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ORIGINAL RESEARCH

Acute effect of different blood flow restriction protocols on muscle damage

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Abstract

The aim of this study is to examine the acute effect of different blood flow restriction (BFR) protocols on muscle damage. Thirty (age 19.77±1.30 years) healthy young men were included in the study. Participants were randomly divided into three groups: Experiment 1 (continuous BFR+ barbell squat, n=10), Experiment 2 (intermittent BFR + barbell squat, n=10), and Control (only barbell squats without BFR, n=10). In 80% of their 1RMs, they performed barbell squat exercises for a total of six sets, with two repetitions in each set and a 3-minute rest interval between sets. For markers of muscle damage creatine kinase (CK), lactate dehydrogenase (LDH), aspartate transaminase (AST), and alanine transaminase (ALT), blood was drawn from the individuals twice before and immediately after the exercise. Analysis of variance in repeated measures (Repeated Measures ANOVA) test was used to analyze the data. In statistical analysis, the level of significance was accepted as p<.05. As a result of the research, it was determined that there was a difference between groups in LDH values. It was determined that the ALT, AST, and CK values of the participants did not differ according to the experimental and control groups. However, it was observed that the pre-measurement and post-measurement averages differed over time. It was concluded that intermittent BFR from BFR protocols weakens markers of muscle damage compared to other groups.

Keywords: Acute effect, blood flow restriction, exercise, muscle damage.

Introduction

High-intensity or prolonged exercise is a potent stimulus for neuromuscular adaptations. This stimulant is essential for increasing muscle strength, overall strength, and power (Kraemer et al., 2006). Therefore, resistance exercises that stimulate muscle adaptations are of great importance for athletes and individuals who exercise for recreational aim. Exercises can consist of both concentric and eccentric contractions. Muscle strength development is achieved due to eccentric contractions rather than concentric contractions. Because more force can be produced during eccentric contraction. Eccentric contractions are proven to have a very important effect on increasing muscle strength, thus providing hypertrophy (Jones et al., 2016; Kraemer et al., 2002). Therefore, resistance exercises with eccentric contractions are often preferred to increase the neuromuscular response (Schoenfeld, 2016; Osmond, 2017). American College of Sports Physicians (ACSM) recommends doing weight training with 6 to 12 repetitions in at least 65-75% of 1 RM for muscle hypertrophy to occur (ACSM, 2009). If the intensity of the training falls below the recommended level, it is stated that muscle hypertrophy and muscle strength cannot be improved (Demirci, 2019).

The blood flow restriction method was first studied by the Japanese physiotherapist Yoshiaki Sato in the 1960s. Sato named this method KAATSU training (Şahin, 2021). The blood flow restriction (BFR) method is an exercise protocol that consists of restricting blood flow with external pressure by attaching a tourniquet to the proximal muscle of the

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targeted development. External pressure is provided by manually or pneumatically inflating the cuff to a pressure that allows arterial blood flow and restricts venous blood flow (Tütüneken, 2021). In this hypoxic environment, the effects of exercise increase, and there are significant increases in muscle strength and muscle mass (Demirci, 2019). The benefits of resistance exercise with BFR have been documented in studies (Hughes et al., 2017). Slysz et al. (2016) performed 3 sets of two dynamic lower body exercises on the participants using BFR and examined the effect on muscle fibre size by taking a biopsy sample. At the end of the study, they concluded that skeletal muscle and fibre hypertrophy, especially type II fibre, occurred after high-frequency BFR training.

Muscle damage was first defined by Hough in 1902 as loss of muscle function, fatigue, pain, and loss of strength after unfamiliar exercises and high-intensity exercises (Ohba et al., 2001). Skeletal muscle damage is related to the intensity and volume of the exercise but is more pronounced after an unconventional exercise. Even a single exercise protocol plays a protective role against muscle damage that will occur after a subsequent exercise of the same intensity or more. Considering the effective regeneration process and the protectiveness of exercise after the muscle damage marker revealed by exercise, it can be thought that muscle damage is inevitable in terms of adaptation to training (Smith & Miles, 2000).

Resistance exercises involving eccentric contractions have been shown to cause more muscle damage. The occurred muscle damage causes a decrease in physical performance (Howatson et al., 2012; Greer et al., 2007; Dorrell & Gee, 2016; Schoenfeld, 2016), cognitive functions, and flexibility (Howatson et al., 2012). Many studies demonstrated that the presence of proteins such as creatine kinase (CK), myoglobin (MB) and lactate dehydrogenase (LDH) in venous blood are general markers of muscle damage (Rebalka & Hawke, 2014; Matsumoto et al., 2009; Ra et al., 2013; Gee & Deniel, 2016). Similar to eccentric exercise, it is of concern whether BFR can cause exercise-induced muscle damage. The literature gives inconsistent results about the effects of resistance exercise applied with BFR on muscle damage (Takarada et al., 2000; Sieljacks et al., 2016). Muscle damage has been demonstrated to occur 24-48 hours after low-intensity resistance exercises with BFR (Takarada et al., 2000). In their studies examining the muscle-damaging effect of BFR, they observed loss of muscle strength and delayed muscle pain during the first few days (Umbel et al., 2009; Wernbom et al., 2012). They showed significant changes in various indirect measures of muscle damage (delayed onset muscle soreness, decreased strength, oedema, increased myoglobin, and CK), indicating high muscle damage (Alvarez et al., 2020; Sieljacks et al., 2016). Contrary to these studies, there are studies stating that BFR does not decrease long-term maximal voluntary contractions or increase muscle pain (Loenneke et al., 2013; Thiebaud et al., 2013).

The possibility of BFR side effects such as rhabdomyolysis cannot be excluded, especially in clinical settings. The underlying mechanisms and the muscle injury response following BFR are unknown. Most of the studies in the literature examined the effects of low-intensity (Thiebaud et al., 2013), and high-intensity BFR (Curty et al., 2018) exercises on muscle damage. However, studies examining the acute effect of high-intensity resistance exercise with BFR on muscle damage in different protocols have not been encountered. At the same time, the barbell squat exercise is one of the most challenging and effective exercises for lower extremity hypertrophy, strength, and power development (Myer et al., 2014; Lee & Lee, 2018). They require greater external loads for the lower extremities due to their larger circumference, and higher pressures or wider cuffs to provide comparable performance gains seen in the upper extremities. Considering these, it would be interesting to investigate whether continuous and intermittent use of the BFR with wider cuffs affects muscle damage during the squat exercise. While studies indicate that chronic exercise has an anti-inflammatory effect, the effect of acute exercise needs to be better understood. Therefore, this study aimed to compare the acute effects of different BFR protocols (continuous BFR versus intermittent BFR) on muscle damage after exercise.

Methods

Research Model

In this study, it was determined that the Pretest-Posttest Model with a Control Group was suitable for the research due to reasons such as the presence of at least two groups formed by objective assignment and using one or more of them as experimental and control groups, taking measurements from all groups both before and after the experiment (Karasar, 2012).

Participants

Thirty healthy young males (age 19.77±1.30 years, height 1.77±.06 cm, body weight 68.13±10.01 kg) voluntarily participated in the study. Persons who did not have lower extremity injuries, did not smoke, did not use alcohol, did not use drugs that would affect their blood levels and exercise performance, and were homogeneous in terms of age, height and body weight were included in the study. The participants were questioned whether they had any health problems and/or whether they had regular drug use, or whether they had a recent illness and were included in the study by paying attention to these criteria. Ethics committee approval was obtained from Iğdır University for this study. Procedures and risks were explained to all participants before their written consent was taken. A voluntary consent form was signed by the participants included in the study. The research was conducted following the Declaration of Helsinki. Participants were instructed to avoid intense and strenuous exercise, use any pain relievers and anti-inflammatory drugs, and maintain their regular diet and lifestyle habits throughout the study at least 72 hours before the sessions.

Experimental Design

Participants were randomly divided into three groups; experiment1 (continuous BFR+ barbell squat, n=10), experiment2 (intermittent BFR+ barbell squat, n=10), and control group (only barbell squats without BFR, n=10). The study was completed in 4 weeks. Participants visited the laboratory 4 times to collect data. At their first visit, participants were introduced to the 1RM test procedure and BFR. At their second visit, height and weight measurements were obtained, and a maximal repeat test was applied. On their third visit, the first blood restriction was performed. The BFR and barbell squat exercise protocols were applied on the fourth visit.

Familiarization Experimental Sessions

Four weeks before the main experiment, participants conducted two practice sessions to minimize possible learning effects. During the familiarization session, the participants performed 4 sets of barbell squat exercises with a load of 40% of their estimated 1RM, with the experimental groups under BFR and the control group without BFR. They did two repetitions in each set.

1 Repetition Maximum Test

The test was performed on a free-weight system. After the general warm-up application, the 1 RM test was started. With the request of the participant and the weight prescribed by the researcher, the first set was lifted between 7-10 repetitions. They were asked to repeat by adding 2.5-5 kg according to the weight they lifted and the difficulty they felt. The weight gain process was continued until the participant could do only 1 repetition. The weight of 1 repetition lifted was recorded by the researcher in kg. A 5-minute rest interval was given between each 1RM attempt (Kafkas et al., 2018).

BFR Band Application and Exercise Plan

Considering the studies in the literature to provide BFR, many different devices have been used including sphygmomanometer cuffs (Laurentino et al., 2012), elastic pneumatic cuffs (Fahs et al., 2011), nylon pneumatic cuffs (Manini et al., 2011) and elastic knee bandage (Loenneke et al., 2010). For muscle adaptation, the degree of restriction of blood flow and exercise with BFR is more important than the device. When the literature is examined, positive muscle adaptations have been observed with all methods used for blood flow restriction (Slysz et al., 2016). Therefore, occlusion bands were used for this study. Before wrapping the tapes, the perceived pressure scale was introduced to the participants. 0 out of 10 was defined as no pressure, 7 out of 10 as painless medium pressure, and 10 out of 10 as painful intense pressure. After each band around the femur, participants were asked to rate the perceived pressure of the bands on a scale of 0-10 (Price et al., 1983). To the participants forming the Experiment1 group; The occlusion bands were attached to the proximal part of the leg just before the exercise and continued without being removed during the rest periods. After the last set, the bands were removed. It was administered to the Experiment 2 group only during exercise and was released at each rest interval. The control group was asked to complete the resistance exercise sets without using BFR. Moreover, to maximize intrarater reliability, 7.6 cm wide bands were applied by the same researcher to give 7 points out of 10 on the pressure scale. Besides, a 7 out of 10 rating was confirmed to cause venous rather than arterial occlusion in all participants studied in this study (Wilson et al., 2013). During the experimental sessions, the participants performed the barbell squat exercise under three different conditions, with continuous BFR, intermittent BFR, and without BFR. They performed barbell squat exercises for a total of six sets, with two repetitions per set and a 3-minute rest interval between sets in 80% of their 1RMs (Wilk et al., 2021). The repetitions were performed with a controlled movement tempo consisting of a 2-second eccentric phase of the movement and a maximum velocity concentric phase of the movement. The movement tempo was checked and made to be consistent with that used in the 1RM test.

Blood Sampling and Muscle Damage Testing Protocols

In the participants in the research group, blood was taken from the antecubital vein by the specialist nurse twice, before and immediately after the blood draw exercise protocol, and the blood was transferred to the biochemistry tube. The blood taken into the biochemistry tubes was turned upside down 3-5 times. After the blood samples were left to rest for 30 minutes, they were centrifuged for 5 minutes in a refrigerated centrifuge at 4000 rpm. The obtained sera were separated from the serum part and transferred to microcentrifuge tubes and labeled for the analysis of biochemistry profiles. It was stored at -200C until the day of analysis. All parameters were studied in creatine kinase, lactate dehydrogenase, aspartate transaminase, and alanine transaminase medical biochemistry laboratory. It was studied with the spectrophotometric method in a biochemistry autoanalyzer.

Statistical Analysis

The data collected from the participants were checked one by one and transferred to the SPSS 23.0 package program. For statistical analysis, first of all, the data was checked whether it showed a normal distribution by examining the skewness and kurtosis values. After the analysis, it was determined that the values changed in the range of -2,….,+2 (George & Mallery, 2001). Repeated measures analysis of variance (Repeated Measures ANOVA) was used to analyze the data. All assumptions are provided so that analysis of variance can be used in repeated measurements. LSD test was used to determine the source of the difference in the significant value. In statistical analysis, the level of significance was accepted as p<.05.

Table 1

Comparison of the muscle damage values of the participants according to the groups and measurement times (Mean±SD).

ALT	n	Pre-measurement	Post-measurement	F	p
Continuous BFR	10	12.10±3.92	19.60±7.84	2.015	.153
Intermittent BFR	10	13.10±4.97	17.80±7.33		
Control	10	11.80±2.89	28.00±7.84		
		F=92.607; p=.000		The group X time interaction F=11.663; p=.000	
AST	**n**	**Mean±SD**	**Mean±SD**	**F**	**p**
Continuous BFR	10	20.00±6.60	30.30±14.01	2.012	.153
Intermittent BFR	10	18.30±6.56	24.10±7.41		
Control	10	22.80±5.82	33.80±8.49		
		F=55.003; p=.000		The group X time interaction F=1.789; p=.186	
LDH	**n**	**Mean±SD**	**Mean±SD**	**F**	**p**
Continuous BFR	10	135.50±19.97	161.40±22.95	4.244	.025*
Intermittent BFR	10	134.30±28.18	151.10±24.89		
Control	10	136.90±20.22	229.20±85.19		
		F=27.851; p=,000		The group X time interaction F=7.787; p=.002	
CK	**n**	**Mean±SD**	**Mean±SD**	**F**	**p**
Continuous BFR	10	105.30±23.25	219.00±91.21	1.320	.284
Intermittent BFR	10	108.50±50.57	162.40±61.86		
Control	10	110.50±29.07	223.00±63.27		
		F=55.132; p=.000		The group X time interaction F=2.464; p=.104	

ALT: Alanine transaminase; AST: Aspartate transaminase; LDH: Lactate dehydrogenase; CK: Creatine kinase; * p<0.05.

Results

When Table 1 was examined, no difference was found between the groups in the ALT measurements of the participants (F=2.015; p=.153). It was determined that the pre-measurement and post-measurement averages of the participants differed according to time (F=92.607; p=.000). In this case, it was observed that the lowest mean of measurement was in the intermittent BFR group, and the highest mean belonged to the control group. The effect of time on the group was found to be significant (F=11.663; p=.000).

When the AST values of the individuals were examined, no difference was found between the groups (F=2.012; p=.153). However, when the pre-measurement and post-measurement averages in AST values are examined, it is stated that they vary according to time (F=55.003; p=.000). This change seems to be in favor of the intermittent BFR group. It was determined that the mean of measurement of the continuous BFR group decreased after the intermittent BFR group compared to the control group. The interaction of time in the group was not significant (F=1.789; p=.186).

LDH values of young men were found to differ between groups (F=4.244; p=.025). It was determined that the measurement averages differed according to time (F=27.851; p=.000). In this case, it was found that the lowest mean belonged to the intermittent BFR group and the highest mean belonged to the control group. Finally, the interaction of time on the groups is significant (F=7.787; p=.002). It was determined that the CK value did not differ between the groups (F=1.320; p=.284). However, it is observed that the measurement averages differ according to time (F=55.132; p=.000) and this difference is due to the intermittent BFR group. It was concluded that the mean of measurement in the control group was higher than in the intermittent and continuous BFR group. The interaction of time in the group is not significant (F=2.464; p=.104).

Discussion

The usage of BFR in resistance exercises increased acute physiological effects such as cell swelling, metabolic stress, and endocrine responses (Loenneke et al., 2012; Takano et al., 2005). BFRs were likely to increase ATP production by glycolytic and phosphonic pathways. Because explosive performance levels were dependent on these substrates and metabolic factors, the use of BFR can be an effective method for improving muscle strength. However, the potential benefits of BFR would depend on a variety of exercise variables (type of exercise, number of repetitions and sets performed, load used) and the pressure, duration, and level of pressure exerted during BAC. Practical BFR was first proposed in 2009 (Loenneke & Pujol, 2009), and since then, acute (Loenneke et al., 2012; Wilson et al., 2013) and chronic (Loenneke et al., 2013) data have been applied to the knee instead of pressure cuffs. This showed that the application of bands can respond similarly to more expensive devices.

After the first research on resistance exercises with BFR emerged in 2000, concerns have arisen about the safety of this exercise method and especially about causing muscle damage (Takarada et al., 2000; Wernbom et al., 2008). These concerns seem to have arisen in the study of Loenneke et al. (2014) with the statements of the existing literature that such exercises cause little or no muscle damage.

This study aimed to analyze the acute effects of high-intensity barbell squat exercises on muscle damage with different BFR protocols. Among the results of our study, it was determined that AST, ALT, LDH, and CK values, which were muscle damage markers, differed according to the time between the pre-measurement and the post-measurement means. It was concluded that intermittent BFR from BFR protocols weakens markers of muscle damage compared to other groups.

Bjørnsen et al. (2019) reported that resistance exercise with acute BFR, which they applied in 20% to 30% of 1RM, increased CK. Moreover, Yasuda et al. (2015) performed resistance exercises with 20% of their 1RMs in a study that included 3 participants and reported peak CK values at the end of the study. Penailillo et al. (2020) compared the effect of changes in cardio-metabolic demand and indirect markers of muscle damage in healthy males as eccentric exercise with and without BFR. As a result of the study, they determined that the CK values of both groups increased. Dos Santos et al., (2020) in their study on the effects of blood flow restriction on leukocyte profile and muscle damage, observed that BFR-related resistance exercise showed no difference in neutrophils, and they achieved a greater level of leukocytosis and lymphocytosis after exercise. They stated that this leukocyte blood profile may be associated with less muscle damage and faster muscle recovery 24 to 48 hours after exercise. Franz et al. (2018) measured muscle damage responses caused by eccentric exercise. The study concluded that the creatine kinase marker did not show a statistical difference between the ischemic preconditioning eccentric exercise group and the group performing only eccentric exercise. Significant changes were observed only in the eccentric group at 48 to 72 hours after exercise, while small but significant increases were observed only at 72 hours in the exercise group with BFR. Sieljacks et al. (2016) completed two exercise sessions separated by 14 days with 17 healthy young males and stated that although no significant change was observed in CK at the 1st hour in both groups, serum CK increased 48 hours after exercise in both groups. On the 4th day, they stated that the serum CK level increased 13 to 36 times. Contrary to these studies, Goldfarb et al. (2008) found in their study that low-intensity resistance exercise applied with partial vascular occlusion did not show significant changes over time. Clark et al. (2011) reported that they did not find any difference between inflammation markers in their study in which they applied resistance exercise with restricted blood flow for 4 weeks in young and healthy adults. Madarame et al. (2013) stated that BFR application during low-intensity resistance exercise did not affect the inflammatory responses caused by exercise. Besides, Takarada et al. (2000) detected no increase in oxidative stress and inflammatory markers after low-intensity resistance exercise with vascular occlusion. Wilson et al., (2013) aimed to investigate the acute effects of low-intensity practical BFR on muscle damage. 12 male participants completed the leg press exercise in 30% of their 1RM with and without BFR. Swelling, decreases in strength, and delayed muscle soreness were investigated as indirect markers of muscle damage. They found that there was no difference between BFR and the control group in delayed muscle soreness at baseline or 24 hours after exercise. Wernbom et al. (2009) stated that BFR exercise caused more delayed muscle soreness. However, delayed muscle soreness alone may not be a good indicator of muscle damage (Loenneke et al., 2014). Moreover, Loenneke et al. (2013) tried to determine whether BFR alone or in combination with exercise would lead to long-term reductions in torque. As a result of the study, they concluded that BFR by itself or in combination with resistance exercise did not lead to long-term reductions in muscle function. They noted that the study could not ignore muscle damage, as torque was the only indirect predictor of muscle damage investigated and other indirect markers were not measured. The difference between the effects of BFR and resistance exercise on muscle damage may be related to the magnitude of the changes in indirect measures of muscle damage, the educational status of the individual, the muscle group to which the exercise was applied, the intensity of the exercise, and the difference in the protocols applied.

In summary, our study results showed that resistance exercise with BFR alleviates markers of muscle damage. Curty et al. (2018) performed high-intensity resistance exercises (130% of 1RM) with BFR to confirm the protective effect of BFR. At the end of the study, the researchers confirmed that BFR has a mitigating effect on some indirect markers of muscle damage. Neto et al. (2018) investigated the effect of low-load resistance exercise on oxidative stress and muscle damage from continuous and intermittent BFR. They concluded that continuous or intermittent BFR did not increase muscle damage after exercise and did not affect oxidative stress markers.

Conclusion

Since the advent of this method, many operating procedures have been standardized (Sumide et al., 2009) to improve the safety and efficacy of certain parameters, including charge density (Suga et al., 2010), cuff size (Rossow et al., 2012), pressure, and BFR application protocols. Studies investigated the effect of continuous and intermittent BFR on muscle activation (Yasuda et al., 2013), metabolic stress, hemodynamics and muscle strength (Fitschen et al., 2014). However, most studies have used a single exercise with unilateral and single-joint execution. Previous studies have included studies of muscle strength or muscle mass in the lower extremities between continuous and intermittent BFR (Fitschen et al., 2014). It is important to identify the safest and most effective methods for performing BFR training and to understand the effects of continuous and intermittent BFR during physical exercise sessions. Moreover, muscle damage should be determined. Other studies have evaluated the effects of continuous BFR and resistance exercise relative to the non-BFR group through biochemical markers of muscle damage. However, studies evaluating the effect of BFR protocols on biochemical markers of muscle damage are limited. We hypothesized that high-intensity resistance exercise (80% of 1RM is considered high-intensity exercise, see: ACSM, 2009) would significantly increase muscle damage compared to continuous and intermittent BFR. The results of our current study supported our hypothesis. Because we found that training with BFR has a mitigating effect on muscle damage. In particular, we concluded that intermittent training with BFR significantly reduced muscle damage compared to other groups. In addition, it is observed that intense and continuous exercise is accompanied by the production of free radicals that cause changes in cell membranes (Neto et al., 2018). This can lead to a decrease in muscle function, the release of muscle enzymes, marked histological changes, and muscle fibre injury accompanied by an inflammatory process leading to muscle pain (Nosaka & Clarkson, 1995). Therefore, through this procedure, it will be possible to provide new information to the scientific and clinical public and provide greater safety for prescribing BFR and resistance training, as well as support future studies. Future experiments are still required to analyze the safety and efficacy of this technique in limited populations and whether these responses occur at markers of muscle damage. More research on other potentially altered physiological traits is needed to more precisely assess the effects of BFR training.

Authors' Contribution

Study Design: SY, Data Collection: SY, Statistical Analysis: SY, MB, Manuscript Preparation: SY, MB

Ethical Approval

Ethics committee approval was obtained for the study from Iğdır University and it was conducted in accordance with the World Medical Association Code of Ethics, also known as the Declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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