Original Research

The Effects of Vascular Occlusion Training on Respiratory Exchange Ratio and Energy Expenditure When Coupled With Cardiovascular Training

JUSTIN SPRICK†, RICHARD LLOYD‡, and JAMES ELDRIDGE‡

Department of Kinesiology, University of Texas of the Permian Basin, Odessa, TX, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 8(1) : 57-64, 2015. Vascular occlusion training is a novel training modality that has received considerable attention in the exercise science literature. The current study is the first of its kind to look at the effects of vascular occlusion training on substrate utilization when combined with aerobic training. This study examined the effects of pairing a vascular occlusion training protocol with a bout of submaximal aerobic exercise on energy expenditure (EE) and fuel use during exercise. Subjects performed a 20 minute bout of sub-maximal aerobic exercise either exclusively, or after performing a body weight squat protocol either with or without vascular occlusion. Peak lactate concentrations, EE and respiratory exchange ratio (RER) were all measured. A repeated measures analysis of variance was performed to look at differences among groups and interactions among protocols. The results suggest no difference in peak lactate (7.29 mmol/dl vs. 10.17 mmol/dl; F=0.946; p>0.05) or EE (92.09 Kcals vs 93.48 Kcals; F=0.898 p>0.05) among protocols. However, there does appear to be a shift in substrate utilization towards fatty acid oxidation by performing either a vascular occlusion training protocol (mean RER= 0.836) or a protocol of body weight squats (mean RER= 0.823) prior to aerobic training in comparison to performing aerobic training alone (mean RER= 0.881). There were, however, no significant differences between the occlusion protocol and the body weight squat protocol prior to the aerobic training. These results suggest that while there are no differences in overall caloric expenditure between protocols, performing either a resistance training protocol or a vascular occlusion training protocol shifts substrate utilization in favor of fatty acid oxidation over the oxidation of carbohydrates.

KEY WORDS: Substrate utilization, RER, submaximal exercise

INTRODUCTION

Vascular occlusion training is a novel training modality that has received considerable attention in the exercise science literature (1, 5, 7-9). This type of training involves decreasing blood flow to the active muscles through the use of a blood pressure cuff or other restrictive device during exercise (5). Vascular occlusion training has been demonstrated as an alternative method for increasing muscular hypertrophy in numerous special populations including astronauts, individuals affected by neuro-muscular diseases, and the elderly (5). This form of training is an appealing alternative to traditional resistance

Table 1. Demographicdata.

	Males N=3		Females N=4	
	Mean	Sd	Mean	Sd
Age (years)	22.0	1.0	20.5	0.7
Height (cm)	176.5	4.5	159.5	8.6
Weight (kg)	70.2	9.2	53.1	4.2
% Fat	13.1	5.0	17.0	6.3

training for individuals with musculo-skeletal injuries since vascular occlusion training loads are typically only 20% of 1 repetition maximum (1RM) whereas the American College of Sports Medicine (ACSM) recommends lifting a weight of at least 65% of 1RM for 2-3 sets in traditional exercise programs (2,5).

Furthermore, vascular occlusion training increases plasma concentrations of growth hormone (GH) and norepinephrine (Nor) during exercise (1,9). Specifically, Abe et al. (2006) reported a significant increase in plasma [GH] following an acute bout of treadmill walking with vascular occlusion. Additionally, Takarada et al. observed an increase in both plasma [GH] as well as plasma [Nor] levels following an acute bout of resistance training with vascular occlusion (9). Since both of these hormones are associated with an activation of lipolysis, it is speculated that this type of protocol may show promise in accelerating fatty acid metabolism if paired with a bout of submaximal aerobic exercise (3). The current investigation is novel because it measured the effects of pairing a vascular occlusion training protocol with a bout of submaximal aerobic exercise on respiratory exchange ratio (RER) and energy expenditure (EE) to determine if a shift in substrate utilization towards fatty acid mobilization were apparent.

METHODS

Participants

Institutional Review Board approval was obtained and subjects were recruited from the University of Texas of the Permian Basin (UTPB) Kinesiology classes with the requirements being that they successfully complete a physical activity and readiness questionnaire, an informed consent, and that they would not participate in any form of regular cardiovascular training for the 4 weeks of the study. Additionally, participation was limited to individuals whose body composition analysis was found to be less than 30% body fat for females and less than 20% body fat for males as determined by air-plethysmography (Bod-Pod, Life Measurement Instruments) analysis. Subjects fasted for a minimum of 4 hours prior to testing as recommended by the bod-pod manufacturers. Since regular cardiovascular training can elicit adaptations that would favorably alter fatty acid metabolism independently of the protocols utilized in the current investigation, subjects who regularly participated in any form of structured aerobic training were excluded from participation. Subjects who participated in regular resistance training activities were permitted to participate since the adaptations associated with resistance training do not significantly alter fatty acid metabolism during an acute bout of aerobic exercise such as the one that will be performed during the current investigation. Subjects (n=7) for the study consisted of 3 males and 4 females between the ages of 21-24.

Protocol

All subjects reported to the exercise physiology lab at UTPB under the prescribed conditions. The total experiment consisted of 4 sessions that lasted approximately 2 hours each over the course of 4 weeks. Each session occurred exactly 7days later than the previous session and was not preceded by any type of physical activity or the ingestion of a meal or stimulant for at least 4 hours prior to testing. The first session consisted of having each participant complete the required documentation as well as a maximal oxygen consumption (VO_2max) treadmill test using indirect calorimetry techniques (AEI Moxus metabolic cart). This baseline data collection established the intensity that corresponds to 40-70% of VO_2max for the experimental sessions. Although 40-70% of VO_2max is a broad range of intensities, the treadmill settings remained the same for each subject between protocols so the RER should be reflective of the consistent substrate usage by each subject throughout protocols. The following 3 experimental sessions were randomized via a random number assignment for each subject but consisted of the following protocols.

Resistance Squats (RES) - Subjects performed five sets of body weight squats until failure with a 30 second rest interval between each set. Following the body weight squats, blood lactate was assessed via a thumb prick in 1 minute intervals until peak lactate was reached. Following assessment of lactate, subjects then exercised on a treadmill for 20 minutes duration at an intensity corresponding to 40-70% of predetermined VO_2max. RER and EE were measured during both the exercise bout and in the 1 hour period following just as in the OCS protocol. This session served as a control to compare the effects of occlusion training to that of the effects of the same exercise with the same intensity being performed in the absence of occlusion.

Occlusion Squats (OCS) - Thigh size blood pressure cuffs (Ocelo Inc.) were fitted to the proximal end of the subject's thighs and the following vascular occlusion warm up procedure was then performed. The cuffs were initially inflated to a pressure of 120 mmHg and increased in a step wise fashion in 20mmHg increments until a target pressure of 200mmHg was reached. This procedure was utilized by Abe et al. and is believed to ensure circulation of both peripheral and local blood supply (1). Once the final pressure of 200 mmHg was reached, the subject then performed 5 sets of body weight squats to failure with a 30 second rest interval between each set. The cuffs remained inflated during and after each set and the cuffs were re-inflated back to 200mmHg between each set if any pressure was lost during the exercise. This pressure was selected based on previous research by Takarada et al. and has been demonstrated to increase both GH and Nor levels significantly above baseline (9). After completion of the final set the cuffs were deflated and removed and the subject was then allowed a 10 minute rest interval before beginning the next part of the session. The subject then exercised on a treadmill for 20 minutes duration at an intensity corresponding to 40-70% of predetermined VO_2max while RER and EE were measured using indirect calorimetry methods. Immediately following the exercise protocol, RER and EE were continually measured for 1 hour while in the seated position. This served as a measurement of the post exercise energy expenditure induced by the preceding protocol.

Exclusive Cardiovascular Training (ECT) - Subjects arrived at the exercise physiology lab and blood lactate concentrations were measured to ensure that the levels were within acceptable resting parameters. Subjects then exercised for a 20 minute duration at an intensity corresponding to 40- 70% of their predetermined VO_2max while RER and EE were measured during both the exercise bout and in the 1 hour period following cessation of exercise via indirect calorimetry. This served as a second control to measure the response of the variables of interest to cardiovascular training alone in comparison to the response observed when the training is preceded by resistance training both with and without occlusion.

Blood Sampling and Metabolic Measures - Blood samples were collected after cessation of the last set of squats by a thumb prick in 1 minute intervals for plasma lactate concentration analysis until peak lactate was reached (Lactate Plus, Nova Biomedical). Open circuit spirometry was used to determine VCO_2 and VO_2. The Weir equation was used to calculate EE during the 20 minutes of exercise and for the hour immediately after exercise based on the measured VCO_2 and VO_2 (11). Variables measured included: the differences in blood lactate concentrations between protocols, the differences in the RER observed during the cardiovascular segment of the training, the differences in the RER observed during the excess post exercise oxygen consumption (EPOC) and during the 50 minutes post- EPOC, the differences in EE observed during the cardiovascular segment of the training, and the differences in EE observed during the EPOC and in the 50 minutes post-EPOC. Measurements were split into the 10 minute period immediately following exercise and the 50 minutes thereafter to separate the EPOC from the return to baseline.

Statistical Analysis

A repeated measures analyses of variance (rANOVA) was conducted to compare the mean peak lactate concentrations among protocols, the mean caloric expenditure among protocols, and the mean RER among protocols. The mean values for caloric expenditure and RER were subdivided into 3 separate time segments to determine interaction effects between protocols: during exercise, during the 10 minute EPOC period immediately following the cessation of exercise, and during the 50 minute period following the EPOC.

RESULTS

Subjects (n=7) included in the data analyses consisted of 3 males and 4 females students from UTPB. Demographic data for the subjects are presented in table 1.

The analysis of the lactate concentrations revealed no significant differences between protocols OCS and RES (F=0.946; p>0.05). The mean values were significantly higher for protocol OCS compared to ECT and for protocol RES compared to protocol ECT (F=6.442, p<0.05, see figure 1).

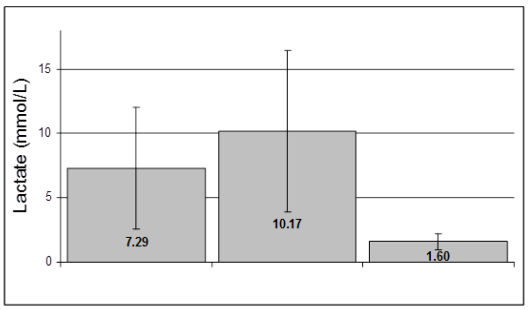

Figure 1. Peak lactate values between protocols.

The repeated measures analysis determined no significant differences were evident for the main effect of the type of protocol on changes in caloric expenditure (F=0.898, p>0.05, see figure 2).

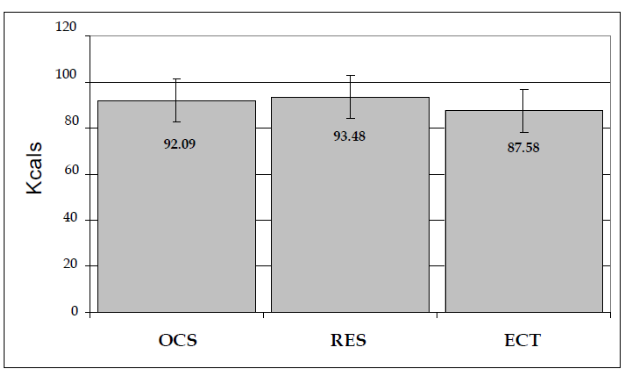

Figure 2. Mean responses to caloric expenditure for thethree protocols.

The repeated measures analysis determined no significant interaction between the main effect of the type of protocol and trial/time for differences in caloric expenditure (F=0.241, p>0.05).

For the comparison of RER, the repeated measures analysis found significant differences among the main effect of protocol for the overall RER values between protocols OCS and ECT (F=12.693, p<0.05) and between protocols RES and ECT (F=42.490, p<0.05). There were however no significant differences for this value between protocols OCS and RES (F=1.281, p>0.05). Specifically, the mean RER value for protocol OCS was 0.836 compared to the mean RER value for protocol RES which was 0.823. Both of these values were significantly lower than the value recorded for protocol ECT which was 0.881 (p < .05, see figure 3).

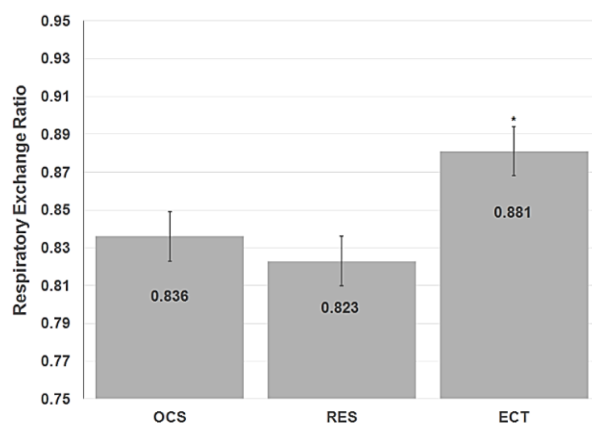

Figure 3. Mean responses to RER for the three protocols. *There were significant differences between protocols OCS and ECT and between protocols RES and ECT but not between protocols OCS and RES (p<.05).

The repeated measures analysis determined no significant interaction between the main effect of the type of protocol and trial/time

Table 2. Mean interactionsbetween trial andprotocolforcaloric expenditure.

	DuringExercise		EPOC		PostEPOC	
	Mean	SD	Mean	SD	Mean	SD
OCS	168.47	44.649	23.086	4.8054	84.7	23.887
RES	170.64	50.782	23.600	6.5625	86.2	27.051
ECT	167.51	43.643	20.557	5.3531	74.657	22.263

Table 3. Mean interactionsbetween protocolandtrial forRER.

	DuringExercise		EPOC		PostEPOC	
	Mean	SD	Mean	SD	Mean	SD
OCS	0.834	0.0327	0.880	0.0571	0.792	0.0610
RES	0.840	0.0294	0.860	0.0432	0.770	0.0428
ECT	0.868	0.0186	0.941	0.0530	0.834	0.0709

for differences in RER values for each subdivided time segment exercise, EPOC, or post-EPOC (F=0.641, p>0.05).

Table 3 represents the mean interactions between protocol and trial for RER.

DISCUSSION

The purpose of this study was to determine if performing a vascular occlusion training protocol prior to engaging in submaximal aerobic exercise would increase caloric expenditure and fatty acid oxidation both during and immediately after exercise. The significant findings for this study were the differences among RER values between protocols OCS and ECT and between protocols RES and ECT. These differences reflect a change in substrate utilization in which more fatty acids are preferentially oxidized for fuel thanglucose. There were, however, no significant differences in total caloric expenditure either between protocols or their interaction among the time segments of exercise, EPOC or post-EPOC. Collectively these findings suggest that while the total number of kcals expended during and after aerobic exercise is not altered by performing either a vascular occlusion training protocol or a resistance training protocol, substrate utilization shifts to increased fat utilization versus carbohydrates utilization if either a vascular occlusion training protocol or resistance training protocol precedes the bout of submaximal aerobic exercise.

Previous research has also studied the effects of performing resistance training prior to aerobic training in comparison to performing aerobic training alone. Specifically, Drummond et al. compared the effects of 4 different exercise protocols on EE in the EPOC period (4). The protocols examined were either to perform resistance training alone, aerobic training alone, resistance training before aerobic training, or aerobic training before resistance training. Although substrate utilization was not directly measured by Drummond et al., they did find that oxygen consumption was elevated significantly higher during the protocol in which resistance training was performed prior to aerobic training than it was when aerobic training was performed alone. When combining resistance and aerobic training in the same session, however, the researchers found that EE was greatest when aerobic training preceded resistance training.

The present study conflicts with the findings of Drummond et al. since no significant differences in EE were found during and after aerobic exercise between either the pre-aerobic exercise occlusion protocol or the pre- aerobic exercise series of non-occluded body weights squats (4). However, the findings of the present study could have application when planning an exercise regimen that consists of both aerobic and resistance training that is performed in the same session. Based on these findings, it would seem that performing either resistance training or vascular occlusion training before aerobic exercise favorably shifts substrate utilization during aerobic exercise towards fatty acids.

The observation that there were no significant differences between protocols OCS and RES for any of the variables measured likely occurred because total training volume was not accounted for during the vascular occlusion protocol or resistance training protocol. During both protocols the subjects exercised to the point of volitional fatigue during all 5 sets that preceded the bout of submaximal aerobic training. Due to the difficulty of performing vascular occlusion training, the subjects likely performed many more repetitions without the occlusion than with it, which in turn generated a much larger amount of lactate during the squats without occlusion than was originally anticipated.

Although subjects were instructed to fast for the 4 hours prior to each session, there were no measures taken to ensure dietary control outside of the 4 hour window. Since general daily diet can contribute to substrate utilization during exercise, this could also be a confounding factor.

Even in the absence of differences between protocols occlusion squats and resistance squats, the findings of this study have implications for individuals who are engaging in a regular submaximal aerobic exercise protocol for the purpose of weight loss. These results suggest that performing either a vascular occlusion training protocol like the one utilized in this study or performing a resistance training protocol consisting of 5 sets of body weight squats to volitional fatigue both favorably alter substrate utilization in a manner that accelerates fatty acid oxidation while sparing muscle glycogen as reflected by the difference in RER.

Since individuals exercising for weight loss typically desire to use body fat as a substrate for fuel rather than oxidize stored carbohydrates for energy this practice could be implemented by these individuals before they perform their bout of submaximal aerobic exercise to help facilitate fat loss.

Furthermore, the findings from the current study also have applications for special populations such as individuals suffering from musculo-skeletal limitations. These individuals could apply a vascular occlusion training regimen such as the one utilized in the current investigation to shift substrate utilization in favor of fatty acids during a subsequent submaximal aerobic training regimen.

In summary, it seems that both vascular occlusion training and traditional resistance training in the form of 5 sets of body weight squats to volitional fatigue can be used to stimulate fatty acid oxidation when coupled to a bout of submaximal aerobic training. This strategy could be utilized in special populations or in the general population as well as a method of increasing fatty acid utilization during exercise for the purpose of weight loss.

REFERENCES

1. Abe T, Kearns C Sato Y. Muscle size and strength are increased following walk training with restricted venous blood flow form the leg muscle. J Appl Physiol 100: 1460-1466, 2006.

2. American College of Sports Medicine Position stand: Progression models in resistance training for healthy adults. Med Sci Sports Exerc 34: 364-380, 2002.

3. Borer K. Advanced Exercise Endocrinology. Champaign, IL: Human Kinetics, 127-148, 2013.

4. Drummond M, Vehrs P, Schaalje B, Parcell A. Aerobic and resistance exercise sequence affects excess post exercise oxygen consumption. J Strength Conditioning 19: 332-227, 2005.

5. Loenneke J, Wilson G, Wilson J. A mechanistic approach to blood flow occlusion. Int J Sports Med 31, 1-4, 2010.

6. Moren F, Volker K. Molecular and Cellular Exercise Physiology. Champaign, IL: Human Kinetics, 2005. 299-307

7. Nakajima T, Kurano L, Lida M, Takano H, Oonuma H, Morita T, Meguro K, Sato Y, Nagata T. Use and safety of KAATSU training: results of a national survey. Int J KAATSU Training Res 2: 5-13, 2006.

8. Sato Y. The history and future of KAATSU training. Int J KAATSU Training Res 1: 1-5, 2005.

9. Takarada Y, Nakamura Y, Aruga O, Miyazaki S, Ishii N. Rapid increase in plasma growth hormone after low-intensity resistance exercise with vascular occlusion. J Appl Physiol 88: 61-65, 2000.

10. Tanner R, Fuller K, Ross M. Evaluation of three portable lactate analyzers: Lactate Pro, Lactate Scout, and Lactate Plus. Eur J Appl Physiol 109: 551-559, 2010.

11. Weir J. New methods for calculating metabolic rate with special reference to predict protein metabolism. J Physiol 109: 1-9, 1949.