

The Efficacy of Blood Flow Restriction Training for Grip Strength and Disability in Lateral Epicondylitis



Gede Parta Kinandana^{1*}, Anak Ayu Nyoman Trisna Narta Dewi¹, I Made Niko Winaya¹,
Ni Komang Ayu Juni Antari¹, Ari Wibawa¹, I Putu Gde Surya Adhitya¹

ABSTRACT

Background: Lateral epicondylitis is a work-related musculoskeletal disorder caused by inflammation of the extensor carpi radialis longus and brevis muscles tendons with symptoms of pain in the lateral side of the elbow and decreased range of motion that causes forearm muscle weakness and disability. This study aimed to compare the effectiveness of blood flow restriction (BFR) training with resistance exercise (RE) in increasing grip strength and forearm disability in lateral epicondylitis patients.

Methods: This study used the randomized controlled trial design that involved 28 subjects who were divided into intervention and control groups. All subjects received the treatment 3 times per week for 4 weeks, including the standard ultrasound therapy and electro-muscular stimulation interventions for 20 mins with additional treatment of the low-load BFR training for the intervention group and the high-intensity RE for the control group. This study measured grip muscle strength using a handgrip dynamometer, and functional ability was measured using a patient-rated tennis elbow evaluation questionnaire (PrTEEQ) before and after the treatment session. The statistical analyses of paired t-tests and independent t-tests were used in this study.

Results: This study found significant differences between pretest and posttest scores in the measurements of forearm muscle strength (change= 20.0~49.0%, p -values <0.001) and PrTEEQ (change= 64.5~70.5%, p -value <0.001) in the intervention and control groups. In addition, the independent t-tests resulted in significant differences in the score changes of forearm muscle strength and PrTEEQ measurement between these groups with p -values <0.001.

Conclusion: This study described that BFR training had better effects on grip strength and functional ability than RE in people with lateral epicondylitis.

Keywords: blood flow restriction, handgrip strength, lateral epicondylitis, strengthening exercise.

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¹Department of Physical Therapy, College of Medicine, Universitas Udayana, PB Sudirman Street, Denpasar 80232, Bali, Indonesia;

*Corresponding author:
Gede Parta Kinandana;
Department of Physical Therapy, College of Medicine, Universitas Udayana, PB Sudirman Street, Denpasar 80232, Bali, Indonesia;

gede_parta@unud.ac.id

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INTRODUCTION

Lateral epicondylitis, often referred to as tennis elbow, is a work-related musculoskeletal disorder caused by the tendon's inflammation of either one or both of the extensor carpi radialis longus and extensor carpi radialis brevis. Lateral epicondylitis is described as chronic symptomatic degeneration of the wrist extensor muscle tendon involving its attachment to the lateral humeral epicondyle¹ Lateral epicondylitis is a common condition affecting up to 3% of the population, which is generally experienced by the adult age group with peak cases in the age range of 35-54 years, without sex predisposition.² The

pain of the tennis elbow range from mild discomfort to severe pain that may last about months to years while using the elbow repeatedly without the appropriate treatment.² The clinical feature in people with lateral epicondylitis is the pain in the lateral epicondyle area, generally around tendon attachments, which decreases the range of motion (ROM) and muscle strength that affects some daily activities and quality of life.^{3,4}

The treatment of lateral epicondylitis is oriented toward alleviating pain, maintaining ROM, and improving the strength and endurance of the affected muscles³ through several approaches, including electrophysical modalities (low-level laser therapy, low-frequency

electrical stimulation, and extracorporeal shockwave therapy⁵), exercise therapy (stretching and resistance exercises⁶), and manual therapies (massage and joint mobilization⁶). Exercise therapy is an essential treatment that can be effective and convenient with little risk of side effects that may harm the patient. Many studies have shown that resistance exercise (RE), especially the type of eccentric exercise, effectively decreases the pain and increases grip strength and elbow function after 4-8 weeks of an exercise program for lateral epicondylitis.⁷ The previous study's eccentric exercise was the participants' wrist actively extending against the contralateral hand, which attempts to push the involved wrist into

a flexed position. A literature review by Ma and Wang demonstrated the benefits of providing eccentric strengthening exercises in increasing grip strength and PrTEEQ scores during 12 weeks of training.⁸

Blood flow restriction (BFR) training is a strengthening exercise involving a tourniquet or pressurised cuff in the proximal area of the body part being trained. The cuff contained in the tourniquet is then inflated at a specific pressure (mostly 150 mmHg) to produce partial arterial occlusion and full venous occlusion.⁹ BFR training aims to mimic the effects of high-intensity exercise by recreating a hypoxic environment using pressurized cuffs.^{9,10} Hypoxic environments are believed to accelerate the healing process needed for muscle and tendon injury. Some conditions that result in decreased muscle mass, such as cancer, HIV/AIDS, diabetes, and COPD or conditions with painful symptoms, may benefit from both strengthening exercises; however, these populations are less likely to tolerate the exercise, which is done in high intensity. People with lateral epicondylitis show a significant decrease in muscle strength and handgrip function, which need to be addressed, while at the same time, less tolerable for strengthening exercise approach. Therefore, BFR training can be useful where this exercise can create a hypoxic environment like high-intensity exercise, but only with low-intensity exercise, which tends to be more easily tolerated in people who experience pain or other inflammatory condition, including lateral epicondylitis.¹¹ Also, there have not been many studies that prove the effectiveness of BFR training, specifically in lateral epicondylitis and directly compare it to whether it is superior to the standard strengthening exercises protocol.

The prevalence of lateral epicondylitis is a common orthopedic case in Indonesia because sports enthusiasts such as tennis, badminton and baseball are increasing. The physician also recommended using non-drug and non-invasive treatments, including ice compression, electrotherapy, and exercise, to address the lateral epicondylitis that has shown excellent results in clinical practice. However, limited studies supported the clinical

experiences of exercise therapy, such as RE and BFR training, in patients with lateral epicondylitis in Indonesia.¹² Based on the explanation above, the author conducted a study by applying the BFR training approach to the management of lateral epicondylitis and comparing it with the RE, which was generally done and well-studied, as well as to prove how practical BFR training was able to increase muscle strength and disability when compared to other strengthening exercises.

METHODS

This study used a pre-test and post-test control group design that aims to determine the effectiveness of BFR training compared to RE in increasing grip strength and functional ability in an individual with lateral epicondylitis. This study used the handgrip dynamometer (HGDyn) to measure the grip strength and the patient-rated tennis elbow evaluation questionnaire (PrTEEQ) to measure the hand functional ability, which was performed before and after the patients received the treatments. This study passed the ethical eligibility with the registered number 2317/UN14.2.2.VII.14/LT/2021 from Research Ethics Commission, College of Medicine, Universitas Udayana/Sanglah General Hospital, Denpasar, Bali.

This study's population was all lateral epicondylitis patients who visited the author's (GPK) physical therapy clinics. A total of 79 samples were obtained through a consecutive sampling technique in the period from August to November 2021. The samples were then adjusted to this research's inclusion and exclusion criteria. The inclusion criteria in this study were 1) subjects with a positive test of lateral epicondylitis, which has been determined based on physical therapy assessment procedures; 2) the presence of pain in the lateral epicondyle of the humeral bone; 3) show decreased muscle strength and functional ability; 4) subjects have a body mass index (BMI) in the normal category (18.5-24.9 kg/m²) to overweight (25.0-29.9 kg/m²); and 5) age between 35 to 55 years old. While the exclusion criteria of this study were 1) refusal to be a sample in this study; 2) presences of bilateral symptoms; 3) presences of sensory and motor impairment of

the upper extremities; 4) samples with systemic disease and metabolic disorders; 5) history of trauma and surgery on the elbow; 6) having a history of malignancy and peripheral vascular disorders.

A physical therapist carried out several examination steps to diagnose lateral epicondylitis, including history taking and specific examinations. As for the history taking, the subjects must show symptoms including 1) pain in the lateral epicondyle or 1-2 cm distal to the lateral epicondyle and 2) pain and weakness during wrist extension movements. Meanwhile, through specific examination, a subject can be diagnosed as having Lateral epicondylitis if 1) positive sharp and sudden pain in the lateral epicondyle area during Cozen's test, 2) positive pain in the lateral epicondyle area during Mill's test, and 3) positive for pain in the epicondyle area laterally during the Maudsley's Test. The presence of positive two out of three tests indicates the subject had lateral epicondylitis.

Out of 79 samples, only 28 samples were eligible for randomization. These samples were then randomly allocated into the intervention group (IG) that received BFR training and the control group (CG) that received RE, with 14 samples in each group. All subjects received the treatment 3 times per week for 4 weeks, including the standard ultrasound therapy and electro-muscular stimulation interventions for 20 mins with additional treatment of the low-load (20%-40% of 1 repetition maximum (RM)) BFR training for the intervention group and the high-intensity RE (70%-80% of 1 RM) for the control group. The physical therapist applied the occlusive cuff on the upper arm (brachium) with a pressure of 1.2 times of patient's systolic blood pressure.¹³ This study used types of exercises of dorsiflexion and palmarflexion of the wrist with a weight-adjusted dumbbell. Both invention and control groups received 4 sets of 12 repetitions with 60 seconds rest of interval for each set. During the study, 3 samples were lost to follow-up, while 1 subject was discontinued due to positive COVID-19. The procedure can be seen in the flow diagram below (Figure 1).

The subjects of this study used HGDyn to measure isometric handgrip strength

by pulling the dynamometer spring with maximum effort in a 5-seconds and then releases it. The patients were measured in the seated position with the elbow fully extended using a hydraulic HGDyn by a physical therapist.¹⁴ The measurement was carried out three times, and the average value was used in the analysis. The 15-item questionnaire of PrTEEQ was also used to measure forearm pain and disability in the subjects by instructing them to answer 15 questions (5 pain items, 6 specific activity items, and 4 general activity items), where each question received a score ranging from 0 (no pain/difficulty) to 5 (worst pain imaginable/unable to perform). The scores per item were summed and divided by 100 to get the total score in percentage (%). The PrTEEQ was a reliable and sensitive instrument for lateral epicondylitis with excellent internal reliability and consistency (0.94, 0.93, 0.85 for pain, specific activities, and general activities subscales, respectively).¹⁵

Statistical analysis

The mean and standard deviation of patients' characteristics were calculated in both study groups. The Kolmogorov-Smirnov test was used to examine the normal distribution of the variables. A paired t-test was performed to assess if there had been any significant differences between the pre-test and post-test scores in the two groups for HGDyn and PrTEEQ measurements. The independent t-test was utilized to quantify the significance of treatment change differences between the two groups' data. SPSS version 23.0 was used to analyze the data.

RESULTS

Table 1 showed that there were 7 male (58.3%) and 5 women (41.7%) subjects with a mean age of 46 ± 3.1 years in the IG, and 8 male (66.7%) and 4 female (33.3%) subjects with a mean age of 45.8 ± 2.7 years in the CG.

The results of paired sample *t*-test showed that there was a significant improvement in both two groups for handgrip strength measurement (change IG= 10.9 ± 1.1 (49.0%); change CG= 4.8 ± 1.0 (20.0%)) and functional ability measurement (change IG= 50.9 ± 1.3 (70.5%); change CG= 28.3 ± 3.7 (64.5%)) before and after the interventions with *p*-values < 0.001 (Table 2). When compared between the two groups, the independent *t*-test showed significant differences between IG and CG after the interventions in both the HGDyn and PrTEEQ measurements with *p*-values < 0.001 (Table 3).

DISCUSSION

This study demonstrated that the mean age of participants was 46 years old, and more than 62% of participants were males. After four weeks of treatments, both intervention and control groups showed significant improvements in HGDyn and PrTEEQ measurements. Moreover, this study found that BFR training had better grip strength and functional ability results than RE in people with lateral epicondylitis.

In this study, the BFR training might increase the forearm muscle diameter and strength with a load that tends to be lower when compared to resistance exercise. The possible reason for this finding was the BFR training method applied a low-intensity loading that did not trigger any pain from the subjects during muscle contraction, which subjects tend to feel more comfortable during exercise and get a higher increase in muscle mass compared to the RE which uses a higher load.^{8,11} Additionally, it was noted in a prior study that BFR training concurrently lowered plasma volume during laying rest compared to RE, which signified a fluid transfer into the cell and may have been an initiator of muscle growth and endurance for functional tasks involving the elbow joint.¹⁶

Few studies showed the direct benefit of BFR training for lateral epicondylitis; however, several studies show the effectiveness of BFR training in rehabilitation for tendinopathy problems. Skovlund et al., through their case study on the effect of low-load blood flow

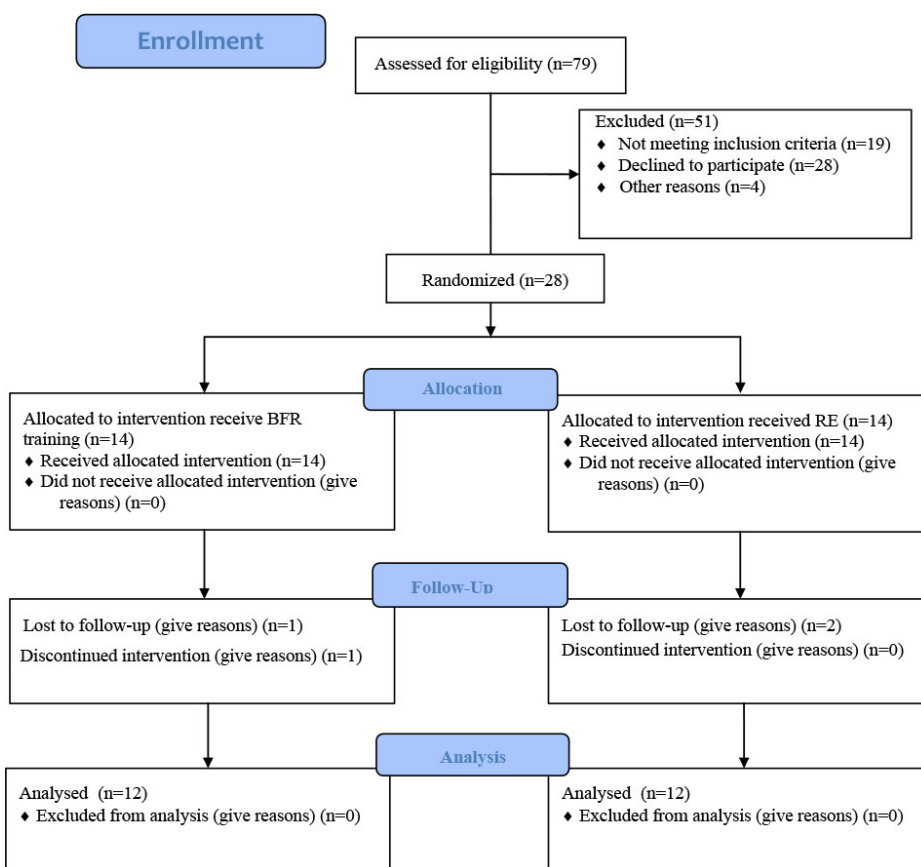


Figure 1. Flowchart of sample enrolment process, including group allocation, participation in two interventions: blood flow restriction training (BFR training) and resistance exercise (RE), follow-up and analysis.

restriction (LL-BFR) exercise on chronic patellar tendinopathy, showed similar results to this study where through 3 weeks of LL-BFR training, there was a 50% reduction in pain scores during single-leg decline squat functional activity. The investigators assumed that the improvement in the subject's condition was due to structural changes in tendons and tissue vascularization after LL-BFR training.^{17,18} Another study found that BFR could activate the mechanistic target of rapamycin signaling pathway as an essential cellular mechanism to enhance muscle-tendon protein synthesis during the tendon healing process.¹⁹ Thus, LL-BFR training intervention might have facilitated the repair of tendon structure in lateral epicondylitis patients.

The main benefit of providing BFR training for the subject is that with a low load, it can achieve the same morphological and mechanical changes and adaptations as RE using a high load. Low loads tend to provoke little or no symptoms when compared to high loads, so BFR training is best used when the goal of treatment is to improve muscle strength, but RE (with high loads) tend to provoke the symptoms, which tends to make the subject feel uncomfortable, affects the subject's psychological condition that makes them refuse to do exercises, and can even increase the risk of tendon re-inflammation. The study by Centner et al. described their finding through ultrasound imaging, LL-BFR (using only 20-35% of their 1 maximum repetition

(1RM) resulted in changes in morphology, mechanical properties, materials, and cross-sectional area diameters similar to those of HL-RE administration. (70-85% 1RM).²⁰ The authors suggest that these changes are caused by several factors, including 1) tissue hypoxia that stimulates proliferation, which can increase the speed of tendon repair; 2) LL-BFR training recruited more motor units during the training; and 3) continuous BFR training in gradual load improvement might cause chronicle training adaptation within a greater proportion of faster-twitch muscle fibers than traditional exercises alone.^{13,20}

A healthy tendon is a stiff tendon. Tendons respond to high-intensity loads by adaptively becoming stiffer. They achieve this by increasing the number of cross-links between adjacent collagen fibers and changing the composition of the extracellular matrix of the tendon. While the exact mechanism underlying the effect of BFR training on tendon adaptation is still unknown, cell culture-based studies have shown that hypoxia (a common lack of oxygen supply in BFR-types of training) can stimulate tendon cell proliferation and be an effective strategy to increase the rate of collagen synthesis which is usually slower.^{9,10,21} Jiang et al. explained that hypoxic-conditioned culture medium increases the proliferation and migration

Table 1. Distribution of baseline characteristic among intervention group (IG) receiving BFR training and control group (CG) receiving resistance exercise*.

Characteristic	IG (N = 12) mean ± SD	CG (N = 12) mean ± SD
Age (years)	46.00 ± 3.075	45.83 ± 2.725
Gender		
Male, n (%)	7 (58.3)	8 (66.7)
Female, n (%)	5 (41.7)	4 (33.3)

Abbreviation: SD, standard deviation.

* Data are presented as mean ± standard deviation unless otherwise indicated. One-way analysis of variance was used for continuous variables and Pearson's chi-squared test for categorical variables.

Table 2. Handgrip strength (HGDyn) and tennis elbow disability (PrTEEQ) measurement at baseline and their change over the 4-week intervention between the BFR training (IG) and resistance exercise group (CG).

Measurement	IG				CG			
	At baseline Mean ± SD	After 4-week intervention Mean ± SD	% change	<i>p-value</i> ^a	At baseline Mean ± SD	After 4-week intervention Mean ± SD	% change	<i>p-value</i> ^a
HGDyn	22.308 ± 5.844	33.233 ± 6.091	48.97	<0.001	24.025 ± 5.856	28.842 ± 5.785	20.04	<0.001
PrTEEQ	72.250 ± 3.538	21.333 ± 3.933	70.47	<0.001	72.125 ± 3.908	43.833 ± 3.114	64.54	<0.001

Abbreviation: SD, standard deviation; HGDyn, handgrip dynamometer; PrTEEQ, patient-rated tennis elbow questionnaire.

p-value^a was calculated using paired *t test* for within-group comparison over the 4-week intervention.

Table 3. Comparison of the change in handgrip strength (HGDyn) and tennis elbow disability (PrTEEQ) measurement between the BFR training group (IG) and resistance exercise group (CG) after 4-week intervention.

Measurement	IG		CG		<i>p-value</i> ^b
	Change at baseline and after 4-week intervention Mean ± SD	% change	Change at baseline and after 4-week intervention Mean ± SD	% change	
HGDyn	10.925 ± 1.103	48.97	4.817 ± 1.009	20.04	<0.001*
PrTEEQ	50.917 ± 1.345	70.47	28.292 ± 3.720	64.54	<0.001*

Abbreviation: SD, standard deviation; HGDyn, handgrip dynamometer; PrTEEQ, patient-rated tennis elbow questionnaire.

p-value^b was calculated using independent *t test* for between-group comparison over the 4-week intervention.

**p*<0.05 = significant result

of tendon stem cells which is associated with accelerated healing of tendon tissue. Those studies explain how BFR training can result in tissue repair in people with lateral epicondylitis, which impacts pain and increases handgrip strength and functional ability in the elbow.²¹

The previous meta-analysis study by Slysz et al., with a total of 400 participants from 19 different studies, supported this study regarding the effectiveness of BFR exercise in increasing muscle size and strength.²² The authors of this study explained that adding BFR training during exercise could consistently increase muscle size and strength, although the effect size varied among the loads (i.e., low-intensity or moderate-intensity) and types of exercise (i.e., aerobic or anaerobic). They suggested the arterial occlusion pressure was >150 mmHg and the load applied to BFR training >25% of 1 RM to produce muscle hypertrophy²², which has verified that this study used a load range of 20 - 40% of 1 RM and has shown promising results compared to high-intensity RE.

There were several limitations should be explained in this study. First, the number of subjects in this study was still relatively small, so the results of this study cannot be generalized properly to the population. Second, the lateral epicondylitis severity levels varied, affecting different clinical symptoms among the patients referred to training intensity adjustment. Third, several variables that can impact the study results cannot be controlled, such as physical activity and fitness level, lifestyle and habits carried out by the sample, and sample compliance in following the physical therapy intervention schedule. Fourth, this study did not use a control group that did not receive either BFR training or RE intervention. Because of this, researchers have yet to be able to measure the effect of one of the standard interventions given to the two groups, which are the EMS and UST. Fifth, outcome measurements in this study were carried out before the treatment (pre-test) and after the 12th treatment (post-test). Due to the limited number of measures taken, the results of this study have not been able to describe precisely the changes in pain level and muscle strength at the end of each treatment, so it is unknown whether these

two interventions can provide short-term effects. Finally, there was no continuous follow-up on the sample after the end of treatment. Therefore, this study has not been able to explain the long-term effect of the two treatment groups on improving handgrip strength and elbow functions.

CONCLUSION

Based on the results of this study, the low-load BFR training improved handgrip strength and functional ability score better than high-intensity RE training in lateral epicondylitis patients.

CONFLICT OF INTEREST

The authors have no conflict of interest to report.

ETHICAL CONSIDERATION

This study has passed the ethical eligibility with numbers 2317/UN14.2.2.VII.14/LT/2021 from Research Ethics Commission, College of Medicine, Udayana University / Sanglah General Hospital, Denpasar, Bali.

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AUTHOR CONTRIBUTIONS

GPK conceived and carried out the study design, data collection, data analysis, and wrote the manuscript; AANTND and IMNW conducted the data collection, data analysis, searched the literatures and wrote the manuscript; NKAJA, AW, and IPGSA searched the literatures and revised the manuscript. All authors read and approved the final version of the manuscript and agreed with the order of presentation of the authors.

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