DERLEME REVIEW

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Resistance Exercise with Blood Flow Restriction: A Novel Training Technique to Maximize Strength and Hypertrophy: A Brief Review

Kan Akışı Kısıtlamalı Direnç Egzersizi: Kuvvet ve Hipertrofiyi En Üst Düzeye Çıkarmak İçin Yeni Bir Antrenman Tekniği: Kısa Derleme

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ABSTRACT Low-load resistance exercise with blood flow restriction has been known to stimulate muscle development that is comparable to conventional High-load Resistance Exercise. Resistance exercise with blood flow restriction is a pretty new training technique that can be an option to High-load Resistance Exercise for increasing muscle mass and strength not only in athletes but also in healthy people and elderly people, or rehabilitation for injured athletes with load restrictions. This brief review study aims to summarize the existing literature concerning the basic principles of resistance exercise with blood flow restriction and to provide a brief description of blood flow restriction training to maximize strength and hypertrophy. Blood flow restriction training can be performed when High-load Resistance Exercise is not tolerated because of pain or other contraindications such as absolute weight-bearing restrictions, for instance after surgical procedures to regain strength and muscle mass. High-load Resistance Exercise is associated with high mechanical tension, however in some cases, this is not warranted. In these cases, resistance exercise with blood flow restriction seems to be a better option. Consequently, blood flow restriction training should not replace High-load Resistance Exercise for the general public or uninjured athletes, but blood flow restriction training can be used as an alternating training tool or in situations where High-load Resistance Exercise is inadvisable.

Keywords: Blood flow restriction; hypertrophy; resistance training; Kaatsu; occlusion

ÖZET Kan akışı kısıtlama ile birlikte kombine olarak yapılan düşük yüklü direnç egzersizlerinin, geleneksel yüksek yüklü direnç egzersizleri ile karşılaştırılabilir kas büyümesi sağladığı gösterilmiştir. Kan akışı kısıtlama antrenmanı, sadece sporcularda değil, aynı zamanda sağlıklı insanlarda, yaşlı erişkinlerde veya yüksek yüklü antrenmanlara bağlı yaralanma sorunları olan sporcularda kas boyutunu ve kuvvetini geliştirmek için yüksek yüklü direnç antrenmanına alternatif olabilecek oldukça yeni bir antrenman tekniğidir. Bu kısa derleme çalışması, kan akışı kısıtlama antrenmanının temel ilkeleri ile ilgili mevcut literatürü özetlemeyi ve kuvvet ve hipertrofiyi en üst düzeye çıkarmak için kan akışı kısıtlama antrenmanının kısa bir tanımını sağlamayı amaçlamaktadır. Kan akışı kısıtlama antrenmanı, yüksek yüklü direnç antrenmanlarının tolere edilemediği durumlarda, kuvvet ve hipertrofi kazandırmak amacıyla yapılabilir. Kan akışı kısıtlama antrenmanı, ağrı veya ağırlık kaldıramama kısıtlamaları gibi diğer kontraendikasyonlar nedeniyle yüksek yüklü direnç egzersizleri tolere edilmediğinde, örneğin kuvvet ve kas kütlesini yeniden kazanmak için cerrahi prosedürlerden sonra yapılabilir. Yüksek yüklü direnç egzersizleri yüksek mekanik gerilim ile ilişkilidir, ancak bazı durumlarda yüksek yükü tolere etmek mümkün olmayabilir, bu gibi durumlarda kan akışı kısıtlamalı direnç egzersizi iyi bir seçenek olarak görülebilir. Sonuç olarak, kan akışı kısıtlama antrenman metodu, genel popülasyon ve sakatlık geçirmemiş sporcular için yüksek yüklü direnç egzersizlerinin yerini almamalıdır, ancak kan akışı kısıtlama antrenmanı, alternatif bir antrenman aracı olarak veya yüksek yüklü direnç egzersizlerinin tavsiye edilmediği durumlarda kullanılabilir.

Anahtar Kelimeler: Kan akışı kısıtlama; hipertrofi; direnç antrenmanı; Kaatsu; oklüzyon

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Blood flow restriction (BFR) training, was first introduced in Japan in the 1960s. Essentially, BFR is not a new training modality and it has been around for decades, and the research in BFR training is increasing at an exponential rate. BFR training was originally referred to as "Kaatsu training" which means "additional pressure" and was first practices by Yoshiaki Sato, MD. Since then, BFR training has gained popularity not only in the rehabilitation but also in the strength and conditioning community.[1]

During BFR training, it is commonly advised to set the external pressure (mmHg) below arterial pressure but above venous pressure. To achieve this partial restriction, the cuff is inflated to a certain pressure often set relative to Limb Occlusion Pressure/Arterial Occlusion Pressure (LOP/AOP, 40-80%). For BFR in combination with resistance training, it is commonly advised to use low-load as 20-30% of the maximum i.e., one repetition maximum (1RM), with high repetitions per set (30-15-15-15 repetitions) and short inter-set rest (30-60 seconds).[2,3]

Resistance Exercise with Blood Flow Restriction (BFR-RE) (20-30% 1RM) has been shown to develop muscular strength and growth in the same way that High Load Resistance Exercise (HLRE) does.[4,5] Researches have also shown that BFR-RE provide not only muscle hypertrophy[4-10] and strength[4,5,11-14] but also muscular endurance,[8,9] cardiorespiratory endurance and it has been demonstrated to be useful in a variety of demographics, including the elderly,[15] healthy individuals,[16] athletes[9,14,17,18] and also injured individuals.[19] BFR training is also a good option and appears to be a new strategy for improving muscular hypertrophy in physique competitors particularly in combination with HLRE.[20]

It is critical to consider safety considerations when undertaking BFR training in order to achieve the intended positive outcome from BFR training. In BFR training, it's recommended to use cuffs for only one group of extremities. For instance, if your goal is to train your upper extremities, you just wrap cuffs on your arms. Therefore, it's not recommended to use simultaneously for both arms and legs.[1] Briefly, to apply BFR, special pressure cuffs are applied at the top portion of the lower or upper limbs and inflated (gradually by using hand pump device or automated device) which results in arterial blood inflow being reduced and occludes venous return.[21] As previously mentioned, when performing BFR exercise, the common protocol for BFR training is a 30-15-15-15 repetition scheme with short inter-set rest.[22] However, the vast BFR literature also includes 45 repetitions per set to volitional failure protocols.[1,12,16,17]

This training method seems to be very complicated and more research is needed to apply BFR safely. Therefore, this paper aims to provide an evidence-based review of existing literature and shed light on sports scientists, strength and conditioning coaches, and physiotherapists as to how to apply resistance exercise with BFR safely.

RESISTANCE EXERCISE WITH BLOOD FLOW RESTRICTION (BFR-RE)

To understand BFR training, we first need to comprehend the mechanism of hypertrophy. The term "muscle hypertrophy" refers to an increase in muscle diameter. Lifting at least 60% of 1RM load has typically been recommended for the best results in terms of muscle growth and strength. This type of exercise, however, may be contraindicated for specific populations due to the increased levels of mechanical stress exerted on the tissues.[23,24] The mechanical tension can be easily seen when comparing bodybuilders and marathon runners. When comparing the training sessions of bodybuilders and marathon runners, it is found that marathon runners are exposed to more training volume than bodybuilders and experience similar muscle damage. In this case, we may think that this is why bodybuilders are more muscular than marathon runners and the best answer to this question would be to lift the weights.[25,26]

The importance of mechanical tension in immobile patients can only be seen when the patient is bedridden. In such bedridden cases, significant muscle atrophy occurs because the muscle is not used and does not have to exert a considerable amount of energy. A 17% reduction in total muscle volume was observed in the event of immobility for more than 6 weeks as a result of ankle fracture.[27] Muscle atrophy can be minimized during immobilization by using

BFR training. When bedridden cases occur, passive BFR (P-BFR) can be a good option.[1] During ischemic preconditioning (IPC), a technique known as P-BFR is used. Perfusion is followed by reperfusion in P-BFR training method. IPC protocol consists of 5 min perfusion (ischemia) followed by 3 min reperfusion for 3 to 4 sets. This technique is useful, especially when reducing atrophy is the priority.[19]

It is suggested that metabolic stress or metabolite accumulation is the primary cause of the improvement achieved with BFR training.[28] During strenuous exercise, metabolites build up in the body, which is known as metabolic stress. It is important that why metabolic stress leads to more gains. The first theory is the accumulation of metabolites.[26] Another, the more plausible theory is that metabolites build up in the muscle, causing a rise in muscle activation.[29] The last theory is cell swelling. It creates mechanical stress on the muscle fiber, suggesting that the cell needs to expand and grow to properly withstand the tension.[30] BFR exercise, as well as resistance training with low loads, high repetitions, and short rest periods, can increase metabolic stress in training in this context.[26] This allows the muscle to perform several tasks in a short period, resulting in metabolite accumulation.[30] Therefore, BFR training may be preferred during heavy training sessions since metabolic accumulation may increase muscle activation.

Muscle damage is another stimulus for hypertrophy.[26] It occurs as a result of heavy eccentric loading over an entire range of motion (ROM) or new exercises.[31,32] Hypertrophy is mostly caused by mechanical stress, and therefore, muscle damage is often a consequence of intense stress. In some cases, it's difficult to determine if the damage causes hypertrophy rather than tension. There is some evidence of growth-causing damage when focusing on training at specific muscle ROM.[31,33] Exercising with a greater ROM leads to more muscle growth than exercises with a limited ROM.[34,35] This is most likely due to muscle tissue's length-stretch characteristic, which causes more mechanical stress on more muscle fibers as exercises are performed at full ROM.[36]

BFR training aims to use a cuff to create a hypoxic condition that mimics the effects of HLRE. Capillary blood with low oxygen content collects in the area when the cuff is applied, limiting blood output and thus increasing protons and lactic acid levels. Hormone release, hypoxia, cell swelling, BFR training, and high-intensity exercise all have physiological adaptations for muscle.[37] Short-term low-intensity BFR exercise, such as 4-6 weeks, has been shown to improve muscle strength by 10-20%.[9,13,38] These improvements were noted to be comparable to those seen with high-intensity exercise performed without blood flow restriction.[39] Recommended exercise prescription with BFR-RE is shown in Table 1.

BFR combination with resistance exercise, with loads as low as 20% 1RM, generates muscle development and strength improvements comparable to high-load resistance exercise (80% 1RM), making BFR a viable option to conventional resistance training.[40]

TABLE 1: Exercise prescription for resistance exercise with blood flow restriction.[1]

Frequency	2-3 times a week (3 weeks or more), 1-2 times per day (1-3 weeks)
Load	20-40% 1RM
Sets	2-4 sets
Rest	30-60 sec between sets
Repetitions	30-15-15-15 (75 reps) or sets to failure
Cuff pressure	40-50% AOP for upper extremity, 60-80% AOP for lower extremity
Restriction time	5-10 min per exercise (total of 15-20 min in training session)
Exercise selection	Single joint (i.e. biceps curl, triceps extension) or multi joint (i.e. bench press, squat, dead lift) exercise
Restriction style	Continuous (cuffs remain inflated between each set) or intermittent (deflate the cuffs between each set)

1RM: One repetition maximum; AOP: Arterial Occlusion Pressure.

BFR-RE can also be a good option for elderly people. There is some evidence indicating that BFR training is effective in the elderly population. BFR training increases growth hormone and also vascular endothelial growth factor in the elderly population, which is 71 years old on average.[41-43] Moreover, it was found that BFR-RE also increases muscle mass and strength in the elderly population.[15]

If the exercise is completed to failure, resistance training with low loads 30% 1RM and without BFR will result in equal improvements in muscle volume to high load resistance training.[44] External compressive devices, such as pneumatic cuffs or elastic bands, are used to restrict movement at the most proximal parts of the limbs.[45-47]

DETERMINING LIMB OCCLUSION PRESSURE FOR SAFETY APPLICATION

Limb Occlusion Pressure (LOP) or Arterial Occlusion Pressure (AOP) is the minimum level of pressure that you need to occlude arterial inflow to working muscles. Several factors such as cuff shape, cuff width, and individual characteristics, should be considered when determining LOP/AOP. It is crucial that when performing BFR exercise, you need to assess LOP/AOP. LOP/AOP can be adjusted for the lower limb 60%-80% and the upper limb 40%-50% of LOP. There are several ways to assess LOP, one of them is using Doppler ultrasound and automatic regulated cuffs that can assess LOP automatically. LOP can also be measured with a handheld vascular doppler (8 mHz).[1,48]

BFR training has gained popularity in the last decade and different BFR devices can be found in the market. When assessing LOP for the upper extremity the recommended pressure is ranging 40-50% of LOP, and for the lower extremity recommended pressure is ranging from 60% to 80% of LOP.[1]

The LOP is also changeable in terms of limb size, the larger size limb requires more pressure and the thinner limb size requires less pressure to fully occlude blood flow. Similar to that wider cuffs require a low pressure while narrow cuffs require high pressure to achieve 100% LOP. Higher pressures may increase the risk of injury while performing BFR exercise.[49]

LOP can also be changeable regarding different body positions. Hughes et al. have found that the average LOP in standing position is 241 mmHg, in seated position 204 mmHg and supine position 187 mmHg. They conclude that LOP can be changeable regarding body positions and highest in standing positions and the lowest in the supine position.[50] Therefore it is crucial to assess individualized LOP when performing BFR exercises.[51]

CONCLUSION

BFR training has gained popularity for the last decade and can be used as an alternative training technique when HLRE cannot be tolerated. When combined with resistance training, available literature suggests that BFR-RE can be performed 2-3 times a week for 4 weeks or more. Reps scheme can be selected 30-15-15-15 reps. It can be also used with both single joint (i.e. knee flexion, knee extension, biceps curl) and multi-joint exercises (i.e. squat, deadlift, bench press). LOP should be considered when performing BFR training since the pressure can vary among individuals even among limbs. BFR training can be used to maximize strength and hypertrophy but we may not conclude that BFR training is superior to high load resistance training particularly when the aim is to build up strength. Therefore, it is more plausible to use BFR training when a high load cannot be performed, after an injury to returning to sport and also not enough time to train since the BFR time should last up to 20 minutes for a session.

The scope of this review is related to maximizing strength and hypertrophy. Further researches may focus on aerobic exercise with blood flow restriction, P-BFR for diminishing atrophy, and rehabilitation with BFR.

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Authorship Contributions

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