ROL Spor Bilimleri Dergisi / *Journal of ROL Sports Sciences*
Cilt/Volume: 4, Sayı/No: 1, Yıl/Year: 2023, ss. / pp.: 142-157
E-ISSN: 2717-9508
URL: https://roljournal.com/

Kan akışı kısıtlaması ile alt ekstremiteye uygulanan akut egzersizin algılanan efor, kan laktat seviyesi ve kardiyovasküler tepkiler üzerine etkileri

Seda YALÇIN[1]

[1]Iğdır Üniversitesi, Spor Bilimleri Fakültesi

Araştırma Makalesi/*Research Article* **DOI:** 10.5281/zenodo.7740792

Gönderi Tarihi/ *Received:*	Kabul Tarih/ *Accepted:*	Online Yayın Tarihi/ *Published*:
20.12.2022	16.03.2023	20.03.2023

Özet

Bu çalışmanın amacı kan akışı kısıtlamalı (KAK) ve kan akışı kısıtlaması olmadan alt ekstremiteye uygulanan akut squat egzersizinin, egzersiz sonrasında kardiyovasküler tepkiler, kan laktat seviyesi ve egzersizin algılanan zorluk derecesinin etkilerini karşılaştırmaktır. Çalışma 30 (yaş 19,83±1,31 yıl) sağlıklı genç erkek katılımcıdan oluşmaktadır. Katılımcılar randomize olarak deney (KAK+ direnç egzersizi) ve kontrol (sadece direnç egzersizi uygulayan) grubu olmak üzere ikiye ayrılmışlardır. 1 Tekrar maksimum (RM)'larının %90'nında her sette iki tekrar ve setler arasında 3 dakikalık dinlenme aralığı ile toplam altı set boyunca squat egzersizini gerçekleştirmişlerdir. Egzersiz öncesi ve sonrası grupların kan laktat değerleri, kan basıncı ve algılanan efor dereceleri alınmıştır. Verilerin çözümlenmesinde tekrarlayan ölçümlerde varyans analizi (Repeated Measures ANOVA) ve bağımsız örneklem t testi kullanılmıştır. İstatistiksel analizlerde anlamlılık düzeyi p<0,05 olarak kabul edilmiştir. Araştırma sonuçlarına göre katılımcıların kan basıncı, laktat ve egzersizin algılanan zorluk derecelerinde kan akışı kısıtlaması ile uygulanan direnç egzersizi grubunun lehine anlamlı farklar elde edilmiştir. KAK'lı yöntemin geleneksel yönteme tamamlayıcı program olarak, seçilen bazı egzersizlerde kullanılması önerilebilir.

Anahtar Kelimeler: Algılanan efor, egzersiz, kan akışı kısıtlaması, kan basıncı, laktat

The effects of acute exercise applied to the lower extremity with blood flow restriction on perceived exertion, blood lactate level and cardiovascular responses

Abstract

This study, it was aimed to compare the effects of acute squat exercise applied to the lower extremities with and without blood flow restriction (BFR) on post-exercise cardiovascular responses, blood lactate level and perceived exercise intensity. The study consisted of 30 (age 19.83±1.31 years) healthy young male participants. Participants were randomly divided into an experimental (BFR+ resistance exercise) and a control (only performing resistance exercise). In 90% of their 1 Repeat maximum (RM)'s, they performed the squat exercise for a total of six sets, with two repetitions in each set and a 3-minute rest interval between sets. Blood lactate values, blood pressure and perceived exertion degrees of the groups were taken before and after exercise. Repeated measures analysis of variance (Repeated Measures ANOVA) and independent sample t-test were used to analyze the data. In statistical analysis, the significance level was accepted as p<0.05. According to the research results, significant differences were obtained in favor of the resistance exercise group applied with blood flow restriction in the blood pressure, lactate and perceived difficulty levels of the exercise. Using the BFR method in some selected exercises can be recommended as a complementary program to the traditional method.

Keywords: *Blood flow restriction, blood pressure, exercise, lactate, perceived exertion*

Sorumlu Yazar/ Corresponded Author: Seda YALÇIN, **E-posta/ e-mail:** y.seda@hotmail.com

Genişletilmiş Türkçe Özet, makalenin sonunda yer almaktadır.

INTRODUCTION

The concept of training with partial blood flow restriction has become a practice known in Japan as KAATSU, which has existed for almost 40 years (Manini & Clark, 2009). In different participant groups, it has been reported that BFR causes hypertrophy by increasing muscle strength when applied together with aerobic and anaerobic resistance exercises (Burgomaster et al., 2003; Goldfarb et al., 2008; Reeves et al., 2006). Most importantly, training methods used with BFR have been reported to cause muscle hypertrophy even at low workloads (approximately 50% of 1 repeat max). (Takarada et al., 2000). In the blood flow restriction method, a pneumatic cuff or elastic bandage is wrapped around the most proximal part of the legs or arms (Dankel et al., 2017). The aim of BFR is a method that targets venous pooling by restricting blood flow and reducing the amount of oxygen going to the muscle with the support of a special pressure band placed on the proximal part of the limb without inhibiting arterial blood circulation (Pişkin & Aktuğ, 2022).

Resistance exercise is recognized as a powerful stimulant to increase skeletal muscle size and strength. In general, the American College of Sports Medicine (ACSM) recommends that training be at least 70% of 1 RM and resistance training using this intensity to produce large increases in skeletal muscle strength and size (ACSM, 2009). Low-intensity resistance exercise combined with BFR has been shown to increase a person's muscle strength and size by only 20-30% of 1RM (Takarada et al., 2004; Madarame et al., 2008; Karabulut et al., 2010). The factors underlying this method are not clear. However, Loenneke et al. (2012a) have proposed three main mechanisms, stating that cell swelling may be accompanied by the accumulation of blood metabolites and reactive hyperemia. The first of these mechanisms is that cell swelling activates an intrinsic volume sensor that can stimulate various anabolic pathways (Fujita et al., 2007; Fry et al., 2010; Loenneke et al., 2012a). Research also proves that BFR increases metabolic stress during resistance training (Suga et al., 2010), thereby it also increases epinephrine, norepinephrine, and growth factors (Goto et al., 2005). Besides, metabolite accumulation can increase muscle fibre recruitment by activating group III and group IV afferents (Yasuda et al., 2010). As a result, it can increase the uptake of fast-twitch fibres by inhibiting the smaller alpha motor neurons that feed the slow-twitch fibres (Loenneke et al., 2012b).

The purpose of BFR exercise is to completely block the venous flow, not arterial blood flow (Loenneke et al., 2012a). Apart from the morphological, physiological or chronic benefits of BFR, some acute effects of such training are still not understood. In the literature, it is very difficult to reach a consensus on the results of studies investigating the effect of BFR on cardiovascular responses. In their study, Takano et al. (2005) applied exercises to people with low training load, using or not using BFR. As a result of the research, they stated that those who used blood flow restriction during bilateral leg extensions had higher blood pressure and heart rate variables. On the contrary, Vieira et al. (2013) trained young adults and the elderly with 30% of 1RM biceps curls with and without blood flow restriction, and they did not observe any difference in hemodynamic responses between the groups.

Exercise activates the central nervous system and, accordingly, blood pressure. Therefore, BFR can increase the blood fatigue level and, as a result, increase blood pressure through muscle Metabo-reflection (Poton & Polito, 2016). Considering the studies in terms of the intensities of the exercises applied in the study; The lack of high-intensity exercise made it difficult to understand whether the effect of the blood flow restriction method on hemodynamic responses was greater or less than with conventional training models. At the same time, it seems important to know how the convenience of the blood flow restriction method and the BFR affect the perceived level of difficulty during exercise (Wernbom et al., 2006; Wernbom et al., 2009).

Therefore, this study aimed to compare the effects of acute squat exercise applied to the lower extremity with and without blood flow restriction on post-exercise cardiovascular responses, blood lactate level and perceived exercise intensity.

MATERIAL AND METHOD

Research model

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

Research group

Thirty healthy young males (age 19.83±1.31 years, height 1.77±0.06 cm, body weight 69.97±10.31 kg) voluntarily participated in the study. The study was conducted without a history of lower extremity injuries and neuromuscular disorders, not using any medication that may affect cardiorespiratory responses, joint, bone or muscle health problems that may limit movement in practice, hypertension (≥140/90 mmHg or antihypertensive drug use), metabolic disease and Healthy young men not using toxic drugs, and not using exogenous anabolic-androgenic steroids with potential effects on exercise performance were included. Ethics committee approval was received for this study, from the Scientific Research and Publication

Ethics Committee of Iğdır University (Decision date: 14.12.2022 and protocol number: E-37077861-900-87064). Procedures and risks were explained to all participants before written consent. 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 normal diet and lifestyle habits throughout the study at least 72 hours before the sessions.

Experimental design

Participants were randomly divided into two groups experimental (BFR+ resistance exercise) and control (only performing resistance exercise). The research was completed in 3 weeks. Participants visited the laboratory 3 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, lactate measurements, cardiovascular responses, and 1 a repeat maximal test were obtained. In their third visit, the participants performed the BFR and resistance exercise protocol.

Practice experimental sessions

Three weeks before the main experiment, participants conducted two practice sessions to minimize possible learning effects. During the familiarization session, the participants performed three sets of squats with an estimated load of 40, 60%, and 80% of their 1RM in the experimental group under BFR and the control group without BFR. They performed two repeats per set.

1 repetition maximum test

After the general warm-up, all participants performed their estimated 1RM at 20 kg as 10 reps, at 60% 6 reps, at 70% 4 reps, and at 80% 3 reps. Initial test load set to 90% 1RM. The load was then increased by 5-20 kg for each additional set until the participant was unable to perform a concentric phase of movement. In each 1RM trial, the participant performed one repetition at a controlled tempo of movement consisting of a 2-second eccentric movement phase and a maximum rapid concentric phase (Wilk et al., 2020). There was a 5-minute rest period between each 1RM attempt.

BFR band application and exercise plan

BFR resistance training involves applying a wrap device, typically a pneumatic holding cuff, proximal to the muscle being worked. Another option is to use a KAATSU device, but this may not be a practical approach for most populations due to cost and accessibility (Lowery et al., 2014). Therefore, occlusion strips were used for this study. To the participants of the experimental group; Occlusion bands were attached to the proximal part of the leg and were not used in the control group. 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, 10 out of 10 as painful intense pressure. After each band around the femur, participants were asked to rate the perceived pressure of the dressing on a scale of 0-10 (Price et al., 1983). The bands were applied to give 7 points out of 10 on the pressure scale. Strips were applied by the same investigator to maximize interrater reliability. The BFR stimulus was applied just before the exercise and continued without being removed during the rest periods. After the last set, the strips were removed. During the experimental sessions, the participants performed the squat resistance exercise in two different conditions, without BFR and continuous BFR. 90% of their 1RMs performed squat exercises for a total of six sets, with two reps in each set and a 3-minute rest interval between sets. Movement tempo was controlled and consistent with that used in the 1RM test.

Data collection tool

Blood pressure measurement

Renz digital device (model R1; Ankara, Turkey) was used to measure resting blood pressure and participants' pre- and post-exercise systolic, diastolic, and heart rates. Initial measurements were taken three times in succession in the dominant arm, pre-exercise in a comfortable sitting position for 10 minutes and with at least a 1-minute interval between blood pressure measurements. Resting blood pressure was considered the mean of the three measurements. The same measurements were performed by the same researcher after the exercise. Blood pressure measurement was performed following the American Heart Association (Pickering et al., 2005).

Blood lactate concentration

Blood lactate was measured twice in the experimental and control groups, before and after the exercise program. Before the blood sample was taken, asepsis was performed with 70% ethyl solution from the middle finger of the right hand to the distal part of the fingertip. The function was performed using disposable lancets, a suspended blood drop applied to a specific area on a lactate test strip analyzed with a portable lactometer (The Edge™ Blood Lactate Monitoring System, Taiwan).

Perceived effort and pain rating

Borg's (1982) Perceived Difficulty Level (PDL) scale was used to determine the degree of difficulty. This scale consists of numbers from 6 to 20 and difficulty statements (7-very easy, 19-very very difficult) next to some of these numbers. At the beginning of the first set, the Borg scale was explained to the subjects and how they would indicate the difficulty level of the exercise was explained as suggested by the ACSM (ACSM, 1991). After completing the exercise program in both groups, they completed the Borg scale.

Data 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, it was checked whether the data 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) and independent sample t-test were used to analyze the data. In statistical analysis, the level of significance was accepted as p<0.05. In addition, time-dependent percentage changes between groups were calculated using the formula "%Δ= (Post-Test-Pre-Test) /Pre-Test*100".

RESULTS

Table 1. Comparison of cardiovascular and lactate values of participants according to groups and measurement times

Systolic Pressure	N	Pre measurement	Post measurement	%Δ	F	p
		$\bar{X}$ ± s.d.	$\bar{X}$ ± s.d.			
Experimental	15	12.42±1.67	14.00±2.04	12.72	0.288	0.595
control	15	12.56±1.42	13.26±1.82	5.57		
		F=15.132; p=0.001*		Group X Time Interaction F=2.254; p=0.144		
Diastolic Pressure	**N**	$\bar{X}$ ± s.d.	$\bar{X}$ ± s.d.	**%Δ**	**F**	**p**
Experimental	15	5.94±0.930	8.59±2.43	44.61	4.354	0.046*
Control	15	6.35±0.824	6.60±1.09	3.93		
		F=14.570; p=0.001*		Group X Time Interaction F=10.025; p=0.004*		
Heart rate	**N**	$\bar{X}$ ± s.d.	$\bar{X}$ ± s.d.	**%Δ**	**F**	**p**
Experimental	15	81.87±12.35	101.67±13.13	24.18	4.588	0.041*
Control	15	78.27±10.49	87.20±12.81	11.40		
		F=94.056; p=0.000*		Group X Time Interaction F=13.453; p=0.001*		
Lactate	**N**	$\bar{X}$ ± s.d.	$\bar{X}$ ± s.d.	**%Δ**	**F**	**p**
Experimental	15	29.00±10.86	61.87±11.09	113.34	6.756	0.015*
Control	15	30.93±11.98	40.73±9.69	31.68		
		F=197.045; p=0.000*		Group X Time Interaction F=57.591; p=0.000*		

*=p<0.05

When Table 1 was examined, it was determined that the systolic blood pressure values of the participants did not differ according to the experimental and control groups (F=0.288; p=0.595). It was determined that the pre-measurement and post-measurement means of the participants differed according to time (F=15.132; p=0.001). Finally, the group time interaction was not significant (F=2.254; p=0.144). It was determined that the diastolic blood pressure values of the participants differed according to the experimental and control groups (F=4.354; p=0.046). It was determined that the pre-measurement and post-measurement means of the participants differed according to time (F=14.570; p=0.001). Finally, a significant difference was found in the group time interaction (F=10.025; p=0.004). It was determined that the heart rate values of the participants differed according to the experimental and control groups (F=4.588; p=0.041). It was determined that the pre-measurement and post-measurement means of the participants differed according to time (F=94.056; p=0.000). Finally, a significant difference was found in the group time interaction (F=13.453; p=0.001). It was determined that the lactate values of the participants differed according to the experimental and control groups (F=6.756; p=0.015). It was determined that the pre-measurement and post-measurement means of the participants differed according to time (F=197.045; p=0.000). Finally, a significant difference was obtained in the group time interaction (F=57.591; p=0.000).

Table 2. Comparison of the perceived difficulty scores of the participants according to the groups.

PDS		$\bar{X}$ **± s.d.**	**t**	**p**
Experimental	15	14.93±2.08	3.106	0.004*
Control	15	12.60±2.02		

*=p<0.05

When Table 2 was examined, it was determined that the perceived difficulty scores of the participants differed according to the groups (t=3.106; p=0.004).

DISCUSSION

In recent years, the acute and chronic effects of various exercises applied with the BFR method have become a subject of interest. Research performed with different pressure ranges, different sample groups, different time intervals, different devices with or without pneumatics, different methodologies and anatomical regions using many different BFR methods (Slysz, 2016). When BFR and traditional methods were compared, it was stated that the BFR method produces similar muscle performance at a lower exercise intensity and caused less muscle pain, which was an effective alternative method to the traditional training method (Early et al., 2020). Blood flow restriction training assumed to provide beneficial adaptation by different mechanisms (Loenneke et al., 2010a). One of these mechanisms was the accumulation of metabolites such as lactate. Lactate accumulation was important because it showed that growth hormone was stimulated through an acidic intramuscular environment (Takano et al., 2005).

This study compared the acute effects of BFR on lower extremity lactate, cardiovascular responses, and perceived difficulty in males. As a result of the research, a difference was detected between the groups in the blood lactate levels of the participants (F=6.756; p=0.015). The mean of pre-measurement and post-measurement of lactate levels of the men determined to include in the study differed according to time (F=197.045; p=0,000). Finally, a significant difference was obtained in the group time interaction (F=57.591; p=0.000). The results of the study supported the literature.

Gentil et al., (2006) found that whole blood lactate levels increased significantly in blood flow-restricted resistance training compared to the control group in a study involving 12 male participants in which four different resistance training exercises were applied. Takano et al., (2005), in their study involving 11 sedentary male participants, applied pressure to the proximal part of both legs with a specially designed belt to reduce BFR. Participants did 30 repetitions with 20% of one repetition maximum. After a 20-second rest, they performed a three-set resistance exercise protocol until they get tired. As a result of the study, they stated that the blood lactate level increased. Fujita et al., (2007) conducted a study with 6 young men who performed resistance exercise at 20% of 1RM with a pressure cuff placed on the promaximal part of both thighs. It was concluded that the lactate level of the resistance exercise group applied using blood flow restriction was higher than the control group. Kawada & Ishii (2008) found that lactate concentrations were higher than the other group in their study investigating changes in skeletal muscle size, fibre type composition and capillary supply after chronic venous occlusion. In their study, Reeves et al., (2006) performed three experimental methods of light resistance exercise with partial blood flow restriction, moderate resistance exercise without BFR, and partial occlusion without exercise by 8 healthy participants. As a result of the study, they observed higher lactate levels in the group that applied light exercise with partial vascular BFR compared to the group that performed moderate exercise without occlusion. Takarada et al., (2000b) looked at the blood lactate level after low-intensity resistance exercise with vascular occlusion and stated that the lactate level increased compared to the control group. In another similar study that measured the effect of vascular restriction training on athletic performance in college hockey players, they stated that blood lactate levels increased. Contrary to these studies, Loenneke et al. (2010b) compared lactate values between the BFR user and non-user control group in a study that included 12 healthy men and women, but found no difference between the two groups. Although some studies showed a statistical increase in lactate levels, they could not evaluate this as a real change because the minimum difference between conditions was not exceeded (Loenneke et al., 2012b). Vieira et al. (2015) measured blood lactate concentration after exercise and emphasized that it was similar in resistance exercise with BFR and high-intensity exercise groups.

The reasons for the differences in the results of the studies in the literature may include the use of only single-joint exercises (unilateral or bilateral knee extension and unilateral elbow flexion or plantar flexion) in previous studies and the length of reperfusion and rest periods between sets. Another possibility is that obstruction of blood flow may result in slower diffusion of lactate from muscle tissue, resulting in a more pronounced intramuscular acidic environment.

Resistance training represents a complex environment of perceptual signals, including muscle mass, metabolic acidosis, and loading, which can have an impact on cardiovascular responses and the perceived intensity of exercise. Therefore, resistance exercise protocols and general physiological stress were stated to play an important role in cardiovascular responses and perceived difficulty. At the same time, the evaluation of PDL may be useful to expand existing knowledge about BFR and resistance exercises (Vieira et al., 2015).

In this study, the cardiovascular responses of the participants were compared with the perceived difficulty levels, and differences were found between the groups in the heart rate, diastolic blood pressure, lactate and perceived difficulty level values. Although no difference was detected between the groups in systolic blood pressure values, it was determined that the measurement means differed according to time. The results of the study support the literature.

Loenneke et al., (2010b) stated in their study that heart rate and perceived difficulty levels significantly increased in the group with BFR compared to the control group. Increased heart rate has been previously shown to occur with occlusion training, which can be attributed to decreased venous return (Takano et al., (2005). Vieira et al., (2015) detected that low-intensity exercise with BFR showed more PDL. Takano et al., (2005), examined the hemodynamic and hormonal responses to short-term low-intensity resistance exercise using BFR and concluded that blood pressure and heart rate were higher and stroke volume was lower than those who did not use BFRs. Loenneke et al., (2010b) stated an increase in the heart rate and perceived exertion of the participants in the resistance training programs they applied with practical BFR. Neto et al., (2017) stated that systolic blood pressure and heart rate at the end of each exercise increased after exercise applied to the upper extremity with continuous and intermittent BFR.

Renzi et al. (2010) reported that blood pressure increased significantly in the exercise group with BFR. Karabulut & Garcia (2017) in their study investigating hemodynamic responses during blood flow restriction exercise, concluded that hemodynamic responses increased. In the study conducted by Brandner et al. (2014), they stated that the BFR protocol supported a significant increase in blood pressure at the end.

Our research results contradict other results which found no difference in contrast to these studies. Wernbom et al. (2009) conducted a study on 11 healthy participants, participants performed 3 sets of unilateral knee extension exercises at 30% of the maximum 1 repetition. Participants exercised one leg with BFR and the other leg without BFR, and they rated perceived effort after exercise. As a result of the research, they found that the perceived difficulty levels were similar in both experimental conditions. Neto et al., (2016) did not find any difference in blood pressure and diastolic pressure values between the protocols they applied (high-intensity protocol, low-intensity protocol, blood flow restriction protocol and low-intensity). Libardi et al. (2017) concluded that resistance exercise using BFR showed lower systolic and diastolic blood pressure and heart rate values compared to the group not using BFR.

CONCLUSION AND RECOMMENDATIONS

BFR is applied to the region where activity is most intense muscular exercises with high-level pressure above normal blood flow in the respective region limitations, withdrawal, before the withdrawal of the pressure and then, with a result of standing water that creates the blood to that area right, tap more blood supply and oxygenation of survival, therefore, that will perform in muscular activity which is characterized by the expectation of any recovery and development practice.

This style of application formed the method for most studies. However, differences such as positive, negative and ineffective results were noted in each sample group that changed and studied. Therefore, the results of the research cannot present a clear and common judgment picture. Considering the effects of this study according to the groups, it was seen that resistance exercise with BFR affected most cardiovascular responses, lactate and PDL. However, when we look at the studies in the literature, it was also stated that resistance exercises with BFR did not achieve significant results on these variables. Therefore, there is a need for homogeneous studies and in different age groups, consisting of more participants and applied with more repetitions. At the same time, it can be recommended to use the BFR method as a complementary program to the traditional method in some selected exercises. This situation may offer a different alternative method to the trainers.

GENİŞLETİLMİŞ ÖZET

GİRİŞ

Hem kas kütlesini hem de kuvveti artırmanın en yaygın yöntemi, Amerikan Spor Hekimliği Koleji'nin tipik olarak, optimal kas hipertrofisini indüklemek için maksimal gücün %70'ini aşan yüklerle direnç egzersiz eğitiminin kullanılmasını tavsiye ettiği yüksek yoğunluklu direnç egzersizinin performansıdır. KAK'nın amacı, arteriyel kan dolaşımını inhibe etmeden uzvun proksimal kısmına yerleştirilmiş özel baskı bandı desteği ile kan akışını kısıtlayarak ve kasa giden oksijen miktarını azaltarak venöz göllenmeyi hedefleyen bir yöntemdir. Egzersiz, merkezi sinir sistemini ve buna bağlı olarak da kan basıncını aktive eder. Bu nedenle, KAK kandaki yorgunluk düzeyini yükseltebilir ve bunun sonucunda kas metabo refleksiyonu yoluyla kan basıncını artırır (Poton ve Polito, 2016). Araştırmalara, çalışmada uygulanan egzersizlerin yoğunlukları açısından bakıldığında; egzersizlerin yüksek yoğunlukta uygulanmaması kan akışı kısıtlama yönteminin hemodinamik tepkiler üzerindeki etkisinin geleneksel antrenman modellerine kıyasla daha mı yüksek ya da daha mı az olduğunu anlamayı zorlaştırmıştır. Aynı zamanda kan akışı kısıtlama yönteminin rahatlığı ile KAK'nın uygulanan egzersiz esnasında algılanan zorluk derecesini ne yönde etkilediğini bilmek önemli görünmektedir (Wernbom ve ark., 2006; Wernbom ve ark., 2009). Bu nedenle, bu çalışmanın amacı, kan akışı kısıtlamalı ve kan akışı kısıtlaması olmadan alt ekstremiteye uygulanan akut squat egzersizinin, egzersiz sonrasında kardiyovasküler tepkiler, kan laktat seviyesi ve egzersizin algılanan zorluk derecesinin etkilerini karşılaştırmaktır.

YÖNTEM

Araştırmaya 30 sağlıklı genç erkek (yaş 19,83±1,31 yıl, boy uzunluğu 1,77±0,06 cm, vücut ağırlığı 69,97±10,31 kg) gönüllü olarak katılım sağlamıştır. Katılımcılar randomize olarak deney (KAK+ direnç egzersizi) ve kontrol (sadece direnç egzersizi uygulayan) grubu olmak üzere ikiye ayrılmışlardır. Araştırma 3 hafta da tamamlanmıştır. Katılımcılar veri toplamak için laboratuvarı 3 kez ziyaret etmişlerdir. İlk ziyaretlerinde katılımcılar 1RM test prosedürü ve KAK'sı ile tanıştırılmıştır. İkinci ziyaretlerinde boy ve kilo ölçümleri, laktat ölçümleri, kardiyovasküler tepkiler ve bir tekrar maksimum testi elde edilmiştir. Üçüncü ziyaretlerinde ise katılımcılar KAK ve direnç egzersizi protokolünü gerçekleştirmişlerdir. Literatür incelendiğinde kan akışını kısıtlamak için kullanılan tüm yöntemlerle pozitif kas adaptasyonları gözlenmiştir (Slysz ve ark., 2016). Bu yüzden bu çalışma için oklüzyon bantları kullanılmıştır. Deney grubunu oluşturan katılımcılara; bacağın promaksimal kısmına oklüzyon bantları takılmış kontrol grubunda ise kullanılmamıştır. 1TM'larının %90'nın da her sette iki tekrar ve setler arasında 3 dakikalık dinlenme aralığı ile toplam altı set boyunca squat egzersizini gerçekleştirmişlerdir. Egzersiz öncesi ve sonrası grupların kan laktat değerleri, kan basıncı ve algılanan zorluk dereceleri (AZD) alınmıştır. Verilerin çözümlenmesinde tekrarlayan ölçümlerde varyans analizi (Repeated Measures ANOVA) ve bağımsız örneklem t testi kullanılmıştır. İstatistiksel analizlerde anlamlılık düzeyi p<0,05 olarak kabul edilmiştir. Ayrıca gruplar arası zamana bağlı yüzde değişimler "%Δ= (Son Test-Ön Test) /Ön Test*100" formülü kullanılarak hesaplanmıştır.

BULGULAR

Katılımcıların sistolik kan basınç değerlerinin deney ve kontrol gruplarına göre farklılık göstermediği tespit edilmiştir (F=0,288; p=0,595). Katılımcıların ön ölçüm ve son ölçüm ortalamalarının zamana göre farklılık gösterdiği tespit edilmiştir (F=15,132; p=0,001). Son olarak ise grup zaman etkileşimi anlamlı değildir (F=2,254; p=0,144).

Katılımcıların diyastolik kan basınç değerlerinin deney ve kontrol gruplarına göre farklılık gösterdiği tespit edilmiştir (F=4,354; p=0,046). Katılımcıların ön ölçüm ve son ölçüm ortalamalarının zamana göre farklılık gösterdiği tespit edilmiştir (F=14,570; p=0,001). Son olarak ise grup zaman etkileşimin de anlamlı farklılık elde edilmiştir (F=10,025; p=0,004).

Katılımcıların kalp atış hızı değerlerinin deney ve kontrol gruplarına göre farklılık gösterdiği tespit edilmiştir (F=4,588; p=0,041). Katılımcıların ön ölçüm ve son ölçüm ortalamalarının zamana göre farklılık gösterdiği tespit edilmiştir (F=94.056; p=0.000). Son olarak ise grup zaman etkileşimin de anlamlı farklılık elde edilmiştir (F=13,453; p=0,001).

Katılımcıların laktat değerlerinin deney ve kontrol gruplarına göre farklılık gösterdiği tespit edilmiştir (F=6,756; p=0,015). Katılımcıların ön ölçüm ve son ölçüm ortalamalarının zamana göre farklılık gösterdiği tespit edilmiştir (F=197,045; p=0,000). Son olarak ise grup zaman etkileşimin de anlamlı farklılık elde edilmiştir (F=57,591; p=0,000).

Katılımcıların algılanan zorluk derecesi puanlarının gruplara göre farklılık gösterdiği tespit edilmiştir (t=3,106; p=0,004).

TARTIŞMA VE SONUÇ

Bu çalışma, erkelerde KAK'ın alt ekstremite için laktat, kardiyovasküler tepkiler ve algılanan zorluk derecesinin akut etkilerini karşılaştırmıştır. Araştırma sonucunda katılımcıların gruplar arası kardiyovasküler tepkileri ile algılanan zorluk dereceleri karşılaştırılmış ve kalp atış hızının, diyastolik kan basınç, laktat ve AZD değerlerinde gruplar arası farka rastlanmıştır. Sistolik kan basınç değerlerinde ise gruplar arası fark bulunmamasına rağmen ölçüm ortalamalarının zamana göre farklılık gösterdiği tespit edilmiştir.

Gentil ve arkadaşları (2006) 12 erkek katılımcının yer aldığı dört farklı direnç antrenmanın uygulandığı araştırmada tam kan laktat seviyelerinin kontrol grubuna kıyasla kan akışı kısıtlamalı direnç antrenmanlarında önemli derecede arttığı bulgusuna ulaşmışlardır. Loenneke ve arkadaşları (2010b) yapmış oldukları çalışmada kalp atış hızı ve algılanan zorluk derecesi değerlerinin kontrol grubuna göre

KAK'lı grupta önemli ölçüde artış gösterdiğini belirtmişlerdir. Artmış kalp atış hızının, azalmış venöz dönüşe atfedilebilen oklüzyon eğitimi ile daha önce meydana geldiği gösterilmiştir (Takano ve ark., (2005). Loenneke ve arkadaşları (2010b) pratik KAK ile uygulamış oldukları direnç antrenman programlarında katılımcıların kalp atış hızı ve algılanan efor derecelerinde artışlar olduğunu ifade etmişlerdir.

Gruplara göre bu çalışmanın etkileri düşünüldüğünde çoğu kardiyovasküler tepkiler, laktat ve AZD üzerinde KAK'lı direnç egzersizin etkisinin olduğu görülmüştür. KAK'lı yöntemin geleneksel yönteme tamamlayıcı program olarak, seçilen bazı egzersizlerde kullanılması önerilebilir. Bu durum antrenörlere daha farklı alternatif bir yöntem sunabilir.

REFERENCES

American College of Sports Medicine position stand. (2009). Progression models in resistance training for healthy adults. *Medicine and Science in Sports and Exercise*, *41*(3), 687-708.

American College of Sports Medicine. (1991). *Guidelines for exercise testing and prescription.* Williams & Wilkins

Brandner, C.R., Kidgell, D.J., & Warmington, S.A. (2015). Unilateral bicep curl hemodynamics: Low-pressure continuous vs high-pressure intermittent blood flow restriction. *Scandinavian Journal of Medicine & Science in Sports, 25*(6), 770-777.

Borg, G.A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*. *14*(5), 377-381.

Burgomaster, K.A., Moore, D.R., Schofield, L.M., Phillips, S.M., Sale, D.G., & Gibala, M.J. (2003). Resistance training with vascular occlusion: metabolic adaptations in human muscle. *Medicine and Science in Sports and Exercise, 35*(7), 1203-1208.

Dankel, S. J., Buckner, S.L., Counts, B.R., Jessee, M.B., Mouser, J.G., Mattocks, K.T., ... et al. (2017). The acute muscular response to two distinct blood flow restriction protocols. *Physiology International*, *104*(1), 64-76.

Early, K.S., Rockhill, M., Bryan, A., Tyo, B., Buuck, D., & McGinty, J. (2020). Effect of blood flow restriction training on muscular performance, pain and vascular function. *International Journal of Sports Physical Therapy*, *15*(6), 892.

Fujita, S., Abe, T., Drummond, M.J., Cadenas, J.G., Dreyer, H.C., Sato, Y., ... et al. (2007). Blood flow restriction during low-intensity resistance exercise increases S6K1 phosphorylation and muscle protein synthesis. *Journal of Applied Physiology*. 103(3).

Fry, C.S., Glynn, E.L., Drummond, M.J., Timmerman, K.L., Fujita, S., Abe, T., ... et al. (2010). Blood flow restriction exercise stimulates mTORC1 signaling and muscle protein synthesis in older men. *Journal of Applied Physiology, 108*(5), 1199-1209.

Gentil, P., Oliveira, E., & Bottaro, M. (2006). Time under tension and blood lactate response during four different resistance training methods. *Journal of Physiological Anthropology*, *25*(5), 339-344.

George, D., & Mallery. P. (2001). *SPSS for windows step by step: A simple guide and reference 10.0 update.* (3. Baskı). Boston: Allyn and Bacon.

Goldfarb, A.H., Garten, R.S., Chee, P.D. M., Cho, C., Reeves, G.V., Hollander, D.B., ... et al. (2008). Resistance exercise effects on blood glutathione status and plasma protein carbonyls: influence of partial vascular occlusion. *European Journal of Applied Physiology*, *104*(5), 813-819.

Goto, K., Ishii, N., Kizuka, T. & Takamatsu, K. (2005). The impact of metabolic stress on hormonal responses and muscular adaptations. *Medicine & Science in Sports & Exercise*, *37*(6), 955-963.

Karasar, N. (2012). *Scientific research method*. Ankara: Nobel Publications.

Karabulut, M., Abe, T., Sato, Y., & Bemben, M.G. (2010). The effects of low-intensity resistance training with vascular restriction on leg muscle strength in older men. *European Journal of Applied Physiology*, *108*(1), 147-155.

Karabulut, M., & Garcia, S.D. (2017). Hemodynamic responses and energy expenditure during blood flow restriction exercise in obese population. *Clinical Physiology and Functional Imaging*, *37*(1), 1-7.

Kawada, S., & Ishii, N. (2008). Changes in skeletal muscle size, fibre-type composition and capillary supply after chronic venous occlusion in rats. *Acta Physiologica*, *192*(4), 541-549.

Loenneke, J.P., Wilson, G.J., & Wilson, J.M. (2010a). A mechanistic approach to blood flow occlusion. *International Journal of Sports Medicine*, *31*(1), 1-4.

Loenneke, J.P., Kearney, M.L., Thrower, A.D., Collins, S., & Pujol, T.J. (2010b). The acute response of practical occlusion in the knee extensors. *The Journal of Strength & Conditioning Research*, *24*(10), 2831-2834.

Loenneke, J., Fahs, C.A., Rossow, L.M., Abe, T., & Bemben, M.G. (2012a). The anabolic benefits of venous blood flow restriction training may be induced by muscle cell swelling. *Medical Hypotheses*, *78*(1), 151-154.

Loenneke, J.P., Thrower, A.D., Balapur, A., Barnes, J.T., & Pujol, T.J. (2012b). Blood flow–restricted walking does not result in an accumulation of metabolites. *Clinical Physiology and Functional İmaging*, 32(1), 80-82.

Lowery, R.P., Joy, J.M., Loenneke, J.P., de Souza, E.O., Machado, M., Dudeck, J.E., … et al. (2014). Practical blood flow restriction training increases muscle hypertrophy during a periodized resistance training programme. *Clinical Physiology and Functional Imaging*, *34*(4), 317-321.

Libardi, C. A., Catai, A. M., Miquelini, M., Borghi-Silva, A., Minatel, V., Alvarez, I.F., ... et al. (2017). Hemodynamic responses to blood flow restriction and resistance exercise to muscular failure. *International Journal of Sports Medicine*, *38*(2), 134-140.

Madarame, H., Neya, M., Ochi, E., Nakazato, K., Sato, Y., & Ishii, N. (2008). Cross-transfer effects of resistance training with blood flow restriction. *Medicine Science in Sports Exercise*, *40*(2), 258.

Manini, T.M., & Clark, B.C. (2009). Blood flow restricted exercise and skeletal muscle health. *Exercise and Sport Sciences Reviews*, *37*(2), 78-85.

Neto, G.R., Novaes, J.S., Salerno, V.P., Gonçalves, M.M., Piazera, B.K., Rodrigues-Rodrigues, T., … et al. (2017). Acute effects of resistance exercise with continuous and intermittent blood flow restriction on hemodynamic measurements and perceived exertion. *Perceptual and Motor Skills, 124*(1), 277-292.

Pişkin, N.E., & Aktuğ, Z.B. (2022). Investigation of the Effect of Blood Flow Restriction Training Applied to the Lower Extremity on Leg Volume, Leg Mass and Leg Strength. International *Journal of Sport Exercise and Training Sciences-IJSETS*, *8*(3), 82-93.

Pickering, T.G., Hall, J.E., Appel, L.J., Falkner, B.E., Graves, J.W., Hill, M.N., … et al. (2005). Recommendations for blood pressure measurement in humans: an AHA scientific statement from the Council on High Blood Pressure Research Professional and Public Education Subcommittee. *The Journal of Clinical Hypertension*, *7*(2), 102.

Price, D.D., McGrath, P.A., Rafii, A., & Buckingham, B. (1983). The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. *Pain*, *17*(1), 45-56.

Poton, R., & Polito, M. D. (2016). Hemodynamic response to resistance exercise with and without blood flow restriction in healthy subjects. *Clinical Physiology and Functional Imaging*, *36*(3), 231-236.

Reeves, G.V., Kraemer, R.R., Hollander, D.B., Clavier, J., Thomas, C., Francois, M., … et al. (2006). Comparison of hormone responses following light resistance exercise with partial vascular occlusion and moderately difficult resistance exercise without occlusion. *Journal of Applied Physiology*, *101*(6), 1616-1622.

Renzi, C. P., Tanaka, H., & Sugawara, J.U.N. (2010). Effects of leg blood flow restriction during walking on cardiovascular function. *Medicine and Science in Sports and Exercise*, *42*(4), 726.

Slysz, J., Stultz, J., & Burr, J. F. (2016). The efficacy of blood flow restricted exercise: A systematic review & meta-analysis. *Journal of Science and Medicine in Sport*, *19*(8), 669-675.

Suga, T., Okita, K., Morita, N., Yokota, T., Hirabayashi, K., Horiuchi, M., ... et al. (2010). Dose effect on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. *Journal of Applied Physiology*, *108*(6), 1563-1567.

Takarada, Y., Takazawa, H., Sato, Y., Takebayashi, S., Tanaka, Y., & Ishii, N. (2000). Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. *Journal of Applied Physiology*, (88), 2097–2106

Takarada, Y., Nakamura, Y., Aruga, S., Onda, T., Miyazaki, S., & Ishii, N. (2000b). Rapid increase in plasma growth hormone after low-intensity resistance exercise with vascular occlusion. *Journal of Applied Physiology*, *88*(1), 61-65.

Takarada, Y., Tsuruta, T., & Ishii, N. (2004). Cooperative effects of exercise and occlusive stimuli on muscular function in low-intensity resistance exercise with moderate vascular occlusion. *The Japanese Journal of Physiology*, *54*(6), 585-592.

Takano, H., Morita, T., Iida, H., Asada, K.I., Kato, M., Uno, K., … et al. (2005). Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. *European Journal of Applied Physiology*, *95*(1), 65-73.

Vieira, P. J., Chiappa, G.R., Umpierre, D., Stein, R., & Ribeiro, J. P. (2013). Hemodynamic responses to resistance exercise with restricted blood flow in young and older men. *The Journal of Strength & Conditioning Research*, 27(8), 2288-2294.

Vieira, A., Gadelha, A.B., Ferreira-Junior, J.B., Vieira, C.A., de Melo Keene von Koenig Soares, E., Cadore, E. L., ... et al. (2015). Session rating of perceived exertion following resistance exercise with blood flow restriction. *Clinical Physiology and Functional Imaging*, *35*(5), 323-327.

Wernbom, M., Augustsson, J., & Thomeé, R. (2006). Effects of vascular occlusion on muscular endurance in dynamic knee extension exercise at different submaximal loads. *The Journal of Strength & Conditioning research*, *20*(2), 372-377.

Wernbom, M., Järrebring, R., Andreasson, M.A., & Augustsson, J. (2009). Acute effects of blood flow restriction on muscle activity and endurance during fatiguing dynamic knee extensions at low load. *The Journal of Strength & Conditioning Research*, *23*(8), 2389-2395.

Wilk, M., Golas, A., Zmijewski, P., Krzysztofik, M., Filip, A., Del Coso, J., … et al. (2020). The effects of the movement tempo on the one-repetition maximum bench press results. *Journal of Human Kinetics*, *72*(1), 151-159.

Yasuda, T., Abe, T., Brechue, W. F., Iida, H., Takano, H., Meguro, K., ... et al. (2010). Venous blood gas and metabolite response to low-intensity muscle contractions with external limb compression. *Metabolism*, *59*(10), 1510-1519.

KATKI ORANI ***CONTRIBUTION RATE***	**AÇIKLAMA** ***EXPLANATION***	**KATKIDA BULUNANLAR** ***CONTRIBUTORS***
Fikir ve Kavramsal Örgü *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak *Form the research hypothesis or idea*	Seda YALÇIN
Tasarım *Design*	Yöntem ve araştırma desenini tasarlamak *To design the method and research design.*	Seda YALÇIN
Literatür Tarama *Literature Review*	Çalışma için gerekli literatürü taramak *Review the literature required for the study*	Seda YALÇIN
Veri Toplama ve İşleme *Data Collecting and Processing*	Verileri toplamak, düzenlemek ve raporlaştırmak *Collecting, organizing and reporting data*	Seda YALÇIN
Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların Değerlendirilmesi *Evaluation of the obtained finding*	Seda YALÇIN

Destek ve Teşekkür Beyanı/ *Statement of Support and Acknowledgment*

Bu çalışmanın yazım sürecinde katkı ve/veya destek alınmamıştır.

No contribution and/or support was received during the writing process of this study.

Çatışma Beyanı/ *Statement of Conflict*

Araştırmacıların araştırma ile ilgili diğer kişi ve kurumlarla herhangi bir kişisel ve finansal çıkar çatışması yoktur.

Researchers do not have any personal or financial conflicts of interest with other people and institutions related to the research.

Etik Kurul Beyanı/ *Statement of Ethics Committee*

Bu araştırma, Iğdır Üniversitesi Etik Kurulunun 14.12.2022 tarihli ve E-37077861-900-87064 sayılı kararı ile yürütülmüştür.

This research was carried out with the decision of Iğdır University Ethics Committee dated 14.12.2022 and numbered E-37077861-900-87064.