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RESEARCH ARTICLE

Blood Flow Restriction Exercises (BFR) an Effect on Strength Rehabilitation and Muscle Atrophy for Patients with Multiple Femur Fractures Aged 40-50 Years

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Abstract
The present study examined the effect of rehabilitation exercises with BFR in improving muscle strength, thigh muscle hypertrophy, and knee joint flexibility for those with double fractures in the lower body. Methods: 6 volunteer subjects (average age 44 (40–50) years) were randomized into one group that trained in restriction of blood flow period eight weeks. Participants were familiar with all testing and exercise protocols before starting the study. Rehabilitation exercises with BFR were done before and after—form for each player to record the sequence measurements. Quadriceps circumference measurement (cm), the range of motion of the knee joint, and Quadriceps muscle strength measurement were performed on the participants. Independent samples t-test was used to compare the scores obtained from the measurements according to categorical variables. The significance level was determined as P 0.05. Results: Thigh circumference (cm) There was a significant increase in thigh circumference from before the experiment (41.17 cm) to after the investigation (45.33 cm) (p<0,001). There's a remarkable development in post-test measurements (13.97 kg), (p<0,000) compared to pre-test measurements (8.83 kg), indicating an improvement in quadriceps strength. Hamstring strength (kg) in the post-test measurement (10.17 kg) demonstrated a remarkable development compared to the pre-test measurement (7.5 kg) (p<0,003). The post-test measurement (24.5 degrees) showed significant development compared to the pre-test measurement (60.83 degrees) (p<0,000), suggesting an improvement in the range of motion of the flexed knee joint. In conclusion, it shows that blood flow restriction is a safe and effective treatment for people with multiple fractures.

Keywords
BFR Training, Rehabilitation, Strength, Muscular atrophy

INTRODUCTION

Training using blood flow restriction exercise (BFRE) is gaining popularity among researchers and practitioners such as medical personnel, physical therapists, strength and conditioning trainers, and rehabilitation professionals (**Brandner et al., 2019**). Reported benefits include increased muscle strength, alleviation of post-traumatic atrophy, increased neuromuscular activity, decreased pain signaling, and increased bone mineral density (**Lepley et al., 2020; Hughes and Patterson, 2019**).

Exercise deprivation is generally associated with loss of strength, muscle atrophy, and reduced functional capacities in both older adults and the clinical population (**Mujika and Padilla, 2000**). Exercise provides a unique role in creating a strong yet stable synergy for high performance in individuals aged 40-50 years. In addition, the hip serves as an important component of the lower extremity kinetic chain, as deficits in hip strength, power, or endurance are factors that predispose to knee, ankle, or foot injuries (**Sundberg, 2004**).

Many people are exposed to a variety of fractures due to exercise or exposure to accidents

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in public life, and as we age, exposure to dangerous complications becomes more frequent, and these complications include atrophy of the large thigh muscles, weakness and low protein turnover, loss of strength, and an increased risk of developing fragility. Bones and possibly a recurrence of the injury again (**Ardern, 2011**) . Double fractures of the femur can be devastating injuries that severely impact an individual's quality of life. In addition to the physical pain and trauma associated with the injury. Many people are exposed to a variety of fractures due to exercise or exposure to accidents in public life, and as we age, exposure to dangerous complications becomes more frequent, and these complications include atrophy of the large thigh muscles, weakness, and low protein turnover, loss of strength, and an increased risk of developing fragility. Bones and possibly a recurrence of the injury again (**P de Mille, 2017**). The main research problem in the rehabilitation of the elderly is the factor of inability to carry heavy weights appears due to age and the inability of the muscles to bear these weights, which are necessary to restore muscle strength and size. In addition, muscle physiology appears to be altered by exposure to multiple fractures. Thus, the specialists are faced with finding alternative rehabilitation tools that will help this category to fully recover and not return to the injury (**Ohta et al., 2003**)

Blood flow restriction (BFR) therapy was introduced as a means to rapidly induce muscle hypertrophy, thereby increasing muscle strength and endurance at lower loads than standard strengthening regimens. BFR treatment is performed by partially closing the venous outflow from the extremity for a short time using an inflatable tourniquet while performing resistance exercises (**Sgromolo et al., 2020**). This has been found to induce localized cellular and hormonal changes that lead to muscle hypertrophy. Using BFR in combination with resistance exercise, muscle hypertrophy can occur with exercise in only 20% of 1 RMas compared to 60 to 100% of 1 RM recommended by the ACSM, effectively putting the load needed to achieve the desired effect somehow reduces. Since its use in athletes, indications for BFR therapy have been expanded for use in rehabilitation programs after injury or surgery, including knee arthroscopy, total knee arthroplasty, and Achilles tendon ruptures (**ACSM, 2009**). Resistance training with heavy loads cannot achieve the desired goal at the beginning of the injury due to pain, muscle weakness, and functional limitations that prevent achieving these recommended heavy loads. Patients with injuries often require the therapist to reduce the training load, which may limit the achievement of a neuromuscular response to treatment and delay rehabilitation goals (**Jacobson et al., 2020**).

Hence, the importance of this study is that it resorted, for the first time in Iraq, according to the researcher's knowledge, to the use a new method that helps speed up the recovery of the injured and avoid problems of improper rehabilitation in the acute stage, especially for individuals who do not practice sports, as BFR provides a safe and effective low-load treatment method for those with double fractures in the lower body, as it gains more acceptance in clinical settings and more robust clinical trials are published. There has been a shift in the speed of its use and adoption in rehabilitation, especially in the early stages. Scientific trials have not only explored the ability of BFR to maintain and restore lost muscle mass and strength, but data is now available indicating its ability to maintain bone density after a fracture, reduce pain, swelling, and loss of function and recent studies have advocated its use in rehabilitation before a fracture. Therefore, The research aims to identify the effect of rehabilitation exercises with BFR in improving muscle strength, thigh muscle hypertrophy, and knee joint flexibility for those with double fractures in the lower body.

MATERIALS AND METHODS

Participants

The participants were comprised of 6 volunteers with a femoral double fracture, aged between 40-50 years and 21-45 days after their injury. All six patients attend regular physical therapy sessions for lower extremity rehabilitation for various reasons. However, all had chronic quadriceps and/or hamstring muscle weakness and were at least 1.5 months after the last surgical procedure, and their strength development was limited by their inability to successfully use traditional resistance training.

The lower extremities of all individuals were measured for comparison purposes, but some patients also had bilateral rehabilitation needs.

All patients had measurements of the affected lower extremity at least twice during their treatment period, pretest and posttest, and were using BFR therapy as part of their rehabilitation routine for at least 8 weeks. A participant with femoral fracture (4 males and 2 females; see Table 1 for participant characteristics) volunteered to participate in the study and gave written and informed consent for the experimental procedures. Participants had no known history of peripheral or neurological disorders, cardiovascular, pulmonary, or metabolic disease. In addition, none of the participants had participated in any resistance training in the last 2 months.

The participating athlete was informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. This research has been approved by the University Ethics Commission No. 242number and date 30/07/2023 was accepted with the research code number and was carried out according to the recommendations of the Declaration of Helsinki. Additional precautions were taken by the investigator(s) to protect the volunteers in this study.

Data Collection Tools

Form for each player to record the sequence measurements

Quadriceps muscles measurement (cm): Measuring tape is wrapped around quadriceps by specifying two parallel points in the middle of the thigh (Otman vd. 1995).

Goniometer to measure the range of motion of the knee joint

Measurements of joint range of motion (ROM) are part of a physical therapist's daily work. Activities of daily living and exercises can be complicated to perform when ROM is limited, and depending on the demands in daily living, the knee joint requires different ROM. In sports, a few degrees in ROM may make the difference between getting injured or not. The goals for physical therapists are to help the patients to regain full ROM, mobility, strength, and function after sustaining an injury. To measure joints with the manual universal goniometer is considered time-consuming and difficult with respect to repeated measurements.

Initial position

The patient takes a prone position on the abdomen and installs the device on the outer side of the knee joint along the thigh bone. The knee joint is flexed to the maximum extent it can reach. The difference in reading the device is between zero degrees and the angle of maximum flexion of the knee joint (Pereira et al., 2017).

Table 1. Group characteristics

Variables	Descriptive Statistics		
	Average	Standard deviation	Skewness
Age (year)	46	6.401	-0.06
Height (cm)	168.83	5.34	0.10
Body mass (kg)	77.83	7.19	0.58
Days from injury	19.33	5.92	0.02
Gender (Male/female)	Male: 4	Female: 2	
Affected limb	Right: 4	Left: 2	

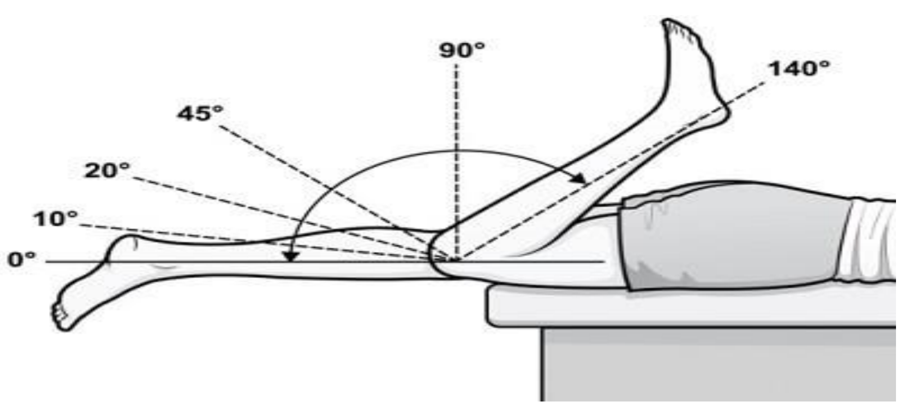

Figure 1. Measurement of knee joint range of motion

Quadriceps muscle strength measurement with dynamometer

The quadriceps muscle strength of the individuals participating in the study was assessed using a hand dynamometer (Medical Commander Power Track 2, USA). The measurements were repeated three times for the right and left sides. The highest value was recorded as Newton (N) (**Bandinelli et al., 1999**).

Performance specifications

Person stands erect on base of the device in appropriate place on middle of the base, hands in front of the thighs, and the fingers of the hands are pointing down. The tester grips the tension column tightly so that the palm of one hand is directed forward and the other is directed to the body. When the tester is ready to pull, he bends his knees forward, forming an angle of 90 °. It must be noted that the back is not bent, as well as the straightening of the arms without any bending in the elbows. At the end of the test, the legs must be fully extended.

Experimental Design

Participants were familiar with all testing and exercise protocols before starting the study. Rehabilitation exercises with BFR were done before and after. Therefore, the total duration of the experimental study was 8 weeks. During the rehabilitation exercises with BFR withdrawal period, the participants were asked to maintain their normal diet and physical activity levels.

Pre- measurements

Measurements and pre tests were performed on a group of members of the experimental research sample consisting of (6) injured, at Specialized Center for Physiotherapy and Physical Rehabilitation in Al-Kut Sports Club on Wednesday 2/2/2022.

Rehabilitation exercises with BFR

The rehabilitation program was applied individually to the injured, taking into account the rehabilitative exercises for pain limits. The rehabilitation program using rehabilitative exercises with the blood flow restriction (BFR) technique took eight weeks, with three rehabilitation units per week, each rehabilitation unit takes 60 minutes (Table 1).

Table 2. Rehabilitation exercise program used with blood flow restriction

Exercise name	*Name of the working muscle*	*Count times a week to exercise*	*Count of repetitions for each exercise*	*Count of sets*	*Rest between sets (seconds)*
Squats	Quadriceps and Hamstring muscles	3	5	5	30 - 60 s
Curly front	quadriceps muscle		15		30 - 60 s
Curly Back	Hamstring muscle		15		30 - 60 s
Push machine (like press)	Quadriceps and Hamstring muscles		10		30 - 60 s
Hack Back	Quadriceps and calves muscles		15		30 s
Raffles miscellaneous	Quadriceps, hamstrings, and calves		10		30 s

Post-measurements

Post-measurements and tests were carried out on a group of experimental research sample members on Thursday 4/4/2022 in the same order as the tribal measurements, under the same conditions, and for each patient separately.

Statistical Analysis

SPSS package program was used in the statistical analysis of our research. It was determined by the normality distribution and skewness coefficients of the data. Significance level was determined as P 0.05 and all data were presented as mean standard deviation (SD) unless stated otherwise. Independent samples t-test was used to compare the scores obtained from the measurements according to categorical variables.

RESULTS

Patients participating in rehabilitation exercises with BFR at 8 weeks no injury was recorded at any stage of the BFR exercises, and no adverse events (both acute and chronic) were reported for anyone doing the BFR exercise.

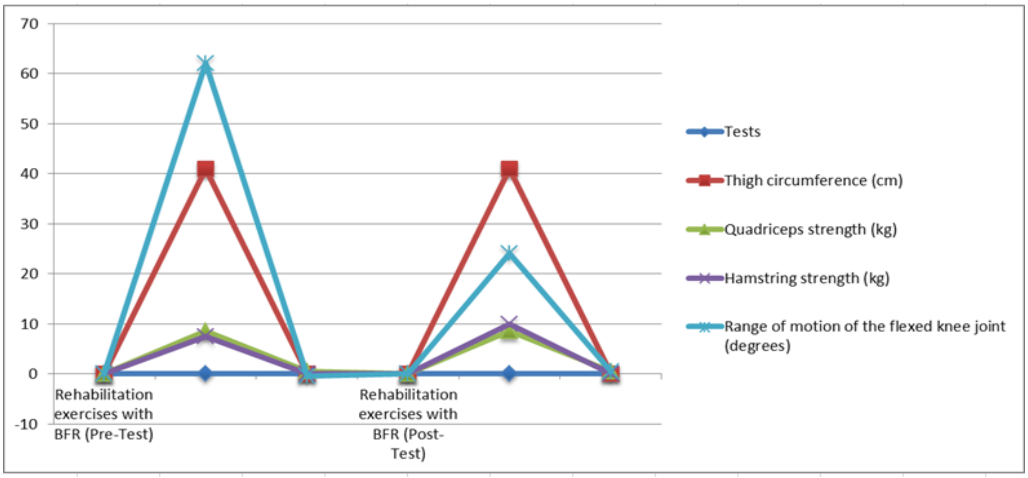

Figure 2. Statistical characterization of the variables examined before and after the Rehabilitation exercises with BFR program of the participant patients.

The findings from the study indicate significant differences between pre and post-tests, with improvements observed in all measured outcomes. Specifically, the results demonstrate the following improvements.

Table 3. Statistical characterization of the variables examined before and after the rehabilitation exercises with BFR program of the participant patients.

	Rehabilitation exercises with BFR (Pre-Test)			Rehabilitation exercises with BFR (Post-Test)		
Tests	X ± SD	Median	Skew ness	X ± SD	Median	Skew ness
Thigh circumference (cm)	41.17±1.60	41	0.041	45.33±1.21	41	0.04
Quadriceps strength (kg)	8.83±1.47	8.5	0.42	13.97±0.82	8.5	0.42
Hamstring strength (kg)	**7.5**±1.05	7.5	0.00	10.17±0.75	10	0.00
Range of motion of the flexed knee joint (degrees)	60.83±4.54	62	0.44-	24.5±2.59	24	0.42

It is evident from Table 3 on the differences between the pre- and post-measurement in (physical tests) for the experimental group (using the (BFR) blood flow restriction technique with qualifying exercises) that there are significant differences between the two measures at the level of 0.05 in all tests and in favor of the post-measurement, where the value of T Between (0.001 to 6.116), these values are greater than the tabular T value at the 0.05 level.

Table 4. Significant differences between the pre- and post-test in the variables under study for the study sample.

Tests	**Pre-test**		**Post-test**		**T value**	**level Sig**	**Type Sig**
	X	**SD**	**X**	**SD**			
Thigh circumference (cm)	41.17	1.60	45.33	1.21	0.001	0.030	Sig
Quadriceps strength (kg)	8.83	1.47	13.97	0.82	1.889	0.000	Sig
Hamstring strength (kg)	7.5	1.05	10.17	0.75	5.487	0.003	Sig
Range of motion of the flexed knee joint (degrees)	60.83	4.54	24.5	2.59	6.116	0.000	Sig

Thigh circumference (cm): There was a significant increase in thigh circumference from before the experiment (41.17 cm) to after the experiment (45.33 cm), ($p<0,001$), suggesting a favorable impact of the telemetry. Quadriceps strength (kg): The researchers observed a remarkable development in post-test measurements (13.97 kg), ($p<0,000$) compared to pre-test measurements (8.83 kg), indicating an improvement in quadriceps strength.

Hamstring strength (kg): The post-test measurement (10.17 kg) demonstrated a remarkable development compared to the pre-test measurement (7.5 kg), ($p<0,003$) indicating an improvement in hamstring strength. Range of motion of the flexed knee joint (degrees): The post-test measurement (24.5 degrees) showed significant development compared to the pre-test measurement (60.83 degrees), ($p<0,000$) suggesting an improvement in the range of motion of the flexed knee joint. Overall, the study suggests that the telemetry intervention was effective in improving thigh circumference, quadriceps and hamstring strength, and the range of motion of the flexed knee joint.

DISCUSSION

BFR resistance training can provide several advantages over traditional moderate-heavy resistance training; for example, these muscle adaptations are achieved despite relatively lower external loads, produce less muscle damage and therefore the frequency of training can be increased; muscle hypertrophy has also been demonstrated as follows: in as little as 1-2 weeks (**Scott et al., 2014**). BFR is combined with several different single-joint lower body (eg, knee extension, knee flexion, ankle plantar flexion) and upper body exercises (eg, elbow flexion, elbow extension) (**Patterson & Brandner, 2017**) as well as compound multiple exercises (-squat and common exercises such as bench press) (**Abe et al., 2012**). However, examination of a training program using a limited number of exercises (for example, one or two) does not reflect typical applied resistance training programs that include one or more exercises for more than one anatomical region (**ACSM, 2009**).

We showed that there are statistically significant differences between the pre-and post-test in favor of the post-test in the variables of muscle strength and range of motion (Table 2), and the researcher attributes this improvement to the use of the blood flow restriction (BFR) training with rehabilitation exercises in the early stage of injury, which greatly helped in performing exercises Rehabilitation with low intensity and many repetitions and without feeling pain, which led to an increase in muscle strength and range of motion, and this is consistent with what was found by (**Petrick et al., 2019 ; Anderson et al., 2019**), who was able to prove that blood flow restriction (BFR) produces beneficial adaptations for skeletal muscles. This provides a safe treatment method for patients to begin strength training in the early stages of rehabilitation to allow for a more effective return to activity and improve patient readiness.

Recent scientific research indicates that blood flow restriction training may lead to adequate strength gains with low-intensity exercise. This method is most appropriate when higher training weights are not appropriate, such as after surgery, compound fractures, or in cases of significant muscle mass loss.

The use of individual training is taken into account when using the blood flow restriction method, but in a safe manner, as the pressure must represent the minimum required for total arterial closure (**Loenneke et al., 2014**). Blood flow restriction training puts muscles under mechanical stress. (This mechanical stress also occurs during high-intensity muscle strengthening.). High pressure helps improve muscle hypertrophy, and growth, by activating specific muscle growth stem cells - releasing muscle growth hormones - hypoxia (lack of oxygen) - swelling of cells within the muscle (**Fujita et al., 2007**)

Development of muscular strength in this study agreed with the findings of that the inclusion of the rehabilitation curriculum on muscular strength exercises and their regular and gradual practice leads to various changes in the muscles such as increasing cross-section of the muscle and increasing size of fast fibers and increasing size and strength of tendons and ligaments and the density of capillaries. Clinical studies have shown that blood flow restriction can be a valid, acceptable, and effective tool for rehabilitation. As demonstrated by Hughes et al., in their systematic review and data analysis, it has been shown to be effective in mitigating strength loss and facilitating its rebuilding. Moreover, BFR training can positively affect muscle size and other physiological variables, and thus adaptations act as an alternative to heavy load when Muscular strength training, especially in the early phase of rehabilitation (Brandner et al., 2019; Hughes et al., 2017)

All of these factors can only occur in normal training when training with high weights, and they can also be achieved during low weight training by restricting blood flow to the muscles because it creates an environment in which muscle growth can occur even if the training weight is reduced to a minimum, which is something It may be important after an injury or surgery. As your body recovers after surgery, you may not be able to put severe stress on your muscles or ligaments. . Low-weight exercises may be required, which has allowed blood flow restriction training to achieve maximum strength with low, yet safe weights (**Hasan and Hasan 2022; Scott, 2014**).

Conclusion

The available data strongly support the use of blood flow restriction as a safe and effective intervention for patients with multiple lower body fractures. The results of this study demonstrate significant improvements in muscle strength, size, and function, as well as a rapid return to normal function. Moreover, the application of blood flow restriction was well-tolerated by patients, as evidenced by the absence of severe pain during exercise. Taken together, these findings suggest that blood flow restriction is a promising therapeutic option for patients with lower body fractures seeking to regain muscle function and mobility. In addition to the significant improvements in muscle strength, size, and function, blood flow restriction has the potential to provide other benefits for patients with lower body fractures. By allowing for more targeted exercise and rehabilitation, blood flow restriction may also help to reduce the risk of further injury or complications during the recovery process.

Moreover, the relatively low intensity of the exercises performed with blood flow restriction may be especially beneficial for patients who are unable to tolerate more strenuous forms of rehabilitation due to pain or other factors. It is worth noting that the current data on blood flow restriction are limited to patients with lower body fractures, and more research is needed to determine its safety and efficacy in other populations. However, the promising results seen in this study suggest that blood flow restriction has the potential to be a valuable tool in the rehabilitation of patients with lower body fractures, and warrant further investigation.

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Disclosure Statement

The author have no conflicts of interest that are directly relevant to the content of this manuscript.

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Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Committee

No.6/242 and date 30/07/2023 was accepted with the research code number and was carried out according to the recommendations of the Declaration of Helsinki

Author Contributions

Study Design, BB, RJ; Data Collection, BB; Statistical Analysis, BB, RJ; Data Interpretation, BB; Manuscript Preparation, BB, RJ; Literature Search, BB, RJ. All authors have read and agreed to the published version of the manuscript.

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