeletal injuries (Baker et al., 2020; Centner et al., 2019; Lebata-Lezaun et al., 2022; Rodrigo-Mallorca et al., 2021; Gronlund et al., 2020). Most of the research on the effects of LL-BFRT have been conducted in young healthy adult populations, with similar beneficial findings as compared to older adults and those with medical conditions. A systematic review and meta-analysis including 400 healthy adult participants from 19 randomized controlled trials (RCTs) assessed the effects of BFRT on muscle strength and cross-sectional area (Slysz et al., 2016). The addition of BFRT to exercise training was found to be effective for augmenting changes in both muscle strength and size, with the effects consistent for both resistance training and aerobic training, despite the relatively short duration of most interventions (Slysz et al., 2016). An earlier meta-analysis which included 11 studies found that BFRT resulted in significantly greater increases in strength and hypertrophy when performed with resistance training rather than walking and performing LL-BFRT 2-3 days per week resulted in greater effect sizes compared to 4-5 days per week (Loenneke et al., 2012). The analysis also found significant correlations between weeks of LL-BFRT duration and strength increases but not for hypertrophy increases. More recently, a systematic review and meta-analysis including 16 RCTs, compared the effects of LL-BFRT with HL-RT on muscle strength (Gronfeldt et al., 2020). The review found that increases in strength significantly increased with both interventions, and concluded they were equally effective for producing gains in maximal voluntary muscle strength. However, another systematic review which included 13 RCTs on healthy adults, found that although both LL-BFRT and HL-RT were effective for increasing strength, HL-RT resulted in larger strength increases than LL-BFRT, although both methods were equally effective for increasing muscle mass (Lixandrao et al., 2018). The superiority of HL-RT for increasing strength remained even with adjustment for potential moderators such as prescription parameters and testing methods. However, the comparable benefits of LL-BFRT to HL-RT for muscle hypertrophy also remained when accounting for the same variables (Lixandrao et al., 2018). Despite conflicting findings when compared with HL-RT, it's clear that LL-BRT is a superior method for muscular adaptations than LL-RT. Therefore, in clinical musculoskeletal rehabilitation settings, when HL-RT may not be appropriate or contraindicated, LL-BFRT may serve as an appropriate alternative and the ideal starting point for introducing resistance training to counteract losses in muscle strength and hypertrophy.

Despite uncertainties and controversy regarding the exact mechanisms of action explaining the effects of BFRT on muscular adaptations, there is increasingly evidence that LL-BFRT can increase strength and hypertrophy of the muscles targeted with occlusion, at a comparable or only slightly inferior rate to traditional HL-RT (Bowman et al., 2019; Cook et al., 2014; May et al., 2018; Thiebaud et al., 2013), and a greater rate than LL-RT (Takrada et al., 2004; Abe et al., 2017;

Yasuda et al., 2005). Strength and hypertrophy increases with LL-BFRT have been observed to occur as quickly as 1-3 weeks, which is comparable to strength gains with HL-RT, but quicker for hypertrophy gains than with HL-RT (Nielsen et al., 2012; Yasuda et al., 2005; Fujita et al., 2008; Abe et al., 2006). Although the lower loads required with BFRT may allow for greater training frequency due to less recovery time being required, BFRT with conventional HL-RT frequency of 2-3 times per week has been shown to increase hypertrophy over 3-8 weeks of training (Ladlow et al., 2018; Manimmanakorn et al., 2013; Thiebaud et al., 2013; Libardi et al., 2015; Yasuda et al., 2016; Cook et al., 2017). Studies have assessed various outcome measures of muscle strength in response to BFRT interventions, with strength increases in isometric (Moore et al., 2004), isokinetic (Takarada et al., 2000), isotonic (Burgomaster et al., 2003), and explosive strength (Nielsen et al., 2017) being found. Increases in strength in the non-occluded upper limbs have also been reported following BFRT applied to the lower limbs bilaterally, suggesting systemic mechanisms are involved (Cook et al., 2014). When LL-BFRT is compared to LL-RT with the same dosage parameters but without blood-flow restriction, strength has been shown to increase more with the application of occlusion in both the ipsilateral and contralateral limbs (Bowman et al., 2019; Bowman et al., 2020).

BFRT musculoskeletal rehabilitation outcomes

Recent evidence suggests that LL-BFRT may be a superior method for augmenting muscular adaptations in early musculoskeletal rehabilitation, due to findings of comparably efficacy for inducing muscular hypertrophy and being only minimally inferior for increasing muscular strength compared to HL-RT (Loenneke et al., 2012; Lixandrao et al., 2018; Manini et al., 2009; Hughes et al., 2019; Abe et al., 2012; Yasuda et al., 2012; Martin-Hernandez et al., 2013). Whilst traditional resistance training utilises heavy training loads of 70% or more of 1 repetition maximum (1-RM), low intensity BFRT typically uses loads in the range of 20-40% of 1RM, which may be more tolerable for patients not able to tolerate high muscle-tendon training loads, while still preventing muscle atrophy and promoting hypertrophy (Krzysztofik et al., 2019; Kataoka et al., 2022; Hill et al., 2020;

Centner et al., 2019; Shiromaru et al., 2019). Additionally, BFRT has been shown to cause exercise-induced hypoalgesia through endogenous opioid and endocannabinoid mechanisms, so could therefore be a useful pain management tool in early musculoskeletal rehabilitation, particularly in the presence of an acute pain response (Hughes et al., 2021; 2020; 2019; Korakakis et al., 2018).

In recent years, the application of BFRT as a rehabilitation method for musculoskeletal conditions has been given increased attention within various clinical populations (Hayhurst et al. 2021). A systematic review and meta-analysis which included 20 studies on BFRT for musculoskeletal rehabilitation, found that BFRT had an overall moderate effect on increasing strength, but was less effective than HL-RT for strength gains (Hughes et al., 2017). However, compared with LL-RT, BFRT was more effective and tolerable as a treatment method (Hughes et al., 2017). Another more recent systematic review which included 10 RCTs on BFRT in lower limb musculoskeletal conditions, concluded that LL-BFRT leads to increases in muscle strength and volume, and also reduces pain at a comparable level to conventional LL-RT and HL-RT (Nitzsche et al., 2021). A recent systematic review and meta-analysis including five studies on knee osteoarthritis found that there was low to moderate quality evidence of no difference between LL-BFRT and traditional HL-RT for pain, function, strength, and muscle size increases (Grantham et al., 2021). Similarly, a systematic review and meta-analysis including 5 RCTs on patients with osteoarthritis and rheumatoid arthritis, found no difference between LL-BFRT and moderate and HL-RT on muscle strength, muscle mass and functionality measures, with LL-BFRT more effect for increasing strength than LL-RT (dos Santos et al., 2021). Another recent meta-analysis including nine studies on various knee disorders found that muscle strength increases were comparably superior for LL-BFRT, and HL-RT compared to LL-RT, with pain improvement superior for LL-BFRT compared to LL-RT and HL-RT (Li et al., 2021). Systematic reviews have also found benefit of LL-BFRT for increasing muscle strength and function in clinical patients during rehabilitation for pre- and post-operative ACL reconstruction (Charles et al., 2020; Caetano et al., 2021; Lu et al., 2020; Glattke et al., 2021; Baron et al., 2020), knee surgery (Wengle et al., 2021), osteoarthritis (Wang et al., 2022; Pitsillides et al., 2021), various knee conditions (Ferlito et al. 2020; Van Cant et al., 2020; Bobes Alvarez et al., 2020;

Barber-Westin et al., 2019; Cuyul-Vasquez et al., 2020), muscular atrophy (Cerqueira et al., 2020), sarcopenia (Beckwee et al., 2019), and elderly patients at risk for various musculoskeletal conditions (Baker et al., 2020; Centner et al., 2019; Lebata-Lezaun et al., 2022; Rodrigo-Mallorca et al., 2021; Gronlund et al., 2020). The safety of BFRT in musculoskeletal rehabilitation has also been assessed as comparable to standard exercise therapy, with a systematic review of 19 studies finding that the likelihood of adverse events is not increased with BFRT, despite suggestions of potential safety concerns (Minniti et al., 2019).

In the last few years there has been an exponential proliferation in interventional research applying LL-BFRT interventions within musculoskeletal rehabilitation settings, due to the ever-increasing indications of therapeutic efficacy. The ever-growing body of evidence includes RCT evidence of potential efficacy for a plethora of musculoskeletal conditions including, polymyositis and dermatomyositis (Mattar et al., 2014), osteoarthritis (Segal et al., 2015; Segal et al., 2015; Femandes-Bryk et al., 2016; Ferraz et al., 2018; Harper et al., 2019; Shakeel et al., 2021), pre and post-operative ACL reconstruction (Ohta et al., 2003; Iversen et al., 2016; Hughes et al., 2018; Hughes et al., 2019; Hughes et al., 2019; Curran et al., 2020; Takarada et al., 2000; Lambert et al., 2019; Kilgas et al., 2019; Zargi et al., 2018; Grapar Zargi et al., 2016), patellofemoral pain (Giles et al., 2017; Constantinou et al., 2022; Korakakis et al., 2018; Ladlow et al., 2018), post knee arthroscopy (Tennent et al., 2017), rheumatoid arthritis (Jonsson et al., 2020; Rodrigues et al., 2020), osteoporosis (Pereira Neto et al., 2018), osteopenia (Linero and Choi, 2021), and muscle atrophy (Noyes et al., 2021; Lipker et al., 2019). Many RCTs have also found benefits of BFRT in elderly populations at risk for sarcopenia and other medical and musculoskeletal disorders (Yokokawa et al., 2008; Karabulut et al., 2013; Abe et al., 2010; Karabulut et al., 2010; Patterson and Ferguson, 2011; Ozaki et al., 2011; Ozaki et al., 2011; Iida et al., 2011; Yasuda et al., 2015; Vechin et al., 2015; Libardi et al., 2015; Shimizu et al., 2016; Thiebaud et al., 2013; Clarkson et al., 2017; Fahs et al., 2015; Araujo et al., 2015; Letieri et al., 2018). Preliminary evidence from non-RCT study designs have indicated potential efficacy of LL-BFRT for ankle sprains (Krieger et al., 2018; Hylden et al., 2015), ankle fractures (Larsen et al., 2021), shoulder injuries (Lambert et al., 2021), reactive arthritis (Jorgensen et al., 2021), thoracic outlet syndrome (Noto et al., 2017), inclusion body myositis (Santos et al., 2014), knee arthroplasty (Gaunder et al., 2017), tibial fractures (Loenneke et al., 2013), meniscus repair (Mason et al., 2021), patellar instability (Brightwell et al., 2022) and spinal cord injury (Gorgey et al., 2016). The application of BFRT to general chronic medical conditions is also continuing to expand, with recent studies indicating potential efficacy for chronic conditions such as type-2 diabetes (Saatmann et al., 2021; Fini et al., 2021), chronic kidney disease and renal decline (Silva et al., 2021; Correa et al., 2021; de Deus et al. 2021), hypertension (Pinto et al., 2016), cardiovascular disease (Ogawa et al., 2021; Madarame et al., 2013), cancer (Wooten et al., 2021; Lopez-Garzon et al., 2022), and coma patients (Barbalho et al., 2019, Biazon et al. 2021).

Effects of BFRT on healthy tendons

Due to a paucity of research, it is unclear what physiological effects BFRT may have on tendons, but the induced ischemic muscular milieu with BFRT may facilitate morphological and mechanical tendon properties through enhanced collagen metabolism and tendon remodelling (Klein et al., 2001; Boesen et al., 2013). Despite these potential beneficial physiological mechanisms of BFRT on tendon healing, the method of training has received a dearth of attention in tendon rehabilitation. This is even more surprising considering the clinical benefits found for other musculoskeletal conditions and the knowledge of resistance training being the most evidence-based treatment available for tendinopathies. However, in the last few years, studies investigating the effects of BFRT on tendon properties in healthy individuals, and clinical outcomes in tendon pathology, have begun to emerge in the literature.

Several studies have investigated the effects of LL-BFRT on healthy tendons, including tendon morphological and mechanical properties (Table 1). A three-arm RCT with 55 participants, compared the effects of LL-BFRT (20-35% of 1-RM) with HL-RT (70-85% OF 1-RM) and a non-exercise control group on healthy Achilles tendon properties (Centner et al., 2019). Participants performed standing and seated resisted calf raises, three times per week for 14 weeks, at 50% occlusion pressure applied to the proximal thigh. Tendon morphological and mechanical properties were assessed by ultrasound, with the Achilles tendon adaptations comparable between both intervention groups. Both groups had significant increases in tendon stiffness and cross-sectional area (CSA), with gastrocnemius strength gains and muscle hypertrophy also comparably increased in both groups (Centner et al., 2019). Similar findings were seen in a RCT comparing LL-BFRT (20-35% of 1-RM) with HL-RT (70-85% OF 1-RM) in healthy patellar tendons (Centner et al., 2021). Participants performed standing and seated resisted calf raises, bilateral leg press and knee extension, three times per week for 14 weeks, at 50% occlusion pressure applied to the proximal thigh. Patellar tendon properties were assessed by ultrasound and magnetic resonance imaging (MRI), with substantial changes found in both groups. Like the previous study on the Achilles tendon, both groups significantly increased tendon stiffness and CSA, and had comparable increases in muscle mass and strength. The only outcome that was significantly different between groups, was that knee extension 1-RM was greater in the LL-BFRT group (Centner et al., 2021). Findings from these RCTs suggests that LL-BFRT performed over 14 weeks produce similar Achilles and patellar tendon adaptations to traditional HL-RT. However, a cohort study comparing LL-BFRT (20% of 1-RM) with HL-RT (80% of 1-RM) did not find that LL-BFRT increased vastus lateralis tendon stiffness, whereas HL-RT significantly increased tendon stiffness (Kubo et al., 2006). Participants performed resisted plantarflexion three times per week for 12 weeks, with an occlusion pressure of 37.7% on the proximal thigh. Stiffness of the vastus lateralis tendon aponeurosis was assessed by ultrasound during isometric knee extension (Kubo et al., 2006). The lack of effect of BFRT on tendon stiffness in this study could be explained by the fact that intervention exercises targeted the plantar flexors and not the vastus lateralis tendon which was assessed with ultrasound.

Studies have also compared LL-BFRT to LL-RT in healthy tendons, investigating the effects of single training sessions and longer interventions. A RCT compared a single session of LL-BFRT (30% of 1-RM) with HL-RT on healthy Achilles tendons (Chulvi-Medrano et al., 2020). Participants performed three sets of 15 repetitions with 30% occlusion pressure at the proximal thigh. Tendon thickness was assessed by ultrasound, with the LL-BFRT group having a significantly greater reduction in tendon thickness compared to standard LL-RT, immediately and 24 hours after exercise. The authors postulated that the significant difference in tendon thickness between groups may be associated with neurotendinous fluid movement in response to LL-BFRT (Chulvi-Medrano et al., 2020). Another RCT comparing LL-BFRT to LL-RT in healthy Achilles tendons over six weeks found no difference in leg stiffness with a maximal hopping test between groups, which was used to measure tendon stiffness (Gavanda et al., 2020). Although there was no change in tendon stiffness, both groups equally improved calf muscle thickness and 1-RM strength. A RCT comparing LL-BFRT (30% of 1-RM) to LL-RT in healthy supraspinatus tendons, found both groups significantly increased tendon thickness, with no significant difference between groups (Brumitt et al., 2020). Participants performed side-lying external rotation twice per week for eight weeks with 50% occlusion pressure at the proximal upper arm. Tendon thickness was assessed with ultrasound and rotator cuff strength with dynamometry, both of which equally increased in both groups. One RCT has compared a single session of LL-BFRT to LL-RT and HL-RT in healthy Achilles tendons, measuring changes in tendon thickness with ultrasound (Picon-martinez et al., 2021). Participants performed four sets and 75 total repetitions of resisted plantarflexion, with 30% occlusion pressure under the knee joint. Achilles tendon thickness was significantly reduced immediately after, 60 minutes and 24 hours post LL-BFRT, with no changes found in the other two groups (Picon-martinez et al., 2021). One cross-sectional study has assessed changes in skin temperature of the Achilles tendon, following a single session of heel raises performed with LL-BFRT (30% of 1-RM) and LL-RT (Canfer et al., 2021). An occlusion pressure of 80% was applied to the distal lower leg and thermograms used to assess tendon skin temperature. Region specific changes in tendon skin temperature were found, with greater and longer reductions at the Achilles tendon insertion following LL-BFRT, but not at the free tendon or musculotendinous junction (Canfer et al., 2021).

Table 2: Characterises of studies on BFRT in healthy tendons

Author, Study design, population	Intervention, exercises, duration	Training parameters	Outcome measures	Outcomes, results
Centner et al. 2019[65] RCT, n=55, Healthy Achilles tendon	1.LL-BFRT: standing & seated calf raises (20-35% 1RM) 2. High load RT (70-85% 1RM) 3. control, 14 weeks	Sets:3, Reps;6-12, Freq: 3 x WK, Prog: increase resistance (5% of 1rm every 4 WK, 20-35%), Int: 20-35% of 1RM. Rest: 1 MIN between sets, 3 MIN between exercises. Occlusion pressure: 50% at proximal thigh	Tendon & muscle properties (US), isometric strength (MVC - isokinetic dynamometer).	Both groups had comparable increases in tendon stiffness & CSA, gastrocnemius muscle CSA and strength. No changes in control group.
Centner et al. 2021[70] RCT, N=29, Healthy patellar tendon	1.LL-BFRT: bilateral leg press & knee extension, standing & seated calf raises (20-35% 1RM) 2. High load RT (70-85% 1RM), 14 weeks	Sets: 4, Reps: 30,15,15,15, Freq: 3 x WK, Prog: increase resistance (5% of 1rm every 4 WK, 20-35%), Int: 20-35% of 1RM. Rest: 1 MIN between sets, 3 MIN between exercises. Occlusion pressure: 50% at proximal thigh	Tendon & muscle properties (US & MRI), strength (1-RM).	Both groups had comparable increases in tendon stiffness & CSA, muscle mass & strength, knee extension 1RM was higher in BFRT group.
Chulvi-Medrano et al. 2020[66] RCT, n=56, Healthy Achilles tendon	1. LL BFRT: plantarflexion 2. LL RT, single session	Sets:3, Reps;15, Freq: single session, Prog: NR, Int: 30% of 1RM. Rest: 30 seconds between sets. Occlusion pressure: 30% at proximal thigh	Tendon thickness (US)	BFRT group had significantly greater decrease in tendon thickness compared to LL-RT, immediately and 24 hours after exercise.
Gavanda et al. 2020[68] RCT, n=21, Healthy achilles tendon	1. LL BFRT: plantarflexion 2. LL RT, 6 weeks	Sets:4, Reps; to muscular failure, Freq: 2 x WK, Prog: occlusion pressure increased every 4 WKs, Int: 30% of 1RM, Rest: 30 seconds between sets. Occlusion pressure: 60% below patella.	Calf volume, gastrocnemius muscle thickness (US), maximal hopping test for leg stiffness, 1-RM smith machine calf raise, pain (VAS)	Leg (tendon) stiffness and calf volume did not change, VAS, 1RM and muscle thickness improved equally in both groups.
Kubo 2006[72], Cohort, n=9, Healthy vastus lateralis tendon	1. LL BFRT (20% of 1RM): plantarflexion 2. HL RT (80% of 1RM), 12 weeks	Sets:4, Reps; 25, 18, 15, 12, Freq: 3 x WK, Prog: NR, Int: 20% of 1RM. Rest: 30 seconds between sets. Occlusion pressure: 37.7% at proximal thigh	knee extension torque (MVC - dynamometer) Tension of VL, calculated from MVC, & muscle volume measurement s. Stiffness of VL tendon (US) during isometric knee extension.	Both groups significantly increased MVC and muscle volume of quadriceps femoris. Specific tension of VL increased significantly 5.5% for HL, but not for LL. Tension and tendon properties were found to remain following LL BFRT, whereas they increased

				significantly after HL RT.
Picon-martinez et al. 2021[67] RCT, n=52, healthy achilles tendon	1. LL BFRT (30% 1RM): plantarflexion 2. LL RT (30% 1RM) 3. HL RT (75% 1RM), single session	Sets:4, Reps; 30, 15, 15, 15, Freq: single session, Prog NR, Int: 30% of 1RM, Rest: 30 seconds between sets. Occlusion pressure: 30% under knee joint	Achilles tendon thickness (US): immediately, 60MIN and 24 hours after training.	Achilles tendon thickness was significantly reduced immediately after, 60 min and 24 hours post-LL BFRT, unchanged in other groups.
Brumitt et al. 2020[71] RCT, n=46, healthy supraspinatus tendon	1. LL BFRT: side-lying external rotation 2. LL RT, 8 weeks	Sets:4, Reps; 30, 15, 15, 15, Freq: 2 x WK, Prog: NR, Int: 30% of 1RM. Rest: 30 seconds between sets. Occlusion pressure: 50% at proximal upper arm	Rotator cuff strength (dynamometry), supraspinatus tendon thickness (US)	BFRT did not augment rotator cuff strength gains or tendon thickness when compared to RT. Both groups significantly increased rotator cuff strength and tendon size.
Canfer et al. 2021[69] Cross sectional, n=12, healthy achilles tendon	1. LL BFRT: bodyweight SL heel raise 2. LL RT	Sets:4, Reps; 30, 15, 15, 15, Freq: single session, Prog: NR, Int: 30% of 1RM Rest: 30 seconds between sets. Occlusion pressure: 80% at distal lower leg.	Thermograms to assess Achilles tendon skin temperature (Tskin)	Region specific changes in Tskin were found, with greater and longer reductions at the Achilles insertion following BFRT.

Abbreviations: LL-BFRT: low-load blood flow restriction training, HL-RT: high load resistance training, RM: repetition maximum, Tskin: skin temperature, SL: single leg, US: ultrasound, MRI: magnetic resonance imaging, MIN: minute, NR: not reported, Int: intensity, Freq: frequency, Prog: Progression, RCT: randomised controlled trial, VL: vastus lateralis, MVC: maximum voluntary contraction, VAS: visual anologue scale, NRS-P: pain numeric rating scale, SLDS: single leg decline squat, n: number, WK: week, ROM: range of motion.

BFRT in tendon rupture rehabilitation

Like tendinopathies, partial or complete tendon ruptures are common in both the general population and athletes, with the Achilles tendon having the highest prevalence of ruptures (Holm et al., 2015). Like tendinopathy, tendon ruptures can also cause significant pain, disability and functional limitations and are associated with significant societal and healthcare costs, whether treated surgically or conservatively, with there being a lack of consensus on optimal rehabilitation methods for tendon ruptures (Nyyssonen et al., 2008). Progressive resistance training is also considered an essential element of rehabilitation following tendon rupture to counteract muscle atrophy and stimulate tendon repair, whether treated conservatively or surgically (Christensen et al., 2021). Currently only two case reports exist in the literature describing a LL-BFRT intervention applied during the rehabilitation of a tendon rupture. An intervention consisting of manual therapy, laser therapy, and resistance training including LL-BFRT forearm and elbow exercises was applied to a weightlifter following a biceps tendon rupture (Wentzell et al., 2018). Parameters of BFRT included 80mmHg occlusion pressure, and four sets (30,15,15,15 repetitions) performed daily for 14 weeks, with progressive increases in training resistance. The patient improved clinical symptoms and returned to pre-injury weightlifting activity. Another case report on rehabilitation for and Achilles tendon rupture investigated an isolated LL-BFRT (30% of 1-RM) intervention which included leg press and calf press exercises (Yow et al., 2018). Two participants performed 4 sets (30,15,15,15 repetitions) at 80% occlusion pressure at the proximal thigh. Both patients improved strength and power as assessed by isokinetic testing and returned to sports activity.

BFRT in tendinopathy rehabilitation

Only three studies have investigated LL-BFRT in patients with tendinopathy, two case reports and one case series, all with patellar tendinopathy. A case report on two collegiate decathletes with patellar tendinopathy investigated a LL-BFRT intervention with single leg press and decline squat exercises (Cuddeford et al., 2020). The two athletes performed four sets of 15-30 repetitions twice per week for 12 weeks during the competitive season with 80% occlusion pressure at the proximal lower extremity. Both patients improved clinical outcomes (pain and function), strength (leg press 1-RM) and had improvements in tendon thickness and resolution of hypoechoic tendon regions on ultrasound. Another case report investigated LL-BFRT (30% of 1-RM) in a basketball player with patellar tendinopathy (Sata et al., 2005). A variety of exercises were performed 5-6 days per week, with 3 sets of 15 repetitions and occlusion pressure of 160-180 mmHg at the proximal lower limb. The patient improved clinical outcomes and returned to playing competitive basketball. The patella tendon was assessed by MRI, which found that signal intensity was reduced following the LL-BFRT intervention, suggesting improved tendon structure. A case series which included seven patients with patellar tendinopathy, investigated a three-week LL-BFRT (30% of 1-RM) intervention including single leg press and knee extension exercises (Skovlund et al., 2020). Patients performed six sets of 5-30 (30, 25, 20, 15, 10, 5) repetitions, three times per week at an occlusion pressure of 120 mmHg, with volume progressed based on pain response. Despite the intervention being short-term, all patients improved clinical outcomes (pain and function), strength (dynamometry), and tendon vascularity (ultrasound doppler) diminished by 31% despite no changes in tendon thickness. The intervention also recorded a very high adherence rate of 98%, suggesting LL-BFRT is a feasible and effective method for patellar tendinopathy rehabilitation (Skovlund et al., 2020). Whilst it is not possible to make definitive recommendations regarding LL-BFRT interventions for use in clinical practice for tendinopathy rehabilitation, the author recommends Skovlund et al.'s protocol as a starting point due to it being the most comprehensive protocol investigated to date in tendinopathy, which not only showed clinical utility but had an extremely high adherence rate. The protocol of four sets (30,15,15,15 repetitions) is commonly recommended in the BFRT and was investigated in some of the tendon pathology case reports and RCTs on healthy tendons, so it may therefore also be recommended as an alternative protocol for clinicians to the Skovlund et al. protocol for Achilles and patellar tendinopathy.

Table 3: Characterises of studies on BFRT in tendon rupture rehabilitation

Author, Study design, population	Intervention, exercises, duration	Training parameters	Outcome measures	Outcomes, results
Wentzell 2018[63], Case report, n=1, Biceps tendon rupture	Manual therapy, laser therapy, progressive strength training including Low-load BFRT: Isometric forearm pronation & supination, elbow flexion & extension 14 weeks	Sets: 4, Reps: 30,15,15,15, Freq: 7 x WK, Prog: increase resistance (1.5-4lbs) difficulty & ROM, Int: 10-30% MVC. Occlusion pressure: 80mmHg at proximal arm.	Pain (NPRS), Function (DASH, Mayo Elbow Performance Index score.	Patient improved clinical outcomes & returned to preinjury activity (weightlifter).
Yow et al. 2018[64] Case report, n=2, Achilles tendon rupture	Low-load BFRT: Leg press, calf press, 6 weeks	Sets: 4, Reps: 30,15,15,15, Freq:NR, Prog: NR, Int: 30% of 1RM. Occlusion pressure: 80%, 180 mm Hg at proximal thigh.	Strength & power (isokinetic testing – Biodex system).	Patients improved strength & power and returned to sports.

Table 4: Characterises of studies on BFRT in tendinopathy rehabilitation

Author, Study design, population	Intervention, exercises, duration	Training parameters	Outcome measures	Outcomes, results
Skovlund et al. 2020[60] , Case series, n=7, Patellar tendinopathy	1. LL-BFRT: SL leg press, knee extension, 3 weeks	Sets: 6, Reps: 5-30, Freq: 3 x WK, Prog: increase volume based on pain response, Int: 10RM, (30% of 1RM). Maximum 105 reps per session. Occlusion pressure: 120 mm Hg at proximal thigh	Pain (NRS-P, SLDS), Function (VISA-P) Tendon vascularity (US), Knee extensor strength (MVC – static dynamometry)	Intervention was effective for improving clinical outcomes & strength. Pain with SLDS reduced by 50%. Tendon vascularity diminished by 31%. No changes in tendon thickness.
Cuddeford et al. 2020[62] Case report, n=1, Patellar tendinopathy	1. LL-BFRT: SL leg press, SLDS, 12 weeks	Sets:4, Reps15-30; Freq 2 x WK: Prog: increase resistance (10lbs Inc), Int: 15-30RM (1RM testing). Occlusion pressure: 80% at proximal lower limb	Pain (VAS), Function (VISA-P), Tendon size (US), hip & knee strength (dynamometry, SL leg press 1RM)	Patients improved clinical outcomes & strength and returned to sports activity. Improvements in tendon thickness and resolution of hypoechoic region
Sata 2005 [61], Case report, n=1, Patellar tendinopathy	1. LL-BFRT: straight leg raises, hip abduction & adduction, calf raise, squat, crunch, back extension, basketball shooting, 3 weeks	Sets: 3, Reps; 15, Freq: 5-6 x WK, Prog: NR Int:15rm (30% of 1RM). Occlusion pressure range: 160-180 mmHg at proximal lower limb.	MRI (signal intensity). Thigh circumference	Patient improved clinical outcomes and returned to playing basketball MRI signal intensity was reduced, and thigh circumference was increased.

Abbreviations: LL-BFRT: low-load blood flow restriction training, HL-RT: high load resistance training, RM: repetition maximum, SL: single leg, US: ultrasound, MRI: magnetic resonance imaging, MIN: minute, NR: not reported, Int: intensity, Freq: frequency, Prog: Progression, RCT: randomised controlled trial, MVC: maximum voluntary contraction, VAS: visual anologue scale, NRS-P: pain numeric rating scale, VISA-P: Victorian Institute of Sport Assessment Patellar, SLDS: single leg decline squat, n: number, WK: week,

Resistance training in Tendinopathy

Resistance training has been synonymous with tendinopathy rehabilitation for many years, particularly lower limb tendinopathies, due to the large body of evidence supporting its use (Burton et al., 2021; Challoumas et al., 2021). The concept of resistance training using isolated eccentric actions to treat lower limb tendinopathy was first suggested by Stanish et al., (1986) and then later popularised by the publication of the Alfredson eccentric heel-drop protocol for Achilles tendinopathy (Alfredson, 1998). Since then, eccentric resistance training has become the most explored and recommended method for treating Achilles and patellar tendinopathies, due to consistently positive findings for pain and function improvement (Malliaras et al., 2013; Saithna et al., 2012). The training parameters of the Alfredson eccentric heel-drop protocol have also been applied to patellar tendinopathy in the form of an eccentric single-leg decline squat protocol, which has shown clinical efficacy (Young et al., 2005; Visnes and Bahr 2007; Saithna et al., 2012). Heavy eccentric overload training using inertial flywheel devices has also been shown to be an effective prevention and rehabilitation method for patellar tendinopathy (Ruffino et al., 2021; Romero-Rodriguez et al., 2011; Gual et al., 2016). Resistance training protocols combining concentric, eccentric and plyometric training have also shown efficacy in treating Achilles tendinopathy (Silbernagel et al., 2007; 2020). Despite conflicting findings regarding the necessity for the elimination of concentric actions from isotonic contractions (Couppe et al., 2015; Lim et al., 2018; Murphy et al., 2019; Mendonca et al., 2020), isolated eccentric training does appear to be a more effective tendinopathy strategy than concentric training (Mafi et al., 2001; Jonsson and Alfredson, 2005; Peterson et al., 2014). However, some studies have reported that up to 45% of patients have poor long-term outcomes for pain and function following heavy eccentric training, with poor findings often more common in the general population compared to athletic populations (Sayana and Maffulli, 2007). More recently, heavy slow resistance training (HSRT), with heavy loaded isotonic contractions has been shown to have comparable or greater outcomes for pain and function improvement for patellar tendinopathy (Kongsgaard et al., 2009; Sprague et al., 2021; Breda et al., 2020; Agergaard et al., 2021), Achilles tendinopathy (Beyer et al., 2015), and plantar heel pain (Rathleff et al., 2015; Riel et al., 2019). Regardless of whether eccentric or HSRT interventions are employed to treat tendinopathies, it is widely accepted that protocols must be delivered with heavy loads to be capable of deriving positive changes in tendon architecture and mechanical properties (Bohm et al., 2015; Farnqvist et al., 2020). Slowly performed muscle contractions under heavy loads are postulated to stimulate tendon adaptations through mechano-transduction of the high forces and loads, which translates to improved tendon compliance and remodelling, with increased collagen production and reduced neovascularization (Murtaugh and Ihm, 2013; Khan and Scott, 2009). Despite these positive effects and physiological mechanisms of HL-RT on tendon structure in tendinopathy, there will inevitably be certain clinical populations who are unable to begin tendon rehabilitation with HL-RT, due to contraindications, advanced age, co-morbidities, or reduced exercise tolerance. Whilst its clear at present that HL-RT should remain the treatment of choice in treating tendinopathies, due to the myriad of evidence showing effectiveness, LL-BFRT may serve as a compliment or regression method for those unable to tolerate HL-RT. Table 5 provides an overview of the traditional resistance training paradigms in tendinopathy rehabilitation, with the addition of the LL-BFRT protocol by Skovlund et al., (2020) as a potentially alternative option, expanding the clinical applicability of resistance training to previously neglected clinical populations.

Table 5: Evidence-based resistance training protocols in lower limb tendinopathy

Characteristics of resistance training protocols in lower limb tendinopathy

Protocol	Tendinopathy	Exercise type	Sets, repetitions	frequency	Duration	Progression	Pain
Stanish and Curwin	Achilles	Eccentric-concentric, power	3, 10-20	Daily	12 weeks	Speed then load	Enough load to be painful in 3rd set
Alfredson	Achilles	Eccentric	3, 15	2 x daily	12 weeks	Increase load as able (backpack)	Enough load to achieve moderate pain
Silbernagel	Achilles	Eccentric-concentric, balance, plyometric	Various	Daily	12 weeks	Volume, type of exercise	Acceptable within defined limits
Beyer	Achilles	Isotonic (HSRT)	3-4, 15-6	3 x week	12 weeks	15-6RM, increase load as able (external weight machine)	Acceptable if not worse after exercise
Rathleff	Plantar heel	Isotonic (HSRT)	3-5, 12-8	3 x week	12 weeks	12-8RM, Increase load as able (backpack)	Acceptable if not worse after exercise
Kongsgaard	Patellar	Isotonic (HSRT)	4, 15-6	3 x week	12 weeks	15-6RM, Increase load as able (external weight machine)	Acceptable if not worse after exercise
Ruffino	Patellar	Eccentric overload (inertial flywheel)	4, 12	1 x week	12 weeks	8RM, increase resistance (flywheel devices)	Acceptable within defined limits
Skovlund	Patellar	Isotonic (BFRT)	6, 5-30 (30, 25, 20, 15, 10, 5)	3 x week	3 weeks	Increase volume as able (external weight machine)	Acceptable within defined limits

RM: repetition maximum; HSRT: Heavy slow resistance training, BFRT: Blood flow restriction training

Clinical implications and practical application

Despite their being a paucity of research to date on the application of LL-BFRT in tendinopathy rehabilitation, the previously reviewed studies indicate that LL-BFRT can produce beneficial clinical effects and structural adaptations to both healthy and pathological tendons. Although no confirmatory RCTs have yet been conducted in a tendinopathy population, preliminary case reports and case series evidence have shown clinical improvements, safety, and feasibility of LL-BFRT in both tendinopathy and tendon rupture rehabilitation. The body of evidence for tendon adaptations following LL-BFRT is more robust for healthy tendons, due to several high-quality RCTs existing, particularly for the Achilles and patellar tendons. The documented beneficial effects of LL-BFRT on the morphological and mechanical properties of healthy tendons include improvements in tendon thickness, vascularity, stiffness, skin temperature and neovascularization. Although these confirmed beneficial adaptations in healthy tendons have not been confirmed in pathological tendons, preliminary evidence in tendinopathy has shown improvements in tendon thickness, vascularity, and MRI signal intensity. However, further large scale high-quality RCTs are required to confirm these positive adaptations in tendinopathy, despite preliminary evidence being suggestive of clinical and structural tendon benefit. Although definitive conclusions and recommendations on LL-BFRT are not possible until such evidence exists, there is a clear scientific rationale supporting its clinical use. The evidence for positive adaptations in healthy tendons and the body of evidence showing clinical improvement following LL-BFRT for other comparable musculoskeletal disorders is suggestive of possible efficacy of LL-BFRT as a tendinopathy treatment. Given these findings and the increased research intensity within the BFRT field in recent years, particularly its application within musculoskeletal rehabilitation, it could be considered surprising how little attention has been given to its application in tendinopathy. As previously discussed, resistance training has the highest quality evidence of effectiveness out of all tendinopathy treatments, with heavy-load eccentric and HSRT typically recommended due to their documented beneficial effects (Challoumas et al., 2021; Irby et al., 2020; Girgis et al., 2021; Murphy et al., 2019; Burton et al., 2021). The long-held belief that resistance training must be applied with heavy-loads to derive positive adaptations in tendinopathy could be a potential barrier and explanation for the dearth of its application in the literature. However, this underutilization of LL-BFRT in tendinopathy rehabilitation, may be counterproductive, as it could be an alternative option for those populations unable to tolerate traditional heavy-load training. Indeed, there may even be clinical scenarios where the practice of heavy-load training is contraindicated such as in early rehabilitation for acute tendinopathies or tendon rupture, or in patients who are frail, elderly or have significant medical co-morbidities (Scarpelli et al., 2021). The 'one-size-fits-all' approach to tendinopathy rehabilitation of prescribing heavy-load resistance training which has become widespread in recent years, is an unrealistic and potentially counterproductive and detrimental practice (Silbernagel et al., 2014). There is significant heterogeneity which exists within tendinopathy as a disease entity and in its environmental and clinical presentation, due to the unique individual factors and circumstances of each patient (Steinemann et al., 2020). Therefore, a homogenous prescription of heavy-load training across a heterogeneous disease population is inappropriate and may potentially help to explain why despite its clear benefits, traditional heavy-load training may only be up to 50% effective for long-term clinical improvement in tendinopathy (Burton et al., 2021).

Changes in healthy tendon properties have been shown to be comparable between LL-BFRT and HL-RT, with these positive adaptations representing a possible explanation for the clinical benefit that has been shown in tendinopathy rehabilitation studies. It is widely considered that to optimally derive tendon adaptations with resistance training, heavy loads are quired to increase the magnitude of effect (Bohm et al., 2015; Mersmann et al., 2021; Arampatzis et al., 2020). However, the multitude of physiological responses induced by LL-BFRT could be considered greater than that provided by traditional training. The potent microenvironment created by LL-BFRT and the muscular and tendinous physiological milieu it induces, may be elicit enough to negate the requirement of heavy-loads to derive positive adaptations. Although this line of inquiry is hypothetical and unproven in tendinopathy, the evidence from studies in healthy tendons and the preliminary evidence in tendinopathy, at least warrants a heighted attention for further investigation. If such findings are confirmed in future research, the consequences for tendinopathy rehabilitation would be significant, with a potential paradigm shift required in resistance training treatment recommendations, away from the current homogenous heavy-loading prescriptions for all patients. The availability of LL-BFRT as a proven, safe, and efficacious treatment option, would increases the viability of options for clinicians and give patients more choice in treatment selection, which may have far-reaching implications in areas such as training adherence, which is currently a significant problem area in resistance training for tendinopathy (Burton et al. 2021). Whilst athletic individuals and those with resistance training experience may have less issues adhering to HL-RT, there may be implementation barriers to its prescription in those unaccustomed to HL-RT or resistance training in general such as elderly populations or those with significant co-existing medical issues (Suga et al. 2021; Freitas et al., 2021). Evidence from other musculoskeletal disorders, has already indicated that LL-BFRT is a safe, viable and effective method for prescribing resistance training in rehabilitation populations unable to tolerate traditional HL-RT for a multitude of reasons such as limited mobility and high pain levels. For example, LL-BFRT has been found to be effective for reducing pain, improving function, and increasing muscle strength and hypertrophy in early rehabilitation for several musculoskeletal disorders suggesting similar benefits may be achievable within tendinopathy populations. The lower training intensity and loads required with LL-BFRT to derive muscle and tendon adaptations, typically range between 20-40% of 1RM, which would likely be more tolerable for patients not able to tolerate high muscle-tendon training loads which are typically 70% of 1-RM in HSRT protocols, while still preventing muscle atrophy and promoting hypertrophy and strength increases (Krzysztofik et al., 2019; Kataoka et al., 2022; Hill et al., 2020; Centner et al., 2019; Shiromaru et al., 2019). Future research should also investigate the feasibility of individualised prescription of LL-BFRT for tendinopathies and the combination of LL-BFRT with other effective treatment option for tendinopathies such as extracorporeal shockwave therapy (Burton et al., 2021; 2021).

Future research – current trials on BFRT in tendon rehabilitation

Despite their being no RCTs completed to date investigating BFRT in tendon rehabilitation, its clear from a search of currently registered RCTs (clinicaltrials.gov) that increased attention is being given to the potential clinical utility of BFRT in tendon pathology. A recently published conference abstract of a completed yet unpublished RCT on BFRT following surgery for Achilles tendon ruptures, indicates that BFRT is superior compared to standard physical therapy for increasing absolute strength in the operative calf (Hansen et al., 2022). Whilst full details of the RCT and BFRT parameters are yet to be published, these preliminary findings are encouraging and mirror the findings of the case series and case reports to date on BFRT in tendon pathologies. The first RCT investigating the effects of LL-BFRT compared to HL-RT in patellar tendinopathy is underway in Denmark (Jensen et al., 2020), by the same research group who conducted the positive case series included in this review (Skovlund et al., 2020). This trial will be the first step in determining if definitive recommendations can be made for BFRT in tendinopathy, building on the preliminary evidence included in this review. Positive findings from this RCT may require a paradigm shift in the clinical rehabilitation of tendinopathy, from the belief that HL-RT is a prerequisite for improving outcomes in tendinopathy, to a possible future where both HL-RT and LL-BFRT are both viable rehabilitation methods, giving clinicians and patients more options and choice during rehabilitation. Other currently in-progress RCTs of BFRT interventions for tendon pathologies include for postoperative biceps tendon rupture (Jildeh et al., 2020), lateral elbow tendinopathy (Palhano et al., 2020; Lear et al., 2019). rotator cuff tendinopathy (Ozcakar et al., 2020), and rotator cuff tears (Banffy et al., 2020; Khalil et al., 2020). The field of clinical tendon rehabilitation eagerly awaits the outcomes of these trials, as findings of therapeutic utility will have wide ranging clinical implications for potentially enhancing patient outcomes (Bielitzki et al., 2021).

Conclusion

The comparable effects of LL-BFRT to HL-RT and superiority over LL-RT for muscular adaptations such as strength and hypertrophy have been previously demonstrated, with recent findings suggesting the same may be true for tendon adaptations. Despite the paucity of research on the effects of BFRT on healthy tendons and in tendon pathologies such as tendinopathy, preliminary evidence suggests beneficial tendon adaptations do occur, along with improvements in clinical outcomes such as pain and function, which is encouraging. Studies highlighted in this review have found comparable tendon adaptations are derived from LL-BFRT and HL-RT in healthy lower and upper limb tendons, with the greatest evidence for Achilles and patellar tendons. Despite clear evidence of efficacy for its application for other musculoskeletal conditions, BFRT is a novel method in tendinopathy rehabilitation. Therefore, definitive conclusions, and recommendations on BFRT for tendinopathy rehabilitation cannot be made at present, which should be addressed in future research, due to the potential therapeutic benefits highlighted in this review. Despite this, this review makes some preliminary implementation recommendations based on the current limited evidence, which clinicians should interpret with caution, until further confirmatory research exists. The addition of LL-BFRT as a viable rehabilitation method in tendinopathy rehabilitation would be complimentary to currently utilised HL-RT interventions and provide more rehabilitation options for clinicians and for patients unable to tolerate HL-RT during tendon rehabilitation.

REFERENCES

Abe, T., Fujita, S., Nakajima, T., Sakamaki, M., Ozaki, H., Ogasawara, R., Sugaya, M., Kudo, M., Kurano, M., Yasuda, T., Sato, Y., Ohshima, H., Mukai, C., Ishii, N. (2010). Effects of Low-Intensity Cycle Training with Restricted Leg Blood Flow on Thigh Muscle Volume and VO2MAX in Young Men. J. Sports Sci. Med. 9, 452-458.

Abe, T., Kearns, C.F., Sato, Y. (2006). Muscle size and strength are increased following walk training with restricted venous blood flow from the leg muscle, Kaatsu-walk training. J. Appl. Physiol. (1985) 100, 1460-1466. doi: 01267.2005 [pii].

Abe, T., and Loenneke, J.P. (2017). Walking with blood flow restriction: Could it help the elderly to get more out of every step? J. Sci. Med. Sport 20, 964. doi: S1440-2440(17)30477-2 [pii].

Abe, T., Loenneke, J.P., Fahs, C.A., Rossow, L.M., Thiebaud, R.S., Bemben, M.G. (2012). Exercise intensity and muscle hypertrophy in blood flow-restricted limbs and non-restricted muscles: a brief review. Clin. Physiol. Funct. Imaging 32, 247-252. doi: 10.1111/j.1475-097X.2012.01126.x [doi].

Abe, T., Mouser, J.G., Dankel, S.J., Bell, Z.W., Buckner, S.L., Mattocks, K.T., Jessee, M.B., Loenneke, J.P. (2019). A method to standardize the blood flow restriction pressure by an elastic cuff. Scand. J. Med. Sci. Sports 29, 329-335. doi: 10.1111/sms.13340 [doi].

Abe, T., Sakamaki, M., Fujita, S., Ozaki, H., Sugaya, M., Sato, Y., Nakajima, T. (2010). Effects of low-intensity walk training with restricted leg blood flow on muscle strength and aerobic capacity in older adults. J. Geriatr. Phys. Ther. 33, 34-40.

Agergaard, A.S., Svensson, R.B., Malmgaard-Clausen, N.M., Couppe, C., Hjortshoej, M.H., Doessing, S., Kjaer, M., Magnusson, S.P. (2021). Clinical Outcomes, Structure, and Function Improve With Both Heavy and Moderate Loads in the Treatment of Patellar Tendinopathy: A Randomized Clinical Trial. Am. J. Sports Med. 49, 982-993. doi: 10.1177/0363546520988741 [doi].

Alfredson, H., Pietila, T., Jonsson, P., Lorentzon, R. (1998). Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. Am. J. Sports Med. 26, 360-366. doi: 10.1177/03635465980260030301 [doi].

Arampatzis, A., Mersmann, F., Bohm, S. (2020). Individualized Muscle-Tendon Assessment and Training. Front. Physiol. 11, 723. doi: 10.3389/fphys.2020.00723 [doi].

Araujo, J.P., Neto, G.R., Loenneke, J.P., Bemben, M.G., Laurentino, G.C., Batista, G., Silva, J.C., Freitas, E.D., Sousa, M.S. (2015). The effects of water-based exercise in combination with blood flow restriction on strength and functional capacity in post-menopausal women. Age (Dordr) 37, 110-015-9851-4. Epub 2015 Nov 2. doi: 10.1007/s11357-015-9851-4 [doi].

Baker, B.S., Stannard, M.S., Duren, D.L., Cook, J.L., Stannard, J.P. (2020). Does Blood Flow Restriction Therapy in Patients Older Than Age 50 Result in Muscle Hypertrophy, Increased Strength, or Greater Physical Function? A Systematic Review. Clin. Orthop. Relat. Res. 478, 593-606. doi: 10.1097/CORR.0000000000001090 [doi].

Banffy, M.B. (2020). The Effects of Cross-Education and Blood Flow Restriction Study on Patients Undergoing Shoulder Arthroscopy. https://clinicaltrials.gov/ct2/show/NCT04470570

Barbalho, M., Rocha, A.C., Seus, T.L., Raiol, R., Del Vecchio, F.B., Coswig, V.S. (2019). Addition of blood flow restriction to passive mobilization reduces the rate of muscle wasting in elderly patients in the intensive care unit: a within-patient randomized trial. Clin. Rehabil. 33, 233-240. doi: 10.1177/0269215518801440 [doi].

Barber-Westin, S., and Noyes, F.R. (2019). Blood Flow-Restricted Training for Lower Extremity Muscle Weakness due to Knee Pathology: A Systematic Review. Sports Health. 11, 69-83. doi: 10.1177/1941738118811337 [doi].

Baron, J.E., Parker, E.A., Duchman, K.R., Westermann, R.W. (2020). Perioperative and Postoperative Factors Influence Quadriceps Atrophy and Strength After ACL Reconstruction: A Systematic Review. Orthop. J. Sports Med. 8, 2325967120930296. doi: 10.1177/2325967120930296 [doi].

Beckwee, D., Delaere, A., Aelbrecht, S., Baert, V., Beaudart, C., Bruyere, O., de Saint-Hubert, M., Bautmans, I. (2019). Exercise Interventions for the Prevention and Treatment of Sarcopenia. A Systematic Umbrella Review. J. Nutr. Health Aging 23, 494-502. doi: 10.1007/s12603-019-1196-8 [doi].

Beyer, R., Kongsgaard, M., Hougs Kjaer, B., Ohlenschlaeger, T., Kjaer, M., Magnusson, S.P. (2015). Heavy Slow Resistance Versus Eccentric Training as Treatment for Achilles Tendinopathy: A Randomized Controlled Trial. Am. J. Sports Med. 43, 1704-1711. doi: 10.1177/0363546515584760 [doi].

Bielitzki, R., Behrendt, T., Behrens, M., Schega, L. (2021). Time to Save Time: Beneficial Effects of Blood Flow Restriction Training and the Need to Quantify the Time Potentially Saved by Its Application During Musculoskeletal Rehabilitation. Phys. Ther. 101, 10.1093/ptj/pzab172. doi: pzab172 [pii].

Bobes Alvarez, C., Issa-Khozouz Santamaria, P., Fernandez-Matias, R., Pecos-Martin, D., Achalandabaso-Ochoa, A., Fernandez-Carnero, S., Martinez-Amat, A., Gallego-Izquierdo, T. (2020). Comparison of Blood Flow Restriction Training versus Non-Occlusive Training in Patients with Anterior Cruciate Ligament Reconstruction or Knee Osteoarthritis: A Systematic Review. J. Clin. Med. 10, 10.3390/jcm10010068. doi: E68 [pii].

Boesen, A.P., Dideriksen, K., Couppe, C., Magnusson, S.P., Schjerling, P., Boesen, M., Kjaer, M., Langberg, H. (2013). Tendon and skeletal muscle matrix gene expression and functional responses to immobilisation and rehabilitation in young males: effect of growth hormone administration. J. Physiol. 591, 6039-6052. doi: 10.1113/jphysiol.2013.261263 [doi].

Bohm, S., Mersmann, F., Arampatzis, A. (2015). Human tendon adaptation in response to mechanical loading: a systematic review and meta-analysis of exercise intervention studies on healthy adults. Sports Med. Open 1, 7-015-0009-9. Epub 2015 Mar 27. doi: 10.1186/s40798-015-0009-9 [doi].

Bowman, E.N., Elshaar, R., Milligan, H., Jue, G., Mohr, K., Brown, P., Watanabe, D.M., Limpisvasti, O. (2020). Upper-extremity blood flow restriction: the proximal, distal, and contralateral effects-a randomized controlled trial. J. Shoulder Elbow Surg. 29, 1267-1274. doi: S1058-2746(20)30180-4 [pii].

Bowman, E.N., Elshaar, R., Milligan, H., Jue, G., Mohr, K., Brown, P., Watanabe, D.M., Limpisvasti, O. (2019). Proximal, Distal, and Contralateral Effects of Blood Flow Restriction Training on the Lower Extremities: A Randomized Controlled Trial. Sports Health. 11, 149-156. doi: 10.1177/1941738118821929 [doi].

Brandner, C.R., Kidgell, D.J., Warmington, S.A. (2015). Unilateral bicep curl hemodynamics: Low-pressure continuous vs high-pressure intermittent blood flow restriction. Scand. J. Med. Sci. Sports 25, 770-777. doi: 10.1111/sms.12297 [doi].

Brandner, C.R., Warmington, S.A., Kidgell, D.J. (2015). Corticomotor Excitability is Increased Following an Acute Bout of Blood Flow Restriction Resistance Exercise. Front. Hum. Neurosci. 9, 652. doi: 10.3389/fnhum.2015.00652 [doi].

Breda, S.J., Oei, E.H.G., Zwerver, J., Visser, E., Waarsing, E., Krestin, G.P., de Vos, R.J. (2021). Effectiveness of progressive tendon-loading exercise therapy in patients with patellar tendinopathy: a randomised clinical trial. Br. J. Sports Med. 55, 501-509. doi: 10.1136/bjsports-2020-103403 [doi].

Brightwell, B.D., Stone, A., Li, X., Hardy, P., Thompson, K., Noehren, B., Jacobs, C. (2022). Blood flow Restriction training After patellar INStability (BRAINS Trial). Trials 23, 88-022-06017-1. doi: 10.1186/s13063-022-06017-1 [doi].

Brumitt, J., Hutchison, M.K., Kang, D., Klemmer, Z., Stroud, M., Cheng, E., Cayanan, N.P., Shishido, S. (2020). Blood Flow Restriction Training for the Rotator Cuff: A Randomized Controlled Trial. Int. J. Sports Physiol. Perform., 1-6. doi: 10.1123/ijspp.2019-0815 [doi].

Bryk, F.F., Dos Reis, A.C., Fingerhut, D., Araujo, T., Schutzer, M., Cury Rde, P., Duarte, A.,Jr, Fukuda, T.Y. (2016). Exercises with partial vascular occlusion in patients with knee osteoarthritis: a randomized clinical trial. Knee Surg. Sports Traumatol. Arthrosc. 24, 1580-1586. doi: 10.1007/s00167-016-4064-7 [doi].

Burgomaster, K.A., Moore, D.R., Schofield, L.M., Phillips, S.M., Sale, D.G., Gibala, M.J. (2003). Resistance training with vascular occlusion: metabolic adaptations in human muscle. Med. Sci. Sports Exerc. 35, 1203-1208. doi: 10.1249/01.MSS.0000074458.71025.71 [doi].

Burton, I. (2021). Autoregulated heavy slow resistance training combined with radial shockwave therapy for plantar heel pain: Protocol for a mixed-methods pilot randomised controlled trial. Musculoskeletal Care. 19, 319-330. doi: 10.1002/msc.1542 [doi].

Burton, I. (2021). Autoregulation in Resistance Training for Lower Limb Tendinopathy: A Potential Method for Addressing Individual Factors, Intervention Issues, and Inadequate Outcomes. Front. Physiol. 12, 704306. doi: 10.3389/fphys.2021.704306 [doi].

Burton, I., and McCormack, A. (2021). Autoregulated and individualised resistance training versus predetermined and standardised resistance training in tendinopathy: A systematic review protocol. Musculoskeletal Care. doi: 10.1002/msc.1551 [doi].

Burton, I., and McCormack, A. (2021). The implementation of resistance training principles in exercise interventions for lower limb tendinopathy: A systematic review. Phys. Ther. Sport. 50, 97-113. doi: S1466-853X(21)00079-1 [pii].

Caetano, D., Oliveira, C., Correia, C., Barbosa, P., Montes, A., Carvalho, P. (2021). Rehabilitation outcomes and parameters of blood flow restriction training in ACL injury: A scoping review. Phys. Ther. Sport. 49, 129-137. doi: S1466-853X(21)00016-X [pii].

Canfer, R.J., Chaudry, S., Miller, S.C. (2021). Thermographic assessment of the immediate and short term-effects of blood flow restriction exercise on Achilles tendon skin temperature. Phys. Ther. Sport. 49, 171-177. doi: S1466-853X(21)00010-9 [pii].

Canosa-Carro, L., Bravo-Aguilar, M., Abuin-Porras, V., Almazan-Polo, J., Garcia-Perez-de-Sevilla, G., Rodriguez-Costa, I., Lopez-Lopez, D., Navarro-Flores, E., Romero-Morales, C. (2022). Current understanding of the diagnosis and management of the tendinopathy: An update from the lab to the clinical practice. Dis. Mon., 101314. doi: S0011-5029(21)00190-5 [pii].

Centner, C., Jerger, S., Lauber, B., Seynnes, O., Friedrich, T., Lolli, D., Gollhofer, A., Konig, D. (2021). Low-Load Blood Flow Restriction and High-Load Resistance Training Induce Comparable Changes in Patellar Tendon Properties. Med. Sci. Sports Exerc. doi: 10.1249/MSS.0000000000002824 [doi].

Centner, C., and Lauber, B. (2020). A Systematic Review and Meta-Analysis on Neural Adaptations Following Blood Flow Restriction Training: What We Know and What We Don't Know. Front. Physiol. 11, 887. doi: 10.3389/fphys.2020.00887 [doi].

Centner, C., Lauber, B., Seynnes, O.R., Jerger, S., Sohnius, T., Gollhofer, A., Konig, D. (2019). Low-load blood flow restriction training induces similar morphological and mechanical Achilles tendon adaptations compared with high-load resistance training. J. Appl. Physiol. (1985) 127, 1660-1667. doi: 10.1152/japplphysiol.00602.2019 [doi].

Centner, C., Ritzmann, R., Gollhofer, A., Konig, D. (2020). Effects of Whole-Body Vibration Training and Blood Flow Restriction on Muscle Adaptations in Women: A Randomized Controlled Trial. J. Strength Cond Res. 34, 603-608. doi: 10.1519/JSC.0000000000003401 [doi].

Centner, C., Ritzmann, R., Schur, S., Gollhofer, A., Konig, D. (2019). Blood flow restriction increases myoelectric activity and metabolic accumulation during whole-body vibration. Eur. J. Appl. Physiol. 119, 1439-1449. doi: 10.1007/s00421-019-04134-5 [doi].

Centner, C., Wiegel, P., Gollhofer, A., Konig, D. (2019). Effects of Blood Flow Restriction Training on Muscular Strength and Hypertrophy in Older Individuals: A Systematic Review and Meta-Analysis. Sports Med. 49, 95-108. doi: 10.1007/s40279-018-0994-1 [doi].

Centner, C., Zdzieblik, D., Dressler, P., Fink, B., Gollhofer, A., Konig, D. (2018). Acute effects of blood flow restriction on exercise-induced free radical production in young and healthy subjects. Free Radic. Res. 52, 446-454. doi: 10.1080/10715762.2018.1440293 [doi].

Centner, C., Zdzieblik, D., Roberts, L., Gollhofer, A., Konig, D. (2019). Effects of Blood Flow Restriction Training with Protein Supplementation on Muscle Mass And Strength in Older Men. J. Sports Sci. Med. 18, 471-478.

Cerqueira, M.S., Do Nascimento, J.D.S., Maciel, D.G., Barboza, J.A.M., De Brito Vieira, W.H. (2020). Effects of blood flow restriction without additional exercise on strength reductions and muscular atrophy following immobilization: A systematic review. J. Sport. Health. Sci. 9, 152-159. doi: S2095-2546(19)30081-X [pii].

Cerqueira, M.S., Maciel, D.G., Barboza, J.A.M., Centner, C., Lira, M., Pereira, R., De Brito Vieira, W.H. (2021). Effects of low-load blood flow restriction exercise to failure and non-failure on myoelectric activity: a meta-analysis. J. Athl Train. doi: 10.4085/1062-6050-0603.20 [doi].

Challoumas, D., Pedret, C., Biddle, M., Ng, N.Y.B., Kirwan, P., Cooper, B., Nicholas, P., Wilson, S., Clifford, C., Millar, N.L. (2021). Management of patellar tendinopathy: a systematic review and network meta-analysis of randomised studies. BMJ Open Sport. Exerc. Med. 7, e001110. doi: 10.1136/bmjsem-2021-001110 [doi].

Charles, D., White, R., Reyes, C., Palmer, D. (2020). A Systematic Review of the Effects of Blood Flow Restriction Training on Quadriceps Muscle Atrophy and Circumference Post Acl Reconstruction. Int. J. Sports Phys. Ther. 15, 882-891. doi: 10.26603/ijspt20200882 [doi].

Christensen, M., Zellers, J.A., Kjaer, I.L., Silbernagel, K.G., Rathleff, M.S. (2020). Resistance Exercises in Early Functional Rehabilitation for Achilles Tendon Ruptures Are Poorly Described: A Scoping Review. J. Orthop. Sports Phys. Ther. 50, 681-690. doi: 10.2519/jospt.2020.9463 [doi].

Chulvi-Medrano, I., Picon-Martinez, M., Cortell-Tormo, J.M., Tortosa-Martinez, J., Alonso-Aubin, D.A., Alakhdar, Y. (2020). Different Time Course of Recovery in

Achilles Tendon Thickness After Low-Load Resistance Training With and Without Blood Flow Restriction. J. Sport. Rehabil. 30, 300-305. doi: 10.1123/jsr.2019-0403 [doi].

Clarkson, M.J., Conway, L., Warmington, S.A. (2017). Blood flow restriction walking and physical function in older adults: A randomized control trial. J. Sci. Med. Sport 20, 1041-1046. doi: S1440-2440(17)30396-1 [pii].

Clarkson, M.J., Fraser, S.F., Bennett, P.N., McMahon, L.P., Brumby, C., Warmington, S.A. (2017). Efficacy of blood flow restriction exercise during dialysis for end stage kidney disease patients: protocol of a randomised controlled trial. BMC Nephrol. 18, 294-017-0713-4. doi: 10.1186/s12882-017-0713-4 [doi].

Constantinou, A., Mamais, I., Papathanasiou, G., Lamnisos, D., Stasinopoulos, D. (2022). Comparing hip and knee focused exercises versus hip and knee focused exercises with the use of blood flow restriction training in adults with patellofemoral pain: a randomized controlled trial. Eur. J. Phys. Rehabil. Med. doi: 10.23736/S1973-9087.22.06691-6 [doi].

Cook, S.B., Clark, B.C., Ploutz-Snyder, L.L. (2007). Effects of exercise load and blood-flow restriction on skeletal muscle function. Med. Sci. Sports Exerc. 39, 1708-1713. doi: 10.1249/mss.0b013e31812383d6 [doi].

Cook, S.B., Kanaley, J.A., Ploutz-Snyder, L.L. (2014). Neuromuscular function following muscular unloading and blood flow restricted exercise. Eur. J. Appl. Physiol. 114, 1357-1365. doi: 10.1007/s00421-014-2864-3 [doi].

Cook, S.B., LaRoche, D.P., Villa, M.R., Barile, H., Manini, T.M. (2017). Blood flow restricted resistance training in older adults at risk of mobility limitations. Exp. Gerontol. 99, 138-145. doi: S0531-5565(17)30519-3 [pii].

Correa, H.L., Neves, R.V.P., Deus, L.A., Maia, B.C.H., Maya, A.T., Tzanno-Martins, C., Souza, M.K., Silva, J.A.B., Haro, A.S., Costa, F., Moraes, M.R., Simoes, H.G., Prestes, J., Stone, W., Rosa, T.S. (2021). Low-load resistance training with blood flow restriction prevent renal function decline: The role of the redox balance, angiotensin 1-7 and vasopressin(,). Physiol. Behav. 230, 113295. doi: S0031-9384(20)30609-0 [pii].

Counts, B.R., Dankel, S.J., Barnett, B.E., Kim, D., Mouser, J.G., Allen, K.M., Thiebaud, R.S., Abe, T., Bemben, M.G., Loenneke, J.P. (2016). Influence of relative blood flow restriction pressure on muscle activation and muscle adaptation. Muscle Nerve 53, 438-445. doi: 10.1002/mus.24756 [doi].

Couppe, C., Svensson, R.B., Silbernagel, K.G., Langberg, H., Magnusson, S.P. (2015). Eccentric or Concentric Exercises for the Treatment of Tendinopathies? J. Orthop. Sports Phys. Ther. 45, 853-863. doi: 10.2519/jospt.2015.5910 [doi].

Credeur, D.P., Hollis, B.C., Welsch, M.A. (2010). Effects of handgrip training with venous restriction on brachial artery vasodilation. Med. Sci. Sports Exerc. 42, 1296-1302. doi: 10.1249/MSS.0b013e3181ca7b06 [doi].

Cuddeford, T., and Brumitt, J. (2020). In-Season Rehabilitation Program using Blood Flow Restriction Therapy for Two Decathletes with Patellar Tendinopathy: a Case Report. Int. J. Sports Phys. Ther. 15, 1184-1195. doi: 10.26603/ijspt20201184 [doi].

Curran, M.T., Bedi, A., Mendias, C.L., Wojtys, E.M., Kujawa, M.V., Palmieri-Smith, R.M. (2020). Blood Flow Restriction Training Applied With High-Intensity Exercise Does Not Improve Quadriceps Muscle Function After Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial. Am. J. Sports Med. 48, 825-837. doi: 10.1177/0363546520904008 [doi].

Cuyul-Vasquez, I., Leiva-Sepulveda, A., Catalan-Medalla, O., Araya-Quintanilla, F., Gutierrez-Espinoza, H. (2020). The addition of blood flow restriction to resistance exercise in individuals with knee pain: a systematic review and meta-analysis. Braz J. Phys. Ther. 24, 465-478. doi: S1413-3555(19)30583-0 [pii].

da Silva, J.C.G., Silva, K.F., Domingos-Gomes, J.R., Batista, G.R., da Silva Freitas, E.D., Torres, V.B.C., do Socorro Cirilo-Sousa, M. (2019). Aerobic exercise with blood flow restriction affects mood state in a similar fashion to high intensity interval exercise. Physiol. Behav. 211, 112677. doi: S0031-9384(19)30614-6 [pii].

Dankel, S.J., Buckner, S.L., Jessee, M.B., Mattocks, K.T., Mouser, J.G., Counts, B.R., Laurentino, G.C., Loenneke, J.P. (2018). Can blood flow restriction augment muscle activation during high-load training? Clin. Physiol. Funct. Imaging 38, 291-295. doi: 10.1111/cpf.12414 [doi].

de Campos Biazon, T.M.P., Libardi, C.A., Junior, J.C.B., Caruso, F.R., da Silva Destro, T.R., Molina, N.G., Borghi-Silva, A., Mendes, R.G. (2021). The effect of passive mobilization associated with blood flow restriction and combined with electrical stimulation on cardiorespiratory safety, neuromuscular adaptations, physical function, and quality of life in comatose patients in an ICU: a randomized controlled clinical trial. Trials 22, 969-021-05916-z. doi: 10.1186/s13063-021-05916-z [doi].

de Deus, L.A., Neves, R.V.P., Correa, H.L., Reis, A.L., Honorato, F.S., Silva, V.L., de Araujo, T.B., Souza, M.K., Sousa, C.V., Simoes, H.G., Prestes, J., Silva Neto, L.S., Rodrigues Santos, C.A., Melo, G.F., Stone, W.J., Rosa, T.S. (2021). Improving the prognosis of renal patients: The effects of blood flow-restricted resistance training on redox balance and cardiac autonomic function. Exp. Physiol. 106, 1099-1109. doi: 10.1113/EP089341 [doi].

de Oliveira, M.F., Caputo, F., Corvino, R.B., Denadai, B.S. (2016). Short-term low-intensity blood flow restricted interval training improves both aerobic fitness and muscle strength. Scand. J. Med. Sci. Sports 26, 1017-1025. doi: 10.1111/sms.12540 [doi].

de Queiros, V.S., de Franca, I.M., Trybulski, R., Vieira, J.G., Dos Santos, I.K., Neto, G.R., Wilk, M., de Matos, D.G., Vieira, W.H.B., Novaes, J.D.S., Makar, P., Cabral, B.G.A.T., Dantas, P.M.S. (2021). Myoelectric Activity and Fatigue in Low-Load Resistance Exercise With Different Pressure of Blood Flow Restriction: A Systematic Review and Meta-Analysis. Front. Physiol. 12, 786752. doi: 10.3389/fphys.2021.786752 [doi].

Dean, B.J.F., Dakin, S.G., Millar, N.L., Carr, A.J. (2017). Review: Emerging concepts in the pathogenesis of tendinopathy. Surgeon 15, 349-354. doi: S1479-666X(17)30091-4 [pii].

Dos Santos, L.P., Santo, R.C.D.E., Ramis, T.R., Portes, J.K.S., Chakr, R.M.D.S., Xavier, R.M. (2021). The effects of resistance training with blood flow restriction on muscle strength, muscle hypertrophy and functionality in patients with osteoarthritis and rheumatoid arthritis: A systematic review with meta-analysis. PLoS One 16, e0259574. doi: 10.1371/journal.pone.0259574 [doi].

Drummond, M.J., Fujita, S., Abe, T., Dreyer, H.C., Volpi, E., Rasmussen, B.B. (2008). Human muscle gene expression following resistance exercise and blood flow restriction. Med. Sci. Sports Exerc. 40, 691-698. doi: 10.1249/MSS.0b013e318160ff84 [doi].

Ellefsen, S., Hammarstrom, D., Strand, T.A., Zacharoff, E., Whist, J.E., Rauk, I., Nygaard, H., Vegge, G., Hanestadhaugen, M., Wernbom, M., Cumming, K.T., Ronning, R., Raastad, T., Ronnestad, B.R. (2015). Blood flow-restricted strength training displays high functional and biological efficacy in women: a within-subject comparison with high-load strength training. Am. J. Physiol. Regul. Integr. Comp. Physiol. 309, R767-79. doi: 10.1152/ajpregu.00497.2014 [doi].

Fahs, C.A., Loenneke, J.P., Thiebaud, R.S., Rossow, L.M., Kim, D., Abe, T., Beck, T.W., Feeback, D.L., Bemben, D.A., Bemben, M.G. (2015). Muscular adaptations to fatiguing exercise with and without blood flow restriction. Clin. Physiol. Funct. Imaging 35, 167-176. doi: 10.1111/cpf.12141 [doi].

Farnqvist, K., Pearson, S., Malliaras, P. (2020). Adaptation of Tendon Structure and Function in Tendinopathy With Exercise and Its Relationship to Clinical Outcome. J. Sport Rehab. 29, 107-115.

Ferlito, J.V., Pecce, S.A.P., Oselame, L., De Marchi, T. (2020). The blood flow restriction training effect in knee osteoarthritis people: a systematic review and meta-analysis. Clin. Rehabil. 34, 1378-1390. doi: 10.1177/0269215520943650 [doi].

Ferraz, R.B., Gualano, B., Rodrigues, R., Kurimori, C.O., Fuller, R., Lima, F.R., DE Sa-Pinto, A.L., Roschel, H. (2018). Benefits of Resistance Training with Blood Flow Restriction in Knee Osteoarthritis. Med. Sci. Sports Exerc. 50, 897-905. doi: 10.1249/MSS.0000000000001530 [doi].

Fini, E.M., Salimian, M., Ahmadizad, S. (2021). Responses of platelet CD markers and indices to resistance exercise with and without blood flow restriction in patients with type 2 diabetes. Clin. Hemorheol. Microcirc. doi: 10.3233/CH-211229 [doi].

Fleck, S.J. (2011). Non-linear periodization for general fitness & athletes. J. Hum. Kinet 29A, 41-45. doi: 10.2478/v10078-011-0057-2 [doi].

Freitas, E.D.S., Karabulut, M., Bemben, M.G. (2021). The Evolution of Blood Flow Restricted Exercise. Front. Physiol. 12, 747759. doi: 10.3389/fphys.2021.747759 [doi].

Freitas, E.D.S., Miller, R.M., Heishman, A.D., Aniceto, R.R., Larson, R., Pereira, H.M., Bemben, D., Bemben, M.G. (2021). The perceptual responses of individuals with multiple sclerosis to blood flow restriction versus traditional resistance exercise. Physiol. Behav. 229, 113219. doi: S0031-9384(20)30533-3 [pii].

Fry, C.S., Glynn, E.L., Drummond, M.J., Timmerman, K.L., Fujita, S., Abe, T., Dhanani, S., Volpi, E., Rasmussen, B.B. (2010). Blood flow restriction exercise stimulates mTORC1 signaling and muscle protein synthesis in older men. J. Appl. Physiol. (1985) 108, 1199-1209. doi: 10.1152/japplphysiol.01266.2009 [doi].

Gaunder, C.L., Hawkinson, M.P., Tennent, D.J., Tubb, C.C. (2017). Occlusion training: pilot study for postoperative lower extremity rehabilitation following primary total knee arthroplasty. US. Army. Med. Dep. J. (2-17), 39-43.

Gavanda, S., Isenmann, E., Schloder, Y., Roth, R., Freiwald, J., Schiffer, T., Geisler, S., Behringer, M. (2020). Low-intensity blood flow restriction calf muscle training leads to similar functional and structural adaptations than conventional low-load strength training: A randomized controlled trial. PLoS One 15, e0235377. doi: 10.1371/journal.pone.0235377 [doi].

Giles, L., Webster, K.E., McClelland, J., Cook, J.L. (2017). Quadriceps strengthening with and without blood flow restriction in the treatment of patellofemoral pain: a double-blind randomised trial. Br. J. Sports Med. 51, 1688-1694. doi: 10.1136/bjsports-2016-096329 [doi].

Girgis, B., and Duarte, J.A. (2020). Physical therapy for tendinopathy: An umbrella review of systematic reviews and meta-analyses. Phys. Ther. Sport. 46, 30-46. doi: S1466-853X(20)30485-5 [pii].

Glattke, K.E., Tummala, S.V., Chhabra, A. (2021). Anterior Cruciate Ligament Reconstruction Recovery and Rehabilitation: A Systematic Review. J. Bone Joint Surg. Am. doi: 10.2106/JBJS.21.00688 [doi].

Gorgey, A.S., Timmons, M.K., Dolbow, D.R., Bengel, J., Fugate-Laus, K.C., Michener, L.A., Gater, D.R. (2016). Electrical stimulation and blood flow restriction increase wrist extensor cross-sectional area and flow meditated dilatation following spinal cord injury. Eur. J. Appl. Physiol. 116, 1231-1244. doi: 10.1007/s00421-016-3385-z [doi].

Grantham, B., Korakakis, V., O'Sullivan, K. (2021). Does blood flow restriction training enhance clinical outcomes in knee osteoarthritis: A systematic review and meta-analysis. Phys. Ther. Sport. 49, 37-49. doi: S1466-853X(21)00015-8 [pii].

Gronfeldt, B.M., Lindberg Nielsen, J., Mieritz, R.M., Lund, H., Aagaard, P. (2020). Effect of blood-flow restricted vs heavy-load strength training on muscle strength: Systematic review and meta-analysis. Scand. J. Med. Sci. Sports 30, 837-848. doi: 10.1111/sms.13632 [doi].

Gronlund, C., Christoffersen, K.S., Thomsen, K., Masud, T., Jepsen, D.B., Ryg, J. (2020). Effect of blood-flow restriction exercise on falls and fall related risk factors in older adults 60 years or above: a systematic review. J. Musculoskelet. Neuronal Interact. 20, 513-525.

Gual, G., Fort-Vanmeerhaeghe, A., Romero-Rodriguez, D., Tesch, P.A. (2016). Effects of In-Season Inertial Resistance Training With Eccentric Overload in a Sports Population at Risk for Patellar Tendinopathy. J. Strength Cond Res. 30, 1834-1842. doi: 10.1519/JSC.0000000000001286 [doi].

Hansen, O.B. (2022). Effect of Blood Flow Restriction Therapy Following Achilles Rupture and Repair: A Randomized Controlled Trial. https://clinicaltrials.gov/ct2/show/NCT04492059

Harper, S.A., Roberts, L.M., Layne, A.S., Jaeger, B.C., Gardner, A.K., Sibille, K.T., Wu, S.S., Vincent, K.R., Fillingim, R.B., Manini, T.M., Buford, T.W. (2019). Blood-Flow Restriction Resistance Exercise for Older Adults with Knee Osteoarthritis: A Pilot Randomized Clinical Trial. J. Clin. Med. 8, 10.3390/jcm8020265. doi: E265 [pii].

Hayhurst, D., Coppack, R.J., Ingram, C., Conway, D., Cassidy, R.P., Ladlow, P. (2021). Integrating blood flow restriction with low-load resistance exercise in a UK specialist military primary care rehabilitation facility. BMJ Mil. Health. doi: bmjmilitary-2021-001897 [pii].

Hill, E.C. (2020). Eccentric, but not concentric blood flow restriction resistance training increases muscle strength in the untrained limb. Phys. Ther. Sport. 43, 1-7. doi: S1466-853X(19)30605-4 [pii].

Hill, E.C., Housh, T.J., Keller, J.L., Smith, C.M., Anders, J.V., Schmidt, R.J., Johnson, G.O., Cramer, J.T. (2020). Low-load blood flow restriction elicits greater concentric strength than non-blood flow restriction resistance training but similar isometric strength and muscle size. Eur. J. Appl. Physiol. 120, 425-441. doi: 10.1007/s00421-019-04287-3 [doi].

Holm, C., Kjaer, M., Eliasson, P. (2015). Achilles tendon rupture--treatment and complications: a systematic review. Scand. J. Med. Sci. Sports 25, e1-10. doi: 10.1111/sms.12209 [doi].

Hopkins, C., Fu, S.C., Chua, E., Hu, X., Rolf, C., Mattila, V.M., Qin, L., Yung, P.S., Chan, K.M. (2016). Critical review on the socio-economic impact of tendinopathy. Asia Pac. J. Sports Med. Arthrosc. Rehabil. Technol. 4, 9-20. doi: 10.1016/j.asmart.2016.01.002 [doi].

Hughes, L., Grant, I., Patterson, S.D. (2021). Aerobic exercise with blood flow restriction causes local and systemic hypoalgesia and increases circulating opioid and endocannabinoid levels. J. Appl. Physiol. (1985) 131, 1460-1468. doi: 10.1152/japplphysiol.00543.2021 [doi].

Hughes, L., Jeffries, O., Waldron, M., Rosenblatt, B., Gissane, C., Paton, B., Patterson, S.D. (2018). Influence and reliability of lower-limb arterial occlusion pressure at different body positions. PeerJ 6, e4697. doi: 10.7717/peerj.4697 [doi].

Hughes, L., Paton, B., Haddad, F., Rosenblatt, B., Gissane, C., Patterson, S.D. (2018). Comparison of the acute perceptual and blood pressure response to heavy load and light load blood flow restriction resistance exercise in anterior cruciate ligament reconstruction patients and non-injured populations. Phys. Ther. Sport. 33, 54-61. doi: S1466-853X(18)30175-5 [pii].

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, 1003-1011. doi: 10.1136/bjsports-2016-097071 [doi].

Hughes, L., and Patterson, S.D. (2020). The effect of blood flow restriction exercise on exercise-induced hypoalgesia and endogenous opioid and endocannabinoid mechanisms of pain modulation. J. Appl. Physiol. (1985) 128, 914-924. doi: 10.1152/japplphysiol.00768.2019 [doi].

Hughes, L., and Patterson, S.D. (2019). Low intensity blood flow restriction exercise: Rationale for a hypoalgesia effect. Med. Hypotheses 132, 109370. doi: S0306-9877(19)30736-4 [pii].

Hughes, L., Patterson, S.D., Haddad, F., Rosenblatt, B., Gissane, C., McCarthy, D., Clarke, T., Ferris, G., Dawes, J., Paton, B. (2019). Examination of the comfort and pain experienced with blood flow restriction training during post-surgery rehabilitation of anterior cruciate ligament reconstruction patients: A UK National Health Service trial. Phys. Ther. Sport. 39, 90-98. doi: S1466-853X(19)30221-4 [pii].

Hughes, L., Rosenblatt, B., Gissane, C., Paton, B., Patterson, S.D. (2018). Interface pressure, perceptual, and mean arterial pressure responses to different blood flow restriction systems. Scand. J. Med. Sci. Sports 28, 1757-1765. doi: 10.1111/sms.13092 [doi].

Hughes, L., Rosenblatt, B., Haddad, F., Gissane, C., McCarthy, D., Clarke, T., Ferris, G., Dawes, J., Paton, B., Patterson, S.D. (2019). Comparing the

Effectiveness of Blood Flow Restriction and Traditional Heavy Load Resistance Training in the Post-Surgery Rehabilitation of Anterior Cruciate Ligament Reconstruction Patients: A UK National Health Service Randomised Controlled Trial. Sports Med. 49, 1787-1805. doi: 10.1007/s40279-019-01137-2 [doi].

Hunt, J.E., Galea, D., Tufft, G., Bunce, D., Ferguson, R.A. (2013). Time course of regional vascular adaptations to low load resistance training with blood flow restriction. J. Appl. Physiol. (1985) 115, 403-411. doi: 10.1152/japplphysiol.00040.2013 [doi].

Hunt, J.E., Stodart, C., Ferguson, R.A. (2016). The influence of participant characteristics on the relationship between cuff pressure and level of blood flow restriction. Eur. J. Appl. Physiol. 116, 1421-1432. doi: 10.1007/s00421-016-3399-6 [doi].

Hunt, J.E., Walton, L.A., Ferguson, R.A. (2012). Brachial artery modifications to blood flow-restricted handgrip training and detraining. J. Appl. Physiol. (1985) 112, 956-961. doi: 10.1152/japplphysiol.00905.2011 [doi].

Hylden, C., Burns, T., Stinner, D., Owens, J. (2015). Blood flow restriction rehabilitation for extremity weakness: a case series. J. Spec. Oper. Med. 15, 50-56.

Iida, H., Nakajima, T., Kurano, M., Yasuda, T., Sakamaki, M., Sato, Y., Yamasoba, T., Abe, T. (2011). Effects of walking with blood flow restriction on limb venous compliance in elderly subjects. Clin. Physiol. Funct. Imaging 31, 472-476. doi: 10.1111/j.1475-097X.2011.01044.x [doi].

Irby, A., Gutierrez, J., Chamberlin, C., Thomas, S.J., Rosen, A.B. (2020). Clinical management of tendinopathy: A systematic review of systematic reviews evaluating the effectiveness of tendinopathy treatments. Scand. J. Med. Sci. Sports 30, 1810-1826. doi: 10.1111/sms.13734 [doi].

Iversen, E., Rostad, V., Larmo, A. (2016). Intermittent blood flow restriction does not reduce atrophy following anterior cruciate ligament reconstruction. J. Sport. Health. Sci. 5, 115-118. doi: 10.1016/j.jshs.2014.12.005 [doi].

Jensen, K.Y., Jacobsen, M., Schroder, H.D., Aagaard, P., Nielsen, J.L., Jorgensen, A.N., Boyle, E., Bech, R.D., Rosmark, S., Diederichsen, L.P., Frandsen, U. (2019). The immune system in sporadic inclusion body myositis patients is not compromised by blood-flow restricted exercise training. Arthritis Res. Ther. 21, 293-019-2036-2. doi: 10.1186/s13075-019-2036-2 [doi].

Jensen, M.H. (2020). Blood Flow Restriction Training for Treatment of Chronic Patellar Tendinopathy. https://clinicaltrials.gov/ct2/show/NCT04550013

Jessee, M.B., Buckner, S.L., Dankel, S.J., Counts, B.R., Abe, T., Loenneke, J.P. (2016). The Influence of Cuff Width, Sex, and Race on Arterial Occlusion: Implications for Blood Flow Restriction Research. Sports Med. 46, 913-921. doi: 10.1007/s40279-016-0473-5 [doi].

Jessee, M.B., Dankel, S.J., Buckner, S.L., Mouser, J.G., Mattocks, K.T., Loenneke, J.P. (2017). The Cardiovascular and Perceptual Response to Very Low Load Blood Flow Restricted Exercise. Int. J. Sports Med. 38, 597-603. doi: 10.1055/s-0043-109555 [doi].

Jessee, M.B., Mattocks, K.T., Buckner, S.L., Mouser, J.G., Counts, B.R., Dankel, S.J., Laurentino, G.C., Loenneke, J.P. (2018). The acute muscular response to blood flow-restricted exercise with very low relative pressure. Clin. Physiol. Funct. Imaging 38, 304-311. doi: 10.1111/cpf.12416 [doi].

Jildeh, T.R. (2020). Use of Blood Flow Restriction (BFR) Therapy in Post-operative Rehabilitation Following Distal Biceps Tendon Repair. https://clinicaltrials.gov/ct2/show/NCT04503421

Jonsson, A.B., Johansen, C.V., Rolving, N., Pfeiffer-Jensen, M. (2021). Feasibility and estimated efficacy of blood flow restricted training in female patients with rheumatoid arthritis: a randomized controlled pilot study. Scand. J. Rheumatol. 50, 169-177. doi: 10.1080/03009742.2020.1829701 [doi].

Jonsson, P., and Alfredson, H. (2005). Superior results with eccentric compared to concentric quadriceps training in patients with jumper's knee: a prospective randomised study. Br. J. Sports Med. 39, 847-850. doi: 39/11/847 [pii].

Jorgensen, A.N., Aagaard, P., Nielsen, J.L., Frandsen, U., Diederichsen, L.P. (2016). Effects of blood-flow-restricted resistance training on muscle function in a 74-year-old male with sporadic inclusion body myositis: a case report. Clin. Physiol. Funct. Imaging 36, 504-509. doi: 10.1111/cpf.12259 [doi].

Jorgensen, S.L., Bohn, M.B., Aagaard, P., Mechlenburg, I. (2020). Efficacy of low-load blood flow restricted resistance EXercise in patients with Knee osteoarthritis scheduled for total knee replacement (EXKnee): protocol for a multicentre randomised controlled trial. BMJ Open 10, e034376-2019-034376. doi: 10.1136/bmjopen-2019-034376 [doi].

Jorgensen, S.L., and Mechlenburg, I. (2021). Effects of Low-Load Blood-Flow Restricted Resistance Training on Functional Capacity and Patient-Reported Outcome in a Young Male Suffering From Reactive Arthritis. Front. Sports Act. Living 3, 798902. doi: 10.3389/fspor.2021.798902 [doi].

Kacin, A., and Strazar, K. (2011). Frequent low-load ischemic resistance exercise to failure enhances muscle oxygen delivery and endurance capacity. Scand. J. Med. Sci. Sports 21, e231-41. doi: 10.1111/j.1600-0838.2010.01260.x [doi].

Kang, D.Y., Kim, H.S., Lee, K.S., Kim, Y.M. (2015). The effects of bodyweight-based exercise with blood flow restriction on isokinetic knee muscular function and thigh circumference in college students. J. Phys. Ther. Sci. 27, 2709-2712. doi: 10.1589/jpts.27.2709 [doi].

Kara, D. (2020). The Effect of Blood Flow Restriction Training on Muscle Thickness and Symptoms in Patients with Rotator Cuff Tendinopathy. https://clinicaltrials.gov/ct2/show/NCT04333784

Karabulut, M., Abe, T., Sato, Y., Bemben, M.G. (2010). The effects of low-intensity resistance training with vascular restriction on leg muscle strength in older men. Eur. J. Appl. Physiol. 108, 147-155. doi: 10.1007/s00421-009-1204-5 [doi].

Karabulut, M., Bemben, D.A., Sherk, V.D., Anderson, M.A., Abe, T., Bemben, M.G. (2011). Effects of high-intensity resistance training and low-intensity resistance training with vascular restriction on bone markers in older men. Eur. J. Appl. Physiol. 111, 1659-1667. doi: 10.1007/s00421-010-1796-9 [doi].

Karabulut, M., Esparza, B., Dowllah, I.M., Karabulut, U. (2021). The impact of low-intensity blood flow restriction endurance training on aerobic capacity, hemodynamics, and arterial stiffness. J. Sports Med. Phys. Fitness 61, 877-884. doi: 10.23736/S0022-4707.20.11526-3 [doi].

Karabulut, M., McCarron, J., Abe, T., Sato, Y., Bemben, M. (2011). The effects of different initial restrictive pressures used to reduce blood flow and thigh composition on tissue oxygenation of the quadriceps. J. Sports Sci. 29, 951-958. doi: 10.1080/02640414.2011.572992 [doi].

Karabulut, M., Sherk, V.D., Bemben, D.A., Bemben, M.G. (2013). Inflammation marker, damage marker and anabolic hormone responses to resistance training with vascular restriction in older males. Clin. Physiol. Funct. Imaging 33, 393-399. doi: 10.1111/cpf.12044 [doi].

Kataoka, R., Vasenina, E., Hammert, W.B., Ibrahim, A.H., Dankel, S.J., Buckner, S.L. (2022). Muscle growth adaptations to high-load training and low-load training with blood flow restriction in calf muscles. Eur. J. Appl. Physiol. doi: 10.1007/s00421-021-04862-7 [doi].

Khan, K.M., and Scott, A. (2009). Mechanotherapy: how physical therapists' prescription of exercise promotes tissue repair. Br. J. Sports Med. 43, 247-252. doi: 10.1136/bjsm.2008.054239 [doi].

Kilgas, M.A., Lytle, L.L.M., Drum, S.N., Elmer, S.J. (2019). Exercise with Blood Flow Restriction to Improve Quadriceps Function Long After ACL Reconstruction. Int. J. Sports Med. 40, 650-656. doi: 10.1055/a-0961-1434 [doi].

Kim, D., Loenneke, J.P., Ye, X., Bemben, D.A., Beck, T.W., Larson, R.D., Bemben, M.G. (2017). Low-load resistance training with low relative pressure produces muscular changes similar to high-load resistance training. Muscle Nerve 56, E126-E133. doi: 10.1002/mus.25626 [doi].

Klein, M.B., Pham, H., Yalamanchi, N., Chang, J. (2001). Flexor tendon wound healing in vitro: the effect of lactate on tendon cell proliferation and collagen production. J. Hand Surg. Am. 26, 847-854. doi: S0363-5023(01)22297-7 [pii].

Kongsgaard, M., Qvortrup, K., Larsen, J., Aagaard, P., Doessing, S., Hansen, P., Kjaer, M., Magnusson, S.P. (2010). Fibril morphology and tendon mechanical properties in patellar tendinopathy: effects of heavy slow resistance training. Am. J. Sports Med. 38, 749-756. doi: 10.1177/0363546509350915 [doi].

Korakakis, V., Whiteley, R., Epameinontidis, K. (2018). Blood Flow Restriction induces hypoalgesia in recreationally active adult male anterior knee pain patients allowing therapeutic exercise loading. Phys. Ther. Sport. 32, 235-243. doi: S1466-853X(17)30503-5 [pii].

Korakakis, V., Whiteley, R., Giakas, G. (2018). Low load resistance training with blood flow restriction decreases anterior knee pain more than resistance training alone. A pilot randomised controlled trial. Phys. Ther. Sport. 34, 121-128. doi: S1466-853X(18)30358-4 [pii].

Kraemer, W.J., and Ratamess, N.A. (2004). Fundamentals of resistance training: progression and exercise prescription. Med. Sci. Sports Exerc. 36, 674-688. doi: 00005768-200404000-00017 [pii].

Krieger, J., Sims, D., Wolterstorff, C. (2018). A Case of Rhabdomyolysis Caused by Blood Flow-Restricted Resistance Training. J. Spec. Oper. Med. Summer 18, 16-17.

Krogh, S., Jonsson, A.B., Vibjerg, J., Severinsen, K., Aagaard, P., Kasch, H. (2020). Feasibility and safety of 4 weeks of blood flow-restricted exercise in an individual with tetraplegia and known autonomic dysreflexia: a case report. Spinal. Cord. Ser. Cases 6, 83-020-00335-9. doi: 10.1038/s41394-020-00335-9 [doi].

Krzysztofik, M., Wilk, M., Wojdala, G., Golas, A. (2019). Maximizing Muscle Hypertrophy: A Systematic Review of Advanced Resistance Training Techniques and Methods. Int. J. Environ. Res. Public. Health. 16, 10.3390/ijerph16244897. doi: E4897 [pii].

Kubo, K., Komuro, T., Ishiguro, N., Tsunoda, N., Sato, Y., Ishii, N., Kanehisa, H., Fukunaga, T. (2006). Effects of low-load resistance training with vascular occlusion on the mechanical properties of muscle and tendon. J. Appl. Biomech. 22, 112-119. doi: 10.1123/jab.22.2.112 [doi].

Kubota, A., Sakuraba, K., Koh, S., Ogura, Y., Tamura, Y. (2011). Blood flow restriction by low compressive force prevents disuse muscular weakness. J. Sci. Med. Sport 14, 95-99. doi: 10.1016/j.jsams.2010.08.007 [doi].

Labata-Lezaun, N., Llurda-Almuzara, L., Gonzalez-Rueda, V., Lopez-de-Celis, C., Cedeno-Bermudez, S., Banuelos-Pago, J., Perez-Bellmunt, A. (2022). Effectiveness of Blood Flow Restriction Training on Muscle Strength and Physical Performance in Older Adults: A Systematic Review and Meta-analysis. Arch. Phys. Med. Rehabil. doi: S0003-9993(22)00004-1 [pii].

Ladlow, P., Coppack, R.J., Dharm-Datta, S., Conway, D., Sellon, E., Patterson, S.D., Bennett, A.N. (2018). Low-Load Resistance Training With Blood Flow Restriction Improves Clinical Outcomes in Musculoskeletal Rehabilitation: A Single-Blind Randomized Controlled Trial. Front. Physiol. 9, 1269. doi: 10.3389/fphys.2018.01269 [doi].

Lambert, B., Hedt, C., Daum, J., Taft, C., Chaliki, K., Epner, E., McCulloch, P. (2021). Blood Flow Restriction Training for the Shoulder: A Case for Proximal Benefit. Am. J. Sports Med. 49, 2716-2728. doi: 10.1177/03635465211017524 [doi].

Larsen, P., Platzer, O.J., Lollesgaard, L., Pedersen, S.K., Nielsen, P.K., Rathleff, M.S., Bandholm, T., Jensen, S.T., Elsoe, R. (2021). Blood-flow restricted exercise following ankle fractures - A feasibility study. Foot Ankle Surg. doi: S1268-7731(21)00181-8 [pii].

Lasevicius, T., Schoenfeld, B.J., Silva-Batista, C., Barros, T.S., Aihara, A.Y., Brendon, H., Longo, A.R., Tricoli, V., Peres, B.A., Teixeira, E.L. (2019). Muscle Failure Promotes Greater Muscle Hypertrophy in Low-Load but Not in High-Load Resistance Training. J. Strength Cond Res. doi: 10.1519/JSC.0000000000003454 [doi].

Lasevicius, T., Ugrinowitsch, C., Schoenfeld, B.J., Roschel, H., Tavares, L.D., De Souza, E.O., Laurentino, G., Tricoli, V. (2018). Effects of different intensities of resistance training with equated volume load on muscle strength and hypertrophy. Eur. J. Sport. Sci. 18, 772-780. doi: 10.1080/17461391.2018.1450898 [doi].

Lauber, B., Konig, D., Gollhofer, A., Centner, C. (2021). Isometric blood flow restriction exercise: acute physiological and neuromuscular responses. BMC Sports Sci. Med. Rehabil. 13, 12. doi: 10.1186/s13102-021-00239-7 [doi].

Laurentino, G., Ugrinowitsch, C., Aihara, A.Y., Fernandes, A.R., Parcell, A.C., Ricard, M., Tricoli, V. (2008). Effects of strength training and vascular occlusion. Int. J. Sports Med. 29, 664-667. doi: 10.1055/s-2007-989405 [doi].

Laurentino, G.C., Loenneke, J.P., Teixeira, E.L., Nakajima, E., Iared, W., Tricoli, V. (2016). The Effect of Cuff Width on Muscle Adaptations after Blood Flow Restriction Training. Med. Sci. Sports Exerc. 48, 920-925. doi: 10.1249/MSS.0000000000000833 [doi].

Laurentino, G.C., Ugrinowitsch, C., Roschel, H., Aoki, M.S., Soares, A.G., Neves, M.,Jr, Aihara, A.Y., Fernandes Ada, R., Tricoli, V. (2012). Strength training with blood flow restriction diminishes myostatin gene expression. Med. Sci. Sports Exerc. 44, 406-412. doi: 10.1249/MSS.0b013e318233b4bc [doi].

Lear, A. (2019). A Randomized Controlled Trial of Blood Flow Restriction Plus Conventional Physical Therapy vs. Conventional Physical Therapy Alone in the Treatment of Lateral Epicondylitis.
https://clinicaltrials.gov/ct2/show/NCT03978897

Letieri, R.V., Teixeira, A.M., Furtado, G.E., Lamboglia, C.G., Rees, J.L., Gomes, B.B. (2018). Effect of 16weeks of resistance exercise and detraining comparing two methods of blood flow restriction in muscle strength of healthy older women: A randomized controlled trial. Exp. Gerontol. 114, 78-86. doi: S0531-5565(18)30453-4 [pii].

Li, S., Shaharudin, S., Abdul Kadir, M.R. (2021). Effects of Blood Flow Restriction Training on Muscle Strength and Pain in Patients With Knee Injuries: A Meta-Analysis. Am. J. Phys. Med. Rehabil. 100, 337-344. doi: 10.1097/PHM.0000000000001567 [doi].

Lian, O.B., Engebretsen, L., Bahr, R. (2005). Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. Am. J. Sports Med. 33, 561-567. doi: 0363546504270454 [pii].

Libardi, C.A., Chacon-Mikahil, M.P., Cavaglieri, C.R., Tricoli, V., Roschel, H., Vechin, F.C., Conceicao, M.S., Ugrinowitsch, C. (2015). Effect of concurrent training with blood flow restriction in the elderly. Int. J. Sports Med. 36, 395-399. doi: 10.1055/s-0034-1390496 [doi].

Lim, H.Y., and Wong, S.H. (2018). Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review. Physiother. Res. Int. 23, e1721. doi: 10.1002/pri.1721 [doi].

Lipker, L.A., Persinger, C.R., Michalko, B.S., Durall, C.J. (2019). Blood Flow Restriction Therapy Versus Standard Care for Reducing Quadriceps Atrophy After Anterior Cruciate Ligament Reconstruction. J. Sport. Rehabil. 28, 897-901. doi: 10.1123/jsr.2018-0062 [doi].

Lixandrao, M.E., Roschel, H., Ugrinowitsch, C., Miquelini, M., Alvarez, I.F., Libardi, C.A. (2019). Blood-Flow Restriction Resistance Exercise Promotes Lower Pain and Ratings of Perceived Exertion Compared With Either High- or Low-Intensity Resistance Exercise Performed to Muscular Failure. J. Sport. Rehabil. 28, 706-710. doi: 10.1123/jsr.2018-0030 [doi].

Lixandrao, M.E., Ugrinowitsch, C., Berton, R., Vechin, F.C., Conceicao, M.S., Damas, F., Libardi, C.A., Roschel, H. (2018). Magnitude of Muscle Strength and Mass Adaptations Between High-Load Resistance Training Versus Low-Load Resistance Training Associated with Blood-Flow Restriction: A Systematic Review and Meta-Analysis. Sports Med. 48, 361-378. doi: 10.1007/s40279-017-0795-y [doi].

Lixandrao, M.E., Ugrinowitsch, C., Laurentino, G., Libardi, C.A., Aihara, A.Y., Cardoso, F.N., Tricoli, V., Roschel, H. (2015). Effects of exercise intensity and occlusion pressure after 12 weeks of resistance training with blood-flow restriction. Eur. J. Appl. Physiol. 115, 2471-2480. doi: 10.1007/s00421-015-3253-2 [doi].

Loenneke, J.P., Abe, T., Wilson, J.M., Ugrinowitsch, C., Bemben, M.G. (2012). Blood flow restriction: how does it work? Front. Physiol. 3, 392. doi: 10.3389/fphys.2012.00392 [doi].

Loenneke, J.P., Balapur, A., Thrower, A.D., Barnes, J.T., Pujol, T.J. (2011). The perceptual responses to occluded exercise. Int. J. Sports Med. 32, 181-184. doi: 10.1055/s-0030-1268472 [doi].

Loenneke, J.P., Fahs, C.A., Rossow, L.M., Abe, T., Bemben, M.G. (2012). The anabolic benefits of venous blood flow restriction training may be induced by muscle cell swelling. Med. Hypotheses 78, 151-154. doi: 10.1016/j.mehy.2011.10.014 [doi].

Loenneke, J.P., Fahs, C.A., Rossow, L.M., Thiebaud, R.S., Mattocks, K.T., Abe, T., Bemben, M.G. (2013). Blood flow restriction pressure recommendations: a tale of two cuffs. Front. Physiol. 4, 249. doi: 10.3389/fphys.2013.00249 [doi].

Loenneke, J.P., Fahs, C.A., Thiebaud, R.S., Rossow, L.M., Abe, T., Ye, X., Kim, D., Bemben, M.G. (2013). The acute hemodynamic effects of blood flow restriction in the absence of exercise. Clin. Physiol. Funct. Imaging 33, 79-82. doi: 10.1111/j.1475-097X.2012.01157.x [doi].

Loenneke, J.P., Kearney, M.L., Thrower, A.D., Collins, S., Pujol, T.J. (2010). The acute response of practical occlusion in the knee extensors. J. Strength Cond Res. 24, 2831-2834. doi: 10.1519/JSC.0b013e3181f0ac3a [doi].

Loenneke, J.P., Kim, D., Fahs, C.A., Thiebaud, R.S., Abe, T., Larson, R.D., Bemben, D.A., Bemben, M.G. (2017). The influence of exercise load with and without different levels of blood flow restriction on acute changes in muscle thickness and lactate. Clin. Physiol. Funct. Imaging 37, 734-740. doi: 10.1111/cpf.12367 [doi].

Loenneke, J.P., Loprinzi, P.D., Abe, T., Thiebaud, R.S., Allen, K.M., Grant Mouser, J., Bemben, M.G. (2016). Arm circumference influences blood pressure even when applying the correct cuff size: Is a further correction needed? Int. J. Cardiol. 202, 743-744. doi: 10.1016/j.ijcard.2015.10.009 [doi].

Loenneke, J.P., Thiebaud, R.S., Abe, T. (2014). Does blood flow restriction result in skeletal muscle damage? A critical review of available evidence. Scand. J. Med. Sci. Sports 24, e415-422. doi: 10.1111/sms.12210 [doi].

Loenneke, J.P., Thiebaud, R.S., Abe, T., Manfro, I.G., Marin, P.J. (2013). Acute blood flow restricted exercise to treat Duchenne muscular dystrophy: would it be efficacious? Front. Physiol. 4, 114. doi: 10.3389/fphys.2013.00114 [doi].

Loenneke, J.P., Thiebaud, R.S., Fahs, C.A., Rossow, L.M., Abe, T., Bemben, M.G. (2013). Effect of cuff type on arterial occlusion. Clin. Physiol. Funct. Imaging 33, 325-327. doi: 10.1111/cpf.12035 [doi].

Loenneke, J.P., Wilson, G.J., Wilson, J.M. (2010). A mechanistic approach to blood flow occlusion. Int. J. Sports Med. 31, 1-4. doi: 10.1055/s-0029-1239499 [doi].

Loenneke, J.P., Wilson, J.M., Balapur, A., Thrower, A.D., Barnes, J.T., Pujol, T.J. (2012). Time under tension decreased with blood flow-restricted exercise. Clin. Physiol. Funct. Imaging 32, 268-273. doi: 10.1111/j.1475-097X.2012.01121.x [doi].

Loenneke, J.P., Wilson, J.M., Marin, P.J., Zourdos, M.C., Bemben, M.G. (2012). Low intensity blood flow restriction training: a meta-analysis. Eur. J. Appl. Physiol. 112, 1849-1859. doi: 10.1007/s00421-011-2167-x [doi].

Loenneke, J.P., Young, K.C., Wilson, J.M., Andersen, J.C. (2013). Rehabilitation of an osteochondral fracture using blood flow restricted exercise: a case review. J. Bodyw Mov. Ther. 17, 42-45. doi: 10.1016/j.jbmt.2012.04.006 [doi].

Lopez-Garzon, M., Cantarero-Villanueva, I., Legeren-Alvarez, M., Gallart-Aragon, T., Postigo-Martin, P., Gonzalez-Santos, A., Lozano-Lozano, M., Martin-Martin, L., Ortiz-Comino, L., Castro-Martin, E., Ariza-Garcia, A., Fernandez-Lao, C., Arroyo-Morales, M., Galiano-Castillo, N. (2022). Prevention of Chemotherapy-Induced Peripheral Neuropathy with PRESIONA, a Therapeutic Exercise and Blood Flow Restriction Program: A Randomized Controlled Study Protocol. Phys. Ther. doi: pzab282 [pii].

Lorenz, D.S., Bailey, L., Wilk, K.E., Mangine, R.E., Head, P., Grindstaff, T.L., Morrison, S. (2021). Blood Flow Restriction Training. J. Athl Train. 56, 937-944. doi: 10.4085/418-20 [doi].

Lowery, R.P., Joy, J.M., Loenneke, J.P., de Souza, E.O., Machado, M., Dudeck, J.E., Wilson, J.M. (2014). Practical blood flow restriction training increases muscle hypertrophy during a periodized resistance training programme. Clin. Physiol. Funct. Imaging 34, 317-321. doi: 10.1111/cpf.12099 [doi].

Lu, Y., Patel, B.H., Kym, C., Nwachukwu, B.U., Beletksy, A., Forsythe, B., Chahla, J. (2020). Perioperative Blood Flow Restriction Rehabilitation in Patients Undergoing ACL Reconstruction: A Systematic Review. Orthop. J. Sports Med. 8, 2325967120906822. doi: 10.1177/2325967120906822 [doi].

Luebbers, P.E., Fry, A.C., Kriley, L.M., Butler, M.S. (2014). The effects of a 7-week practical blood flow restriction program on well-trained collegiate athletes. J. Strength Cond Res. 28, 2270-2280. doi: 10.1519/JSC.0000000000000385 [doi].

Madarame, H., Kurano, M., Fukumura, K., Fukuda, T., Nakajima, T. (2013). Haemostatic and inflammatory responses to blood flow-restricted exercise in patients with ischaemic heart disease: a pilot study. Clin. Physiol. Funct. Imaging 33, 11-17. doi: 10.1111/j.1475-097X.2012.01158.x [doi].

Madarame, H., Kurano, M., Takano, H., Iida, H., Sato, Y., Ohshima, H., Abe, T., Ishii, N., Morita, T., Nakajima, T. (2010). Effects of low-intensity resistance exercise with blood flow restriction on coagulation system in healthy subjects. Clin. Physiol. Funct. Imaging 30, 210-213. doi: 10.1111/j.1475-097X.2010.00927.x [doi].

Madarame, H., Neya, M., Ochi, E., Nakazato, K., Sato, Y., Ishii, N. (2008). Cross-transfer effects of resistance training with blood flow restriction. Med. Sci. Sports Exerc. 40, 258-263. doi: 10.1249/mss.0b013e31815c6d7e [doi].

Mafi, N., Lorentzon, R., Alfredson, H. (2001). Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. Knee Surg. Sports Traumatol. Arthrosc. 9, 42-47. doi: 10.1007/s001670000148 [doi].

Magnusson, S.P., and Kjaer, M. (2019). The impact of loading, unloading, ageing and injury on the human tendon. J. Physiol. 597, 1283-1298. doi: 10.1113/JP275450 [doi].

Malliaras, P., Barton, C.J., Reeves, N.D., Langberg, H. (2013). Achilles and patellar tendinopathy loading programmes : a systematic review comparing clinical outcomes and identifying potential mechanisms for effectiveness. Sports Med. 43, 267-286. doi: 10.1007/s40279-013-0019-z [doi].

Manimmanakorn, A., Hamlin, M.J., Ross, J.J., Taylor, R., Manimmanakorn, N. (2013). Effects of low-load resistance training combined with blood flow restriction or hypoxia on muscle function and performance in netball athletes. J. Sci. Med. Sport 16, 337-342. doi: 10.1016/j.jsams.2012.08.009 [doi].

Manini, T.M., and Clark, B.C. (2009). Blood flow restricted exercise and skeletal muscle health. Exerc. Sport Sci. Rev. 37, 78-85. doi: 10.1097/JES.0b013e31819c2e5c [doi].

Martin-Hernandez, J., Marin, P.J., Menendez, H., Ferrero, C., Loenneke, J.P., Herrero, A.J. (2013). Muscular adaptations after two different volumes of blood flow-restricted training. Scand. J. Med. Sci. Sports 23, e114-20. doi: 10.1111/sms.12036 [doi].

Martin-Hernandez, J., Marin, P.J., Menendez, H., Loenneke, J.P., Coelho-e-Silva, M.J., Garcia-Lopez, D., Herrero, A.J. (2013). Changes in muscle architecture induced by low load blood flow restricted training. Acta Physiol. Hung. 100, 411-418. doi: 10.1556/APhysiol.100.2013.011 [doi].

Martin-Hernandez, J., Ruiz-Aguado, J., Herrero, A.J., Loenneke, J.P., Aagaard, P., Cristi-Montero, C., Menendez, H., Marin, P.J. (2017). Adaptation of Perceptual Responses to Low-Load Blood Flow Restriction Training. J. Strength Cond Res. 31, 765-772. doi: 10.1519/JSC.0000000000001478 [doi].

Mason, J.S., Crowell, M.S., Brindle, R.A., Dolbeer, J.A., Miller, E.M., Telemeco, T.A., Goss, D.L. (2021). The Effect of Blood Flow Restriction Training on Muscle Atrophy Following Meniscal Repair or Chondral Restoration Surgery in Active Duty Military: A Randomized Controlled Trial. J. Sport. Rehabil., 1-8. doi: 10.1123/jsr.2020-0518 [doi].

Mattar, M.A., Gualano, B., Perandini, L.A., Shinjo, S.K., Lima, F.R., Sa-Pinto, A.L., Roschel, H. (2014). Safety and possible effects of low-intensity resistance training associated with partial blood flow restriction in polymyositis and dermatomyositis. Arthritis Res. Ther. 16, 473-014-0473-5. doi: 10.1186/s13075-014-0473-5 [doi].

Mattocks, K.T., Jessee, M.B., Counts, B.R., Buckner, S.L., Grant Mouser, J., Dankel, S.J., Laurentino, G.C., Loenneke, J.P. (2017). The effects of upper body exercise across different levels of blood flow restriction on arterial occlusion pressure and perceptual responses. Physiol. Behav. 171, 181-186. doi: S0031-9384(16)30821-6 [pii].

May, A.K., Brandner, C.R., Warmington, S.A. (2017). Hemodynamic responses are reduced with aerobic compared with resistance blood flow restriction exercise. Physiol. Rep. 5, 10.14814/phy2.13142. doi: e13142 [pii].

McEwen, J., and Hughes, L. (2020). Pressure Prescription for Blood Flow Restriction Exercise. Med. Sci. Sports Exerc. 52, 1436. doi: 10.1249/MSS.0000000000002316 [doi].

Mendonca, G.V., Vaz, J.R., Pezarat-Correia, P., Fernhall, B. (2015). Effects of Walking with Blood Flow Restriction on Excess Post-exercise Oxygen Consumption. Int. J. Sports Med. 36, e11-e18. doi: 10.1055/s-0034-1395508 [doi].

Mendonca, L.M., Leite, H.R., Zwerver, J., Henschke, N., Branco, G., Oliveira, V.C. (2020). How strong is the evidence that conservative treatment reduces pain and improves function in individuals with patellar tendinopathy? A systematic review of randomised controlled trials including GRADE recommendations. Br. J. Sports Med. 54, 87-93. doi: 10.1136/bjsports-2018-099747 [doi].

Mersmann, F., Laube, G., Marzilger, R., Bohm, S., Schroll, A., Arampatzis, A. (2021). A Functional High-Load Exercise Intervention for the Patellar Tendon Reduces Tendon Pain Prevalence During a Competitive Season in Adolescent Handball Players. Front. Physiol. 12, 626225. doi: 10.3389/fphys.2021.626225 [doi].

Millar, N.L., Silbernagel, K.G., Thorborg, K., Kirwan, P.D., Galatz, L.M., Abrams, G.D., Murrell, G.A.C., McInnes, I.B., Rodeo, S.A. (2021). Tendinopathy. Nat. Rev. Dis. Primers 7, 1-020-00234-1. doi: 10.1038/s41572-020-00234-1 [doi].

Miller, B.C., Tirko, A.W., Shipe, J.M., Sumeriski, O.R., Moran, K. (2021). The Systemic Effects of Blood Flow Restriction Training: A Systematic Review. Int. J. Sports Phys. Ther. 16, 978-990. doi: 10.26603/001c.25791 [doi].

Minniti, M.C., Statkevich, A.P., Kelly, R.L., Rigsby, V.P., Exline, M.M., Rhon, D.I., Clewley, D. (2020). The Safety of Blood Flow Restriction Training as a Therapeutic Intervention for Patients With Musculoskeletal Disorders: A Systematic Review. Am. J. Sports Med. 48, 1773-1785. doi: 10.1177/0363546519882652 [doi].

Moore, D.R., Burgomaster, K.A., Schofield, L.M., Gibala, M.J., Sale, D.G., Phillips, S.M. (2004). Neuromuscular adaptations in human muscle following low intensity resistance training with vascular occlusion. Eur. J. Appl. Physiol. 92, 399-406. doi: 10.1007/s00421-004-1072-y [doi].

Moriggi, R.,Jr, Mauro, H.D., Dias, S.C., Matos, J.M., Urtado, M.B., Camarco, N.F., Neto, I.S., Nascimento, D.C., Tibana, R.A., Assumpcao, C.O., Prestes, J., Urtado, C.B. (2015). Similar hypotensive responses to resistance exercise with and without blood flow restriction. Biol. Sport. 32, 289-294. doi: 10.5604/20831862.1163691 [doi].

Mouser, J.G., Dankel, S.J., Jessee, M.B., Mattocks, K.T., Buckner, S.L., Counts, B.R., Loenneke, J.P. (2017). A tale of three cuffs: the hemodynamics of blood flow restriction. Eur. J. Appl. Physiol. 117, 1493-1499. doi: 10.1007/s00421-017-3644-7 [doi].

Murphy, M.C., Travers, M.J., Chivers, P., Debenham, J.R., Docking, S.I., Rio, E.K., Gibson, W. (2019). Efficacy of heavy eccentric calf training for treating mid-portion Achilles tendinopathy: a systematic review and meta-analysis. Br. J. Sports Med. 53, 1070-1077. doi: 10.1136/bjsports-2018-099934 [doi].

Murtaugh, B., and Ihm, J.M. (2013). Eccentric training for the treatment of tendinopathies. Curr. Sports Med. Rep. 12, 175-182. doi: 10.1249/JSR.0b013e3182933761 [doi].

Neto, G.R., Novaes, J.S., Salerno, V.P., Goncalves, M.M., Batista, G.R., Cirilo-Sousa, M.S. (2018). Does a resistance exercise session with continuous or intermittent blood flow restriction promote muscle damage and increase oxidative stress? J. Sports Sci. 36, 104-110. doi: 10.1080/02640414.2017.1283430 [doi].

Neto, G.R., Sousa, M.S., Costa e Silva, G.V., Gil, A.L., Salles, B.F., Novaes, J.S. (2016). Acute resistance exercise with blood flow restriction effects on heart rate, double product, oxygen saturation and perceived exertion. Clin. Physiol. Funct. Imaging 36, 53-59. doi: 10.1111/cpf.12193 [doi].

Nielsen, J.L., Aagaard, P., Bech, R.D., Nygaard, T., Hvid, L.G., Wernbom, M., Suetta, C., Frandsen, U. (2012). Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood flow restriction. J. Physiol. 590, 4351-4361. doi: 10.1113/jphysiol.2012.237008 [doi].

Nielsen, J.L., Aagaard, P., Prokhorova, T.A., Nygaard, T., Bech, R.D., Suetta, C., Frandsen, U. (2017). Blood flow restricted training leads to myocellular macrophage infiltration and upregulation of heat shock proteins, but no apparent muscle damage. J. Physiol. 595, 4857-4873. doi: 10.1113/JP273907 [doi].

Nitzsche, N., Stauber, A., Tiede, S., Schulz, H. (2021). The effectiveness of blood-flow restricted resistance training in the musculoskeletal rehabilitation of patients with lower limb disorders: A systematic review and meta-analysis. Clin. Rehabil. 35, 1221-1234. doi: 10.1177/02692155211003480 [doi].

Noto, T., Hashimoto, G., Takagi, T., Awaya, T., Araki, T., Shiba, M., Iijima, R., Hara, H., Moroi, M., Nakamura, M., Sugi, K. (2017). Paget-Schroetter Syndrome Resulting from Thoracic Outlet Syndrome and KAATSU Training. Intern. Med. 56, 2595-2601. doi: 10.2169/internalmedicine.7937-16 [doi].

Noyes, F.R., Barber-Westin, S.D., Sipes, L. (2021). Blood Flow Restriction Training Can Improve Peak Torque Strength in Chronic Atrophic Postoperative Quadriceps and Hamstrings Muscles. Arthroscopy 37, 2860-2869. doi: S0749-8063(21)00279-6 [pii].

Nyyssonen, T., Luthje, P., Kroger, H. (2008). The increasing incidence and difference in sex distribution of Achilles tendon rupture in Finland in 1987-1999. Scand. J. Surg. 97, 272-275. doi: 10.1177/145749690809700312 [doi].

Ogawa, H., Nakajima, T., Shibasaki, I., Nasuno, T., Kaneda, H., Katayanagi, S., Ishizaka, H., Mizushima, Y., Uematsu, A., Yasuda, T., Yagi, H., Toyoda, S., Hortobagyi, T., Mizushima, T., Inoue, T., Fukuda, H. (2021). Low-Intensity Resistance Training with Moderate Blood Flow Restriction Appears Safe and Increases Skeletal Muscle Strength and Size in Cardiovascular Surgery Patients: A Pilot Study. J. Clin. Med. 10, 10.3390/jcm10030547. doi: 547 [pii].

Ohta, H., Kurosawa, H., Ikeda, H., Iwase, Y., Satou, N., Nakamura, S. (2003). Low-load resistance muscular training with moderate restriction of blood flow after anterior cruciate ligament reconstruction. Acta Orthop. Scand. 74, 62-68. doi: 10.1080/00016470310013680 [doi].

Okita, K., Takada, S., Morita, N., Takahashi, M., Hirabayashi, K., Yokota, T., Kinugawa, S. (2019). Resistance training with interval blood flow restriction effectively enhances intramuscular metabolic stress with less ischemic duration and discomfort. Appl. Physiol. Nutr. Metab. 44, 759-764. doi: 10.1139/apnm-2018-0321 [doi].

Ozaki, H., Loenneke, J.P., Buckner, S.L., Abe, T. (2016). Muscle growth across a variety of exercise modalities and intensities: Contributions of mechanical and metabolic stimuli. Med. Hypotheses 88, 22-26. doi: 10.1016/j.mehy.2015.12.026 [doi].

Ozaki, T., Muramatsu, R., Sasai, M., Yamamoto, M., Kubota, Y., Fujinaka, T., Yoshimine, T., Yamashita, T. (2016). The P2X4 receptor is required for neuroprotection via ischemic preconditioning. Sci. Rep. 6, 25893. doi: 10.1038/srep25893 [doi].

Palhano, P. (2020). Blood Flow Restriction Exercise in the Treatment of Lateral Epicondylalgia vs Traditional Treatment. https://clinicaltrials.gov/ct2/show/NCT04607356

Palmieri-Smith, R.M., and Lepley, L.K. (2015). Quadriceps Strength Asymmetry After Anterior Cruciate Ligament Reconstruction Alters Knee Joint Biomechanics and Functional Performance at Time of Return to Activity. Am. J. Sports Med. 43, 1662-1669. doi: 10.1177/0363546515578252 [doi].

Patterson, S.D., and Ferguson, R.A. (2011). Enhancing strength and postocclusive calf blood flow in older people with training with blood-flow restriction. J. Aging Phys. Act. 19, 201-213. doi: 10.1123/japa.19.3.201 [doi].

Patterson, S.D., and Ferguson, R.A. (2010). 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. 108, 1025-1033. doi: 10.1007/s00421-009-1309-x [doi].

Patterson, S.D., Hughes, L., Head, P., Warmington, S., Brandner, C. (2017). Blood flow restriction training: a novel approach to augment clinical rehabilitation: how to do it. Br. J. Sports Med. 51, 1648-1649. doi: 10.1136/bjsports-2017-097738 [doi].

Patterson, S.D., Hughes, L., Warmington, S., Burr, J., Scott, B.R., Owens, J., Abe, T., Nielsen, J.L., Libardi, C.A., Laurentino, G., Neto, G.R., Brandner, C., Martin-Hernandez, J., Loenneke, J. (2019). Blood Flow Restriction Exercise: Considerations of Methodology, Application, and Safety. Front. Physiol. 10, 533. doi: 10.3389/fphys.2019.00533 [doi].

Pearson, S.J., and Hussain, S.R. (2015). A review on the mechanisms of blood-flow restriction resistance training-induced muscle hypertrophy. Sports Med. 45, 187-200. doi: 10.1007/s40279-014-0264-9 [doi].

Peterson, M., Butler, S., Eriksson, M., Svardsudd, K. (2014). A randomized controlled trial of eccentric vs. concentric graded exercise in chronic tennis elbow (lateral elbow tendinopathy). Clin. Rehabil. 28, 862-872. doi: 10.1177/0269215514527595 [doi].

Picon-Martinez, M., Chulvi-Medrano, I., Cortell-Tormo, J.M., Alonso-Aubin, D.A., Alakhdar, Y., Laurentino, G. (2021). Acute Effects of Resistance Training with Blood Flow Restriction on Achilles Tendon Thickness. J. Hum. Kinet 78, 101-109. doi: 10.2478/hukin-2021-0032 [doi].

Pinto, R.R., and Polito, M.D. (2016). Haemodynamic responses during resistance exercise with blood flow restriction in hypertensive subjects. Clin. Physiol. Funct. Imaging 36, 407-413. doi: 10.1111/cpf.12245 [doi].

Pitsillides, A., Stasinopoulos, D., Mamais, I. (2021). Blood flow restriction training in patients with knee osteoarthritis: Systematic review of randomized controlled trials. J. Bodyw Mov. Ther. 27, 477-486. doi: S1360-8592(21)00089-9 [pii].

Post, D.R., Stackhouse, W.A., Ostrowski, J.L., Bettleyon, J.D., Payne, E.K. (2022). The Effect of Blood Flow Restriction on Muscle Hypertrophy and Tendon Thickness in Healthy Adults' Distal Lower-Extremity: A Critically Appraised Topic. J. Sport. Rehabil., 1-5. doi: 10.1123/jsr.2021-0176 [doi].

Raskob, G.E., Angchaisuksiri, P., Blanco, A.N., Buller, H., Gallus, A., Hunt, B.J., Hylek, E.M., Kakkar, A., Konstantinides, S.V., McCumber, M., Ozaki, Y., Wendelboe, A., Weitz, J.I., ISTH Steering Committee for World Thrombosis Day. (2014). Thrombosis: a major contributor to global disease burden. Arterioscler. Thromb. Vasc. Biol. 34, 2363-2371. doi: 10.1161/ATVBAHA.114.304488 [doi].

Rathleff, M.S., Molgaard, C.M., Fredberg, U., Kaalund, S., Andersen, K.B., Jensen, T.T., Aaskov, S., Olesen, J.L. (2015). High-load strength training improves outcome in patients with plantar fasciitis: A randomized controlled trial with 12-month follow-up. Scand. J. Med. Sci. Sports 25, e292-300. doi: 10.1111/sms.12313 [doi].

Reis, J.F., Fatela, P., Mendonca, G.V., Vaz, J.R., Valamatos, M.J., Infante, J., Mil-Homens, P., Alves, F.B. (2019). Tissue Oxygenation in Response to Different Relative Levels of Blood-Flow Restricted Exercise. Front. Physiol. 10, 407. doi: 10.3389/fphys.2019.00407 [doi].

Renzi, C.P., Tanaka, H., Sugawara, J. (2010). Effects of leg blood flow restriction during walking on cardiovascular function. Med. Sci. Sports Exerc. 42, 726-732. doi: 10.1249/MSS.0b013e3181bdb454 [doi].

Ribeiro, A.B., de Araujo, C.B., Silva, L.E.V., Fazan-Junior, R., Salgado, H.C., Ribeiro, A.B., Fortes, C.V., Bueno, F.L., de Oliveira, V.C., de F O Paranhos, H., Watanabe, E., da Silva-Lovato, C.H. (2019). Hygiene protocols for the treatment of denture-related stomatitis: local and systemic parameters analysis - a randomized, double-blind trial protocol. Trials 20, 661-019-3854-x. doi: 10.1186/s13063-019-3854-x [doi].

Riel, H., Jensen, M.B., Olesen, J.L., Vicenzino, B., Rathleff, M.S. (2019). Self-dosed and pre-determined progressive heavy-slow resistance training have similar effects in people with plantar fasciopathy: a randomised trial. J. Physiother. 65, 144-151. doi: S1836-9553(19)30058-X [pii].

Rodrigo-Mallorca, D., Loaiza-Betancur, A.F., Monteagudo, P., Blasco-Lafarga, C., Chulvi-Medrano, I. (2021). Resistance Training with Blood Flow Restriction Compared to Traditional Resistance Training on Strength and Muscle Mass in Non-Active Older Adults: A Systematic Review and Meta-Analysis. Int. J. Environ. Res. Public. Health. 18, 10.3390/ijerph182111441. doi: 11441 [pii].

Rodrigues, R., Ferraz, R.B., Kurimori, C.O., Guedes, L.K., Lima, F.R., de Sa-Pinto, A.L., Gualano, B., Roschel, H. (2020). Low-Load Resistance Training With Blood-Flow Restriction in Relation to Muscle Function, Mass, and Functionality in Women With Rheumatoid Arthritis. Arthritis Care. Res. (Hoboken) 72, 787-797. doi: 10.1002/acr.23911 [doi].

Romero-Rodriguez, D., Gual, G., Tesch, P.A. (2011). Efficacy of an inertial resistance training paradigm in the treatment of patellar tendinopathy in athletes: a case-series study. Phys. Ther. Sport. 12, 43-48. doi: 10.1016/j.ptsp.2010.10.003 [doi].

Rossi, F.E., de Freitas, M.C., Zanchi, N.E., Lira, F.S., Cholewa, J.M. (2018). The Role of Inflammation and Immune Cells in Blood Flow Restriction Training Adaptation: A Review. Front. Physiol. 9, 1376. doi: 10.3389/fphys.2018.01376 [doi].

Rossow, L.M., Fahs, C.A., Loenneke, J.P., Thiebaud, R.S., Sherk, V.D., Abe, T., Bemben, M.G. (2012). Cardiovascular and perceptual responses to blood-flow-restricted resistance exercise with differing restrictive cuffs. Clin. Physiol. Funct. Imaging 32, 331-337. doi: 10.1111/j.1475-097X.2012.01131.x [doi].

Ruffino, D., Malliaras, P., Marchegiani, S., Campana, V. (2021). Inertial flywheel vs heavy slow resistance training among athletes with patellar tendinopathy: A randomised trial. Phys. Ther. Sport. 52, 30-37. doi: S1466-853X(21)00124-3 [pii].

Saatmann, N., Zaharia, O.P., Loenneke, J.P., Roden, M., Pesta, D.H. (2021). Effects of Blood Flow Restriction Exercise and Possible Applications in Type 2 Diabetes. Trends Endocrinol. Metab. 32, 106-117. doi: S1043-2760(20)30234-4 [pii].

Saithna, A., Gogna, R., Baraza, N., Modi, C., Spencer, S. (2012). Eccentric Exercise Protocols for Patella Tendinopathy: Should we Really be Withdrawing Athletes from Sport? A Systematic Review. Open Orthop. J. 6, 553-557. doi: 10.2174/1874325001206010553 [doi].

Santos, A.R., Neves, M.T.,Jr, Gualano, B., Laurentino, G.C., Lancha, A.H.,Jr, Ugrinowitsch, C., Lima, F.R., Aoki, M.S. (2014). Blood flow restricted resistance training attenuates myostatin gene expression in a patient with inclusion body myositis. Biol. Sport. 31, 121-124. doi: 10.5604/20831862.1097479 [doi].

Scarpelli, M.C., Bergamasco, J.G.A., Arruda, E.A.B., Cook, S.B., Libardi, C.A. (2021). Resistance Training With Partial Blood Flow Restriction in a 99-Year-Old Individual: A Case Report. Front. Sports Act. Living 3, 671764. doi: 10.3389/fspor.2021.671764 [doi].

Schoenfeld, B.J., Contreras, B., Krieger, J., Grgic, J., Delcastillo, K., Belliard, R., Alto, A. (2019). Resistance Training Volume Enhances Muscle Hypertrophy but Not Strength in Trained Men. Med. Sci. Sports Exerc. 51, 94-103. doi: 10.1249/MSS.0000000000001764 [doi].

Schoenfeld, B.J., Grgic, J., Ogborn, D., Krieger, J.W. (2017). Strength and Hypertrophy Adaptations Between Low- vs. High-Load Resistance Training: A Systematic Review and Meta-analysis. J. Strength Cond Res. 31, 3508-3523. doi: 10.1519/JSC.0000000000002200 [doi].

Scott, B.R., Loenneke, J.P., Slattery, K.M., Dascombe, B.J. (2016). Blood flow restricted exercise for athletes: A review of available evidence. J. Sci. Med. Sport 19, 360-367. doi: 10.1016/j.jsams.2015.04.014 [doi].

Scott, B.R., Loenneke, J.P., Slattery, K.M., Dascombe, B.J. (2015). Exercise with blood flow restriction: an updated evidence-based approach for enhanced muscular development. Sports Med. 45, 313-325. doi: 10.1007/s40279-014-0288-1 [doi].

Segal, N., Davis, M.D., Mikesky, A.E. (2015). Efficacy of Blood Flow-Restricted Low-Load Resistance Training For Quadriceps Strengthening in Men at Risk of Symptomatic Knee Osteoarthritis. Geriatr. Orthop. Surg. Rehabil. 6, 160-167. doi: 10.1177/2151458515583088 [doi].

Segal, N.A., Williams, G.N., Davis, M.C., Wallace, R.B., Mikesky, A.E. (2015). Efficacy of blood flow-restricted, low-load resistance training in women with risk factors for symptomatic knee osteoarthritis. PM R. 7, 376-384. doi: 10.1016/j.pmrj.2014.09.014 [doi].

Segal, S.S. (2014). Blood flow restriction without sympathetic vasoconstriction in ageing skeletal muscle during exercise. J. Physiol. 592, 4607-4608. doi: 10.1113/jphysiol.2014.284018 [doi].

Shakeel, R., Khan, A.A., Ayyub, A., Masood, Z. (2021). Impact of strengthening exercises with and without blood flow restriction on quadriceps of knee osteoarthritis patients. J. Pak. Med. Assoc. 71, 2173-2176. doi: 10.47391/JPMA.377 [doi].

Shimizu, R., Hotta, K., Yamamoto, S., Matsumoto, T., Kamiya, K., Kato, M., Hamazaki, N., Kamekawa, D., Akiyama, A., Kamada, Y., Tanaka, S., Masuda, T. (2016). Low-intensity resistance training with blood flow restriction improves vascular endothelial function and peripheral blood circulation in healthy elderly people. Eur. J. Appl. Physiol. 116, 749-757. doi: 10.1007/s00421-016-3328-8 [doi].

Shiromaru, F.F., de Salles Painelli, V., Silva-Batista, C., Longo, A.R., Lasevicius, T., Schoenfeld, B.J., Aihara, A.Y., Tricoli, V., de Almeida Peres, B., Teixeira, E.L. (2019). Differential muscle hypertrophy and edema responses between high-load and low-load exercise with blood flow restriction. Scand. J. Med. Sci. Sports 29, 1713-1726. doi: 10.1111/sms.13516 [doi].

Sieland, J., Niederer, D., Engeroff, T., Vogt, L., Troidl, C., Schmitz-Rixen, T., Banzer, W., Troidl, K. (2021). Effects of single bouts of different endurance exercises with different intensities on microRNA biomarkers with and without blood flow restriction: a three-arm, randomized crossover trial. Eur. J. Appl. Physiol. 121, 3243-3255. doi: 10.1007/s00421-021-04786-2 [doi].

Silbernagel, K.G. (2014). Does one size fit all when it comes to exercise treatment for Achilles tendinopathy? J. Orthop. Sports Phys. Ther. 44, 42-44. doi: 10.2519/jospt.2014.0103 [doi].

Silbernagel, K.G., Hanlon, S., Sprague, A. (2020). Current Clinical Concepts: Conservative Management of Achilles Tendinopathy. J. Athl Train. 55, 438-447. doi: 10.4085/1062-6050-356-19 [doi].

Silbernagel, K.G., Thomee, R., Eriksson, B.I., Karlsson, J. (2007). Continued sports activity, using a pain-monitoring model, during rehabilitation in patients with Achilles tendinopathy: a randomized controlled study. Am. J. Sports Med. 35, 897-906. doi: 0363546506298279 [pii].

Silva, J.C.G., Aniceto, R.R., Oliota-Ribeiro, L.S., Neto, G.R., Leandro, L.S., Cirilo-Sousa, M.S. (2018). Mood Effects of Blood Flow Restriction Resistance Exercise Among Basketball Players. Percept. Mot. Skills 125, 788-801. doi: 10.1177/0031512518776847 [doi].

Skjong, C.C., Meininger, A.K., Ho, S.S. (2012). Tendinopathy treatment: where is the evidence? Clin. Sports Med. 31, 329-350. doi: 10.1016/j.csm.2011.11.003 [doi].

Slysz, J., Stultz, J., Burr, J.F. (2016). The efficacy of blood flow restricted exercise: A systematic review & meta-analysis. J. Sci. Med. Sport 19, 669-675. doi: 10.1016/j.jsams.2015.09.005 [doi].

Song, J.S., Yamada, Y., Wong, V., Bell, Z.W., Spitz, R.W., Abe, T., Loenneke, J.P. (2021). Hypoalgesia following isometric handgrip exercise with and without blood flow restriction is not mediated by discomfort nor changes in systolic blood pressure. J. Sports Sci., 1-9. doi: 10.1080/02640414.2021.2003569 [doi].

Souza, T.S.P., Pfeiffer, P.A.S., Pereira, J.D.N., Pereira Neto, E.A., Dutra, T.S., Mendonca, M.G.L., Cirilo-Sousa, M.S. (2019). Immune System Modulation in

Response to Strength Training With Blood Flow Restriction. J. Strength Cond Res. doi: 10.1519/JSC.0000000000003323 [doi].

Sprague, A.L., Couppe, C., Pohlig, R.T., Snyder-Mackler, L., Silbernagel, K.G. (2021). Pain-guided activity modification during treatment for patellar tendinopathy: a feasibility and pilot randomized clinical trial. Pilot Feasibility Stud. 7, 58-021-00792-5. doi: 10.1186/s40814-021-00792-5 [doi].

Stanish, W.D., Rubinovich, R.M., Curwin, S. (1986). Eccentric exercise in chronic tendinitis. Clin. Orthop. Relat. Res. (208), 65-68.

Staunton, C.A., May, A.K., Brandner, C.R., Warmington, S.A. (2015). Haemodynamics of aerobic and resistance blood flow restriction exercise in young and older adults. Eur. J. Appl. Physiol. 115, 2293-2302. doi: 10.1007/s00421-015-3213-x [doi].

Steinmann, S., Pfeifer, C.G., Brochhausen, C., Docheva, D. (2020). Spectrum of Tendon Pathologies: Triggers, Trails and End-State. Int. J. Mol. Sci. 21, 10.3390/ijms21030844. doi: E844 [pii].

Suga, T., Dora, K., Mok, E., Sugimoto, T., Tomoo, K., Takada, S., Hashimoto, T., Isaka, T. (2021). Exercise adherence-related perceptual responses to low-load blood flow restriction resistance exercise in young adults: A pilot study. Physiol. Rep. 9, e15122. doi: 10.14814/phy2.15122 [doi].

Sugawara, J., Tomoto, T., Tanaka, H. (2015). Impact of leg blood flow restriction during walking on central arterial hemodynamics. Am. J. Physiol. Regul. Integr. Comp. Physiol. 309, R732-9. doi: 10.1152/ajpregu.00095.2015 [doi].

Takano, H., Morita, T., Iida, H., Asada, K., Kato, M., Uno, K., Hirose, K., Matsumoto, A., Takenaka, K., Hirata, Y., Eto, F., Nagai, R., Sato, Y., Nakajima, T. (2005). Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. Eur. J. Appl. Physiol. 95, 65-73. doi: 10.1007/s00421-005-1389-1 [doi].

Takarada, Y., Sato, Y., Ishii, N. (2002). Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. Eur. J. Appl. Physiol. 86, 308-314. doi: 10.1007/s00421-001-0561-5 [doi].

Takarada, Y., Takazawa, H., Ishii, N. (2000). Applications of vascular occlusion diminish disuse atrophy of knee extensor muscles. Med. Sci. Sports Exerc. 32, 2035-2039. doi: 10.1097/00005768-200012000-00011 [doi].

Tanaka, M., Morifuji, T., Yoshikawa, M., Nakanishi, R., Fujino, H. (2019). Effects of combined treatment with blood flow restriction and low-intensity electrical stimulation on diabetes mellitus-associated muscle atrophy in rats. J. Diabetes 11, 326-334. doi: 10.1111/1753-0407.12857 [doi].

Teixeira, E.L., Barroso, R., Silva-Batista, C., Laurentino, G.C., Loenneke, J.P., Roschel, H., Ugrinowitsch, C., Tricoli, V. (2018). Blood flow restriction increases metabolic stress but decreases muscle activation during high-load resistance exercise. Muscle Nerve 57, 107-111. doi: 10.1002/mus.25616 [doi].

Tennent, D.J., Hylden, C.M., Johnson, A.E., Burns, T.C., Wilken, J.M., Owens, J.G. (2017). Blood Flow Restriction Training After Knee Arthroscopy: A Randomized Controlled Pilot Study. Clin. J. Sport Med. 27, 245-252. doi: 10.1097/JSM.0000000000000377 [doi].

Thiebaud, R.S., Loenneke, J.P., Fahs, C.A., Kim, D., Ye, X., Abe, T., Nosaka, K., Bemben, M.G. (2014). Muscle damage after low-intensity eccentric contractions with blood flow restriction. Acta Physiol. Hung. 101, 150-157. doi: 10.1556/APhysiol.101.2014.2.3 [doi].

Thiebaud, R.S., Loenneke, J.P., Fahs, C.A., Rossow, L.M., Kim, D., Abe, T., Anderson, M.A., Young, K.C., Bemben, D.A., Bemben, M.G. (2013). The effects of elastic band resistance training combined with blood flow restriction on strength, total bone-free lean body mass and muscle thickness in postmenopausal women. Clin. Physiol. Funct. Imaging 33, 344-352. doi: 10.1111/cpf.12033 [doi].

Thiebaud, R.S., Yasuda, T., Loenneke, J.P., Abe, T. (2013). Effects of low-intensity concentric and eccentric exercise combined with blood flow restriction on indices of exercise-induced muscle damage. Interv. Med. Appl. Sci. 5, 53-59. doi: 10.1556/IMAS.5.2013.2.1 [doi].

Van Cant, J., Dawe-Coz, A., Aoun, E., Esculier, J.F. (2020). Quadriceps strengthening with blood flow restriction for the rehabilitation of patients with knee conditions: A systematic review with meta-analysis. J. Back Musculoskelet. Rehabil. 33, 529-544. doi: 10.3233/BMR-191684 [doi].

Vechin, F.C., Libardi, C.A., Conceicao, M.S., Damas, F.R., Lixandrao, M.E., Berton, R.P., Tricoli, V.A., Roschel, H.A., Cavaglieri, C.R., Chacon-Mikahil, M.P., Ugrinowitsch, C. (2015). Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. J. Strength Cond Res. 29, 1071-1076. doi: 10.1519/JSC.0000000000000703 [doi].

Visnes, H., and Bahr, R. (2007). The evolution of eccentric training as treatment for patellar tendinopathy (jumper's knee): a critical review of exercise programmes. Br. J. Sports Med. 41, 217-223. doi: bjsm.2006.032417 [pii].

Wang, H.N., Chen, Y., Cheng, L., Cai, Y.H., Li, W., Ni, G.X. (2022). Efficacy and Safety of Blood Flow Restriction Training in Patients With Knee Osteoarthritis: A Systematic Review and Meta-Analysis. Arthritis Care. Res. (Hoboken) 74, 89-98. doi: 10.1002/acr.24787 [doi].

Warmington, S.A., Staunton, C.A., May, A.K., Brandner, C.R. (2016). Blood flow restriction exercise: acute versus chronic safety. Eur. J. Appl. Physiol. 116, 861-862. doi: 10.1007/s00421-015-3319-1 [doi].

Wengle, L., Migliorini, F., Leroux, T., Chahal, J., Theodoropoulos, J., Betsch, M. (2021). The Effects of Blood Flow Restriction in Patients Undergoing Knee Surgery: A Systematic Review and Meta-analysis. Am. J. Sports Med., 3635465211027296. doi: 10.1177/03635465211027296 [doi].

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. J. Can. Chiropr Assoc. 62, 193-201.

Wooten, S.V., Fleming, R.Y.D., Wolf, J.S.,Jr, Stray-Gundersen, S., Bartholomew, J.B., Mendoza, D., Stanforth, P.R., Stanforth, D., Hernandez, L.M., Tanaka, H. (2021). Prehabilitation program composed of blood flow restriction training and sports nutrition improves physical functions in abdominal cancer patients awaiting surgery. Eur. J. Surg. Oncol. 47, 2952-2958. doi: S0748-7983(21)00533-3 [pii].

Wortman, R.J., Brown, S.M., Savage-Elliott, I., Finley, Z.J., Mulcahey, M.K. (2021). Blood Flow Restriction Training for Athletes: A Systematic Review. Am. J. Sports Med. 49, 1938-1944. doi: 10.1177/0363546520964454 [doi].

Yasuda, T., Fujita, S., Ogasawara, R., Sato, Y., Abe, T. (2010). Effects of low-intensity bench press training with restricted arm muscle blood flow on chest muscle hypertrophy: a pilot study. Clin. Physiol. Funct. Imaging 30, 338-343. doi: 10.1111/j.1475-097X.2010.00949.x [doi].

Yasuda, T., Fukumura, K., Fukuda, T., Iida, H., Imuta, H., Sato, Y., Yamasoba, T., Nakajima, T. (2014). Effects of low-intensity, elastic band resistance exercise combined with blood flow restriction on muscle activation. Scand. J. Med. Sci. Sports 24, 55-61. doi: 10.1111/j.1600-0838.2012.01489.x [doi].

Yasuda, T., Fukumura, K., Fukuda, T., Uchida, Y., Iida, H., Meguro, M., Sato, Y., Yamasoba, T., Nakajima, T. (2014). Muscle size and arterial stiffness after blood flow-restricted low-intensity resistance training in older adults. Scand. J. Med. Sci. Sports 24, 799-806. doi: 10.1111/sms.12087 [doi].

Yasuda, T., Fukumura, K., Tomaru, T., Nakajima, T. (2016). Thigh muscle size and vascular function after blood flow-restricted elastic band training in older women. Oncotarget 7, 33595-33607. doi: 10.18632/oncotarget.9564 [doi].

Yasuda, T., Loenneke, J.P., Ogasawara, R., Abe, T. (2013). Influence of continuous or intermittent blood flow restriction on muscle activation during low-intensity multiple sets of resistance exercise. Acta Physiol. Hung. 100, 419-426. doi: 10.1556/APhysiol.100.2013.4.6 [doi].

Yasuda, T., Loenneke, J.P., Thiebaud, R.S., Abe, T. (2012). Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength. PLoS One 7, e52843. doi: 10.1371/journal.pone.0052843 [doi].

Yokokawa, Y., Hongo, M., Urayama, H., Nishimura, T., Kai, I. (2008). Effects of low-intensity resistance exercise with vascular occlusion on physical function in healthy elderly people. Biosci. Trends 2, 117-123.

Young, M.A., Cook, J.L., Purdam, C.R., Kiss, Z.S., Alfredson, H. (2005). Eccentric decline squat protocol offers superior results at 12 months compared with traditional eccentric protocol for patellar tendinopathy in volleyball players. Br. J. Sports Med. 39, 102-105. doi: 39/2/102 [pii].

Yow, B.G., Tennent, D.J., Dowd, T.C., Loenneke, J.P., Owens, J.G. (2018). Blood Flow Restriction Training After Achilles Tendon Rupture. J. Foot Ankle Surg. 57, 635-638. doi: S1067-2516(17)30645-2 [pii].

Zargi, T., Drobnic, M., Strazar, K., Kacin, A. (2018). Short-Term Preconditioning With Blood Flow Restricted Exercise Preserves Quadriceps Muscle Endurance in Patients After Anterior Cruciate Ligament Reconstruction. Front. Physiol. 9, 1150. doi: 10.3389/fphys.2018.01150 [doi].

Zwerver, J., Bredeweg, S.W., van den Akker-Scheek, I. (2011). Prevalence of Jumper's knee among nonelite athletes from different sports: a cross-sectional survey. Am. J. Sports Med. 39, 1984-1988. doi: 10.1177/0363546511413370 [doi].