Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 10), Art 322, pp. 2821 - 2828, October 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Comparative analysis of growth hormone and blood lactate response to low-load resistance exercises with practical blood flow restriction vs. high-load resistance exercises

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Published online: October 31, 2023
(Accepted for publication : October 15, 2023)
DOI:10.7752/jpes.2023.10322

Abstract
Practical blood flow restriction (PBFR) is an innovative technique that reduces the venous return through the application of a pressure band calibrated using a perceived pressure scale. Owing the scarcity of studies investigating the acute effects of PBFR in conjunction with low-load resistance exercises versus traditional high-intensity exercises on growth hormone (GH) and blood lactate (BL) levels following lower extremity training in collegiate athletes, this study sought to bridge this gap. The research aimed to explore the acute impact of a single session low-load resistance exercises with PBFR, comparing it with high-load resistance exercises without PBFR, specifically focusing on GH and BL levels. A convenience sample of collegiate athletes was divided into an experimental group engaging in low-resistance exercises with PBFR and a control group performing high-resistance exercises without PBFR. GH and BL levels were assessed at three intervals: pre-training, immediately post-training, and 15-min post-training for both groups. There was no significant differences between groups in age, BMI, and the number of training hours per week. Analysis of variance (ANOVA) was employed to elucidate the main and interaction effects between the groups. Notably, a significant main effect of time on GH and BL levels was observed in both groups. While no significant differences emerged in GH secretion between the groups, a notable variance was found in BL secretion levels. This suggests that both low-resistance exercises with PBFR and high-resistance exercises without PBFR can elicit a similar effect on GH secretion. In contrast, the method of high-resistance exercises without PBFR may induce a more pronounced effect on BL secretion. In conclusion, this research demonstrates that PBFR implementation offers athletes dual benefits: it equivalence with low-load exercises, enabling benefits while using lighter training loads, and mitigating BL accumulation for sustained training.
Keywords: resistance exercises; collegiate athletes; hormones; sustained training.

Introduction

Blood flow restriction (BFR) exercise technique has been frequently used lately due to its unique physiological benefits. The technique of BFR includes applying a special band to the proximal part of the exercising limb in order to restrict venous return while maintaining arterial blood flow to the working muscle(s) (Wortman et al., 2021). Hypothetically, this technique leads to a decrease in the amount of oxygen in the working muscles which would produce pooling in the capillaries of the limb, in addition to swelling in muscle cells (Lorenz et al., 2021). Furthermore, it was suggested that BFR would activate the inter-cellular anabolic pathways, and recruit the fast muscle fibers (Yasuda et al., 2009). The hypoxic condition created by the BFR technique places the muscles on a critical condition which consequently generates a high metabolic stress by increasing the accumulation of the blood lactate (BL) (Tanimoto et al., 2005). This, in turn, stimulates the secretion of the anabolic hormones, such as the growth hormone (GH) (Takano et al., 2005) and the insulin like growth factor 1 (IGF1) (Chen et al., 2022).

GH is considered an important hormone in the protein synthesis process inside muscles (Kraemer et al., 2020). However, there is a debate about its effect on muscle hypotrophy. Researchers demonstrated that the use of BFR training stimulates the secretion of GH due to the accumulation of BL in the targeted muscle(s) and the low-PH environment created by the BL accumulation (Oliveira et al., 2020). Therefore, higher levels of GH and BL after the use of BFR would indicate that the desired effect of improving muscle size and strength has occurred. Improving muscle strength is one of the main aims of training exercises especially in athletes. Based on the guidelines from the American College of Sports Medicine, a resistance of 70% from a person's one repetition maximum (1RM) is needed to increase muscle strength and induce muscle hypertrophy (American

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College of Sports, 2009). However, using the BFR technique allows us to decrease the resistance to as low as 20% and get similar levels of muscle strength and hypertrophy. Therefore, the most important benefit from using the BFR technique during training is being able to decrease the amount of resistance while getting the same desired muscular changes. Most of the studies that employed the BFR technique used low-intensity resistance of 20-30% 1RM with 15-30 exercise repetitions and 30-60 seconds interval rest between sets and reported significant improvement in muscle strength and hypertrophy (Oliveira et al., 2020). The frequency of sessions using BFR ranged between 2 sessions within one-week (Inagaki et al., 2011) and 16 sessions within 8 weeks intervals (Takarada, Nakamura, et al., 2000). These studies aimed to examine the adaptation effect of using BFR on muscle physiological factors. However, a study that aimed to assess the acute effect of using the BFR used only one session (Kim et al., 2014).

The traditional way of reducing the venous return in the BFR technique is to use a cuff system that is inflated to a certain pressure (110-240 mm HG). A recent systematic review analyzed 10 studies that used BFR with 250 healthy athletes found improvement in muscle size, muscle strength, and other sport-specific indices in all included studies (Wortman et al., 2021). However, there was a great variation in the pressure employed. Moreover, other researchers found that using the same pressure level for all participants in the same study may occlude the arterial blood supply as well (Wilson, 2021). The occlusion of both arterial and venous blood supply to the muscle was found to reduce the muscle anabolism (Kacin & Strazar, 2011). Therefore, practical blood flow restriction (PBFR) has been introduced to address this concern. In PBFR, a band is used with a pressure that is applied using a perceived pressure scale (PPS). In order to determine the appropriate pressure using the PPS, it was recommended that a pressure with an amount of 7 out of 10 is appropriate to create a venous restriction only (Wilson, 2021).

Several studies have investigated the effect of BFR on muscle strength and muscle size without assessing the biomarkers that may contribute to the desired effects. A recent study (2020) investigated the acute effect (10 and 15-min post-exercise) of using BFR exercises on the upper extremity on BL, GH, and peptide hormone. They found significant results between pre-exercise assessment and post-exercise assessment (Oliveira et al., 2020). Two other studies examined the effect of BFR on some hormones. One study reported an increase on GH levels after the use of BFR along with electrical stimulation on the lower extremity muscles (Slysz et al., 2021). The second article studied the acute effect of BFR compared to regular high-intensity exercises on GH and BL in collegiate females and found a significant increase in both hormones (Kim et al., 2014).

Owing the scarcity of studies investigating the acute effects of PBFR in conjunction with low-load resistance exercises versus traditional high-intensity exercises on GH and BL levels following lower extremity training in collegiate athletes, this study sought to bridge this gap. The research aimed to explore the acute impact of a single session low-load resistance exercises with PBFR, comparing it with high-load resistance exercises without PBFR, specifically focusing on GH and BL levels at 3 intervals (before the session, immediately after the session, and 15-min after the session) in collegiate athletes.

Material and methods

Participants

Student collegiate athletes with an age of 18 years and older who were free from any cardiovascular or respiratory disorders and did not have any injuries during the previous 12 months were included in this study. Collegiate athletes who did not meet the inclusion criteria, who were taking any medications for chronic conditions or any supplements were excluded from the study.

Procedures

This study had ethics approval from the University of Jordan research ethics committee. Eligible participants were interviewed to explain the research requirements and procedures by the study researchers. After their acceptance, collegiate athletes were asked to sign the study informed consent. Participants were asked not to exert any high-intensity effort or drink caffeine (or any other stimulant) 24 hours and to sleep for 8 continuous hours prior to the research session. Participants were divided into the experimental groups who had one session of PBFR with low-intensity (30% 1RM) exercises and the control group who had one session of high-intensity (80% 1RM) exercises.

Study examination

Participants presented to the exercise physiology laboratory at 8 AM to perform the pre-training blood tests of measuring the GH and BL levels. Additional information were also collected including age, number of training hours per week, weight and height to calculate body mass index (BMI). Furthermore, 1RM for the thighs using leg curl and leg extension was determined for each participant in accordance with the American College of Sport Medicine (ACSM) (Bonorino et al., 2019; Liguori, 2021). The post-training assessment included blood tests to measure GH and BL levels immediately after the end of exercises and 15-min later.

Exercise program

The following exercise regimen was used for both experimental and control groups. The training session included leg curl and leg extension exercises with 4 sets each. Participants started with leg extension exercise for 4 sets with a 30-sec rest periods between the sets. Then, participants took a rest for 60 seconds. Afterward, participants performed leg curl exercise for 4 sets with a 30-sec rest periods between the sets.

Exercises in each set were performed continuously (uninterrupted) with a speed of 2-sec for each repetition and a medium exercise performance speed.

Experimental group

Participants in the experimental group performed one session of 30% 1RM with PBFR training. The number of repetitions in every set was 15 times with PBFR. Participants in the experimental group used the elite band (occlusion training bands) for both thighs during the training session. The width of the thigh band was 5 cm, which would produce a pressure between 160-240 mmHg. This pressure range is appropriate for most of individuals who used PBFR (Fahs et al., 2012). The perceived pressure scale (PPS) was used to estimate the recommended pressure (7 out of 10) in training before performing the exercises (Scott et al., 2016; Wilson et al., 2013). The blood flow restriction bands booklet was used (Karvandi, 2016) along with previous studies to design the training session. Participants removed the PBFR band immediately after the end of the training session.

Control group

Participants in the control group performed one session of 80% 1RM without PBFR. The number of repetitions in every set was 10 times (Kim et al., 2017).

Statistical analysis

Descriptive statistics including mean and standard deviation (SD) were used to describe continuous variables. Two-way Analysis of Variance (ANOVA) was used to assess the effect of within-group, between group factors, and interactions between study factors. Post-hoc correction was estimated using Bonferroni statistics and the least significant difference (LSD). Statistical Package for Social Sciences (SPSS) v.28 was utilized for the analysis.

Results

The study sample consisted of 22 healthy male collegiate athletes who were allocated to each exercise group to assure there was no significant differences between groups. The mean ± SD age was 22 ± 2.24 years for the experimental group and 21.36 ± 1.57 years for the control group. The mean ± SD BMI was 23.73 ± 3.52 kg/m^2 for the experimental group and 23.03 ± 3.46 kg/m^2 for the control group. The mean ± SD number of training hours per week was 10.18 ± 2.44 hours for the experimental group and 10 ± 2.57 hours for the control group.

Growth hormone (GH)

The mean ± SD of GH at baseline, immediately after training and 15-min post-training for both groups are presented in **Table 1**. In order to determine the statistically significant differences between factors, ANOVA results for between-subject effects are shown in **Table 2**. GH had statistically significant differences among the time of measurements (P<0.000) only. To determine which measurement times had the significant differences, Bonferroni test was used and its results are presented in **Table 3**. Moreover, **Figure 1** clarifies the changes in GH levels among times of measurement. Based on the post hoc analysis, the findings suggest that the GH levels were significantly different between pre-training and immediately post-training, pre-training and 15-min post-training, and between immediately post-training and 15-min post-training in both groups.

Table 1: Growth hormone levels at pre-training, immediate post-training and 15-min post-training between the experimental and control groups.

Time of measurement	Experimental group (Low-intensity with PBFR) Mean ± SD	Control group (High-intensity without PBFR) Mean ± SD
Pre-training	0.236 ± 0.251	0.210 ± 0.232
Immediate post-training	11.639 ± 1.784	11.822 ± 1.976
15-min post-training	6.123 ± 1.469	6.519 ± 1.400

PBFR**:** Practical blood flow restriction.

Table 2: ANOVA test of between-subjects effects of the growth hormone variable based on the time of measurement, methods used, and the interaction effect between time and methods.

Factors	Degree of freedom	Sum of squares	Mean squares	F-Value	P-Value
Time	2	2876.98	1438.49	990.18	0.000*
Methods	1	0.10	0.10	0.08	0.782
Interaction between time and methods	2	0.09	0.04	0.08	0.920

Table 3: Post hoc bonferroni test for the times of measurement for the growth hormone.

Variable	Time Measurement	Immediate post-training	15-min post-training
Growth hormone	Pre-training	0.000 *	0.000*
	Immediate post- training		0.000*
	15-min post- training		

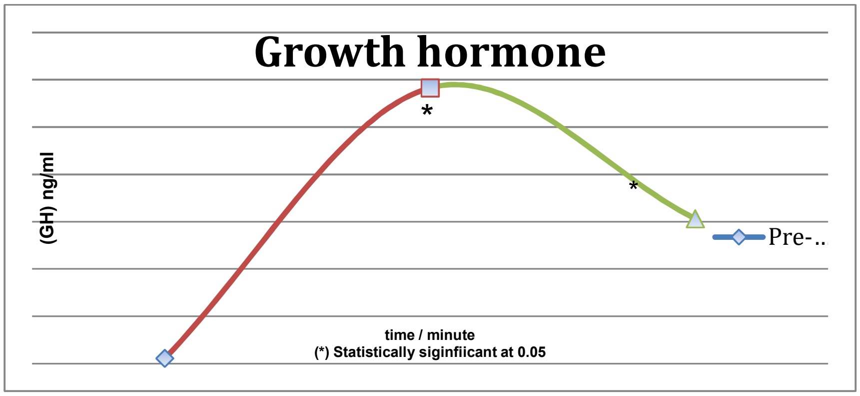

Figure 1: Means of the growth hormone at the 3 times of measurement.

Blood Lactate (BL)

The mean ± SD of BL levels at baseline, immediately after training and 15-min post-training for both groups are presented in **Table 4**. In order to determine the statistically significant differences between factors, ANOVA was used and the results are shown in **Table 5**. There were statistically significant differences in the mean of BL among the times of measurement (P<0.000), methods used (P<0.000), and interaction between time and methods (P<0.000).

Table 4: Blood lactate levels at pre-training, immediate post-training and 15-min post-training between the experimental and control groups.

Time of measurement	Experimental group (Low-intensity with PBFR) Mean ± SD	Control group (High-intensity without PBFR) Mean ± SD
Pre-training	1.287 ± 0.220	1.091 ± 0.075
Immediate post-training	6.133 ± 1.539	10.917 ± 3.008
15-min post-training	2.746 ± 1.065	5.857 ± 2.499

PBFR**:** Practical blood flow restriction.

Table 5: Multiple repeated measures ANOVA of the blood lactate variable based on the time of measurement and group.

Factors	Degree of freedom	Sum of squares	Mean squares	F-Value	P-Value
Time	2	1160.216	580.108	199.123	0.000*
Methods	1	102.168	102.168	38.799	0.000*
Interaction between time and methods	2	53.741	26.870	21.488	0.000*

To determine which of the factors had statistically significant differences based on the specific variable, Bonferroni test was used for the times of measurement and methods used. Furthermore, the least significant difference (LSD) was used for the interaction between time and methods used.

Bonferroni results of the times of measurement are presented in **Table 6**. Moreover, **Figure 2** clarifies the changes in BL levels among times of measurement. Based on the post hoc analysis, the findings suggest that the BL levels were significantly different between pre-training and immediately post-training, pre-training and 15-min post-training, and between immediately post-training and 15-min post-training in both groups. Whereas, Bonferroni results of the methods used are presented in **Table 7**. Based on the post hoc analysis, the findings suggest that the BL levels were significantly higher in the high-intensity method without PBFR.

Finally, **Table 8** shows the LSD results for the interaction between time and methods. The findings suggest that the BL levels are significantly higher using the high-intensity method without the PBFR in immediately post-training and 15-min post-training intervals.

Table 6: Post Hoc Bonferroni Test for the Times of Measurement for the blood lactate.

Variable	Measurement	Immediately post-training	15-min post-training
Blood lactate	Pre-training	0.000 *	0.000*
	Immediate post- training		0.000*
	15-min post- training		

Table 7: Post Hoc Bonferroni Test for the Methods Used for the blood lactate

Variable	Method	Mean	P-Value
Blood lactate	High-intensity without PBFR	5.371	0.000 *
	Low-intensity with PBFR	3.612	

Table 8: The least significant difference test for the interaction between time and methods for the blood lactate

Variable	Time of Measurement	Method	Overall Mean	P-Value
Blood lactate	Pre-Measurement	High-intensity without PBFR	1.189	-
		Low-intensity with PBFR	1.189	
	Post Measurement, Immediately	High-intensity without PBFR	9.873	0.000 *
		Low-intensity with PBFR	6.886	
	15-minu Later	High-intensity without PBFR	5.051	0.000 *
		Low-intensity with PBFR	2.759	

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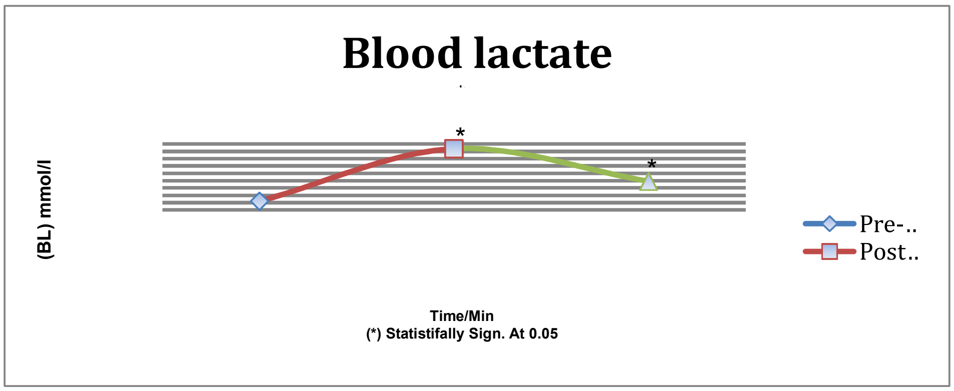

Figure 2: Means of the blood lactate based on the time of measurement.

Discussion

The aim of this study was to investigate the acute effect of a single session low-load resistance exercises along with PBFR compared to a high-load resistance exercises without restriction on GH and BL levels during 3 intervals (pre-training, immediately post-training, and 15-min post-training).

Growth hormone (GH)

The secretion of GH was found significantly different between pre-training and immediate post-training, pre-training and 15-min post-training, as well as between immediately post-training and 15-min post-training intervals in both groups. In the current study, GH had statistically significant within group differences using both methods: low-intensity with PBFR and high-intensity without PBFR. Our findings are consistent with other studies results that used BFR (Madarame et al., 2010; Reeves et al., 2006; Takarada, Nakamura, et al., 2000; Takarada, Takazawa, et al., 2000). Those studies justified the high GH levels, through the resistance exercises that rely on the anaerobic glycolysis process, due to the high-repetition exercises with short rest periods between the sets. Furthermore, those studies indicated that the resistance exercises using BFR that leads to the accumulation of BL concentration and creating a PH environment among the muscular fibers are considered the strongest catalyst to generate a response specific to the GH variable. Additional factors that were reported were recruiting large muscle fibers (lower part of the body) and increasing the activity of the nerve cells that connect the motor unit with the resistance exercises (Madarame et al., 2010). Therefore, it seems that the use of resistance exercises induces the response to secrete the anabolic hormones specifically GH which was reported in several studies that used BFR (Madarame et al., 2010; Reeves et al., 2006; Takarada, Nakamura, et al., 2000; Takarada, Takazawa, et al., 2000).

GH levels remained high during the intervals of measurement in this study. In other studies, the GH level remained high for 30-min post-training (Hasani, 2018). One of the justifications is that the anaerobic resistance exercises induce the secretion of higher levels of GH than those of the aerobic exercises (Hasani, 2018). This may explain why the GH levels remained high immediately post-training and 15-min post training using the low-intensity resistance exercises with PBFR. Furthermore, the acidic environment resulting from the accumulation of the H+ ion during the anaerobic resistance training catalyzes the metabolic receptors in the muscles to send feedback to the nervous system and pituitary gland (hypothalamus) to increase the secretion of GH. This mechanism may take place during the recruitment of a higher number of motor units operating in the training muscles, particularly, the high-intensity resistance trainings (Loenneke et al., 2010).

Regarding the methods used between the experimental (low-intensity with PBFR) and control (high-intensity without PBFR) groups, there were no statistically significant differences in the GH levels. This may be justified by using a similar type of exercises “resistance exercises” in both groups. Therefore, both groups had similar effect on the physiological response of GH secretions.

Blood Lactate (BL)

The secretion of BL was found significantly different between pre-training and immediately post-training, pre-training and 15-min post-training, as well as between immediately post-training and 15-min post-training measurements in both groups. In this study, BL had statistically significant within group differences using both methods: high-intensity without PBFR and low-intensity with PBFR.

Regarding the methods used for exercise training, the secretion of BL showed a significantly higher levels using the high-intensity training method without PBFR. The high-intensity resistance training without PBFR relies on the anaerobic energy production system. Subsequently, a high concentration of BL accumulates since BL is a metabolic product of the anaerobic function. The high BL levels may be a very important indicator of producing anaerobic energy during the given exercises in the current research, as indicated by several studies (Poton & Polito, 2016). However, this finding contradicts the results of other studies that reported a higher accumulation of BL in the methods used low-intensity exercises with BFR (Leite et al., 2015; Shimizu et al., 2016).

Significance

The results of our study in both GH and BL levels support the findings of a 2014 study that investigated the acute effect of BFR (not PBFR) compared to regular high-intensity exercises on GH and BL levels in collegiate females (Kim et al., 2014). Kim et al. found significant increase in both GH and BL immediately after a single exercise training session of both methods.

This research shows that low-intensity exercises with PBFR and high-intensity exercises have similar impacts on GH levels. However, high-intensity exercises have a higher influence on BL accumulation compared to low-intensity exercises with PBFR. This suggests that athletes can derive dual advantages from PBFR implementation. First, GH secretion is equivalence with low-load exercises, allowing athletes to harness benefits while using a lighter training load. Second, PBFR can mitigate BL accumulation, which can hinder sustained training capacity. Integrating PBFR with low-intensity exercises can lead to prolonged and more effective training sessions, circumventing the undesired effects of elevated BL.

Limitations

Our study is not without limitations mainly related to the absence of randomization. In our clinical experiment, we did not randomize collegiate athletes into study groups. Randomization in clinical trials has several benefits such as the prevention of potential bias and enhancement of generalizability. However, there was no significant differences between the study groups in demographic information and all of them were males.

Conclusion

In this comparative study, we explored the differences between two methods of resistance exercises; low-intensity with PBFR and high-intensity without PBFR. We found that time had a significant main effect on GH and BL levels in both groups. Whereas, no significant differences were found in GH secretion between the groups, suggesting that the type of exercise did not significantly affect GH levels. However, there was notable variance in BL secretion levels, suggesting that the exercise regimens had varying impacts on BL levels depending on whether participants were doing low-resistance exercises with PBFR or high-resistance exercises without PBFR. The study suggests that high-resistance exercises without PBFR have a more pronounced effect on BL secretion, suggesting that traditional high-resistance exercises have a stronger impact on the accumulation of BL levels. This indicates that athletes can benefit from using the PBFR in two ways.

The first benefit is having the same effect on secreting the GH with using low-load intensity. The second benefit is having less BL accumulation which helps athletes to continue training longer.

The study provides valuable insights into exercise physiology and sports science, offering practical guidance for exercise program design and customization. It suggests that both low-resistance exercises with PBFR and high-resistance exercises without PBFR can effectively elicit GH responses, allowing for more flexibility in program design. This knowledge can also be used to optimize training protocols for specific objectives, such as increasing GH secretion through low-resistance exercises with PBFR or high-resistance exercises without PBFR.

Theoretical contributions of this study include understanding hormone regulation by examining how different exercise protocols impact the endocrine system. The study also highlights the importance of considering both main and interaction effects in exercise studies.

The study's findings offer practical guidance for exercise program design and customization, enhance our theoretical understanding of hormone regulation in response to exercise, and provide insights into the effects of different exercise modalities on GH and BL levels. These contributions have the potential to improve training and performance outcomes for athletes and fitness enthusiasts while advancing the field of exercise science.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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