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EFFECT OF RESISTANCE AND HIIT TRAINING, WITH AND WITHOUT BLOOD FLOW RESTRICTION (BFR), ON GH AND IGF-1 LEVELS IN MEN

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ABSTRACT

Background. Blood flow restriction (BFR) is a method that involves using inflatable cuffs to carefully limit blood flow into the arteries and adjust the outflow from the veins in working muscles by applying controlled pressure.

Objective. This study aimed to compare the levels of growth hormone (GH) and insulin-like growth factor-1 (IGF-1) in young men after eight weeks of resistance training (RT) and high-intensity interval training (HIIT), with and without blood flow restriction (BFR).

Materials and methods. This study employed a quasi-experimental design, with a sample of 40 men aged 18–25, who were randomly assigned to one of four groups: RT, HIIT, RT+BFR, or BFR+HIIT, with 10 participants per group. Hormonal responses (GH and IGF-1) were assessed at baseline (week 1) and after 8 weeks of training, both pre- and post-training. Data were analyzed using a 2-way [4 (group) × 2 (time)] ANOVA in SPSS (version 26), with statistical significance set at $P \leq 0.05$

Results. After eight weeks of training, a comparison of the mean pre-test and post-test scores revealed that RT led to significant increases in both GH and IGF-1 levels at weeks 1 and 8. The RT+BFR group showed significant increases in GH at both time points and in IGF-1 at week 8. In the HIIT groups, both GH and IGF-1 increased significantly immediately after the interventions ($p \leq 0.05$). However, no significant differences were observed between the groups, indicating no interaction effect.

Conclusion. RT+BFR was effective in stimulating hormone responses; however, RT demonstrated more consistent hormone responses than the other training groups. Furthermore, the combined intervention (BFR+HIIT) did not induce greater metabolic stress, as assessed by GH and IGF-1, compared to sole HIIT.

KEYWORDS

Growth hormone (GH), insulin-like growth factor-1 (IGF1), resistance training (RT), high-intensity interval training (HIIT), blood flow restriction (BFR), men

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INTRODUCTION

In the pursuit of optimal athletic performance, strength training is crucial, targeting improvements in physical abilities[1], strength, power, muscular endurance, and muscle size. Athletes across different sports disciplines often utilize strength and resistance training to promote muscular adaptations that support their specific performance demands[2]. These gains are achieved through neurological and physiological adaptations that enhance an athlete's capability and resilience[3]. A notable development in this area is the integration of Blood Flow Restriction (BFR) with resistance training methods, particularly low-load resistance training and High-Intensity Interval Training (HIIT)[3]. Blood flow restriction (BFR) during low-intensity exercise has the potential to enhance both muscle size and strength[4].

Blood Flow Restriction (BFR) training involves performing exercises while using an external tool, such as blood pressure cuffs or elastic wraps, to apply pressure to the muscles near the limbs (e.g., upper arms or legs). This pressure restricts the flow of arterial blood and impedes venous return, creating a unique training stimulus for the targeted muscles[5]. Recent years have shown that combining low-load resistance training with Blood Flow Restriction (BFR), also known as Kaatsu training, applied to the active muscles can lead to significant gains in hypertrophy and strength, even with loads as low as 30% of 1RM[6]. When combined with low-intensity resistance exercises, BFR training simulates the physiological benefits typically associated with high-load resistance training by restricting arterial inflow and venous outflow during exercise. This induces local hypoxia and increases lactate accumulation, which activates afferent nerves and promotes the secretion of key hormones for muscle hypertrophy, such as GH and IGF-1[7,8].

Growth hormone (GH), secreted by the pituitary gland, plays a crucial role in regulating muscle adaptation and influencing muscle physiology. It promotes muscle growth, repair, and functional improvement through both direct and indirect mechanisms, making it essential for optimizing athletic performance and muscle adaptation to exercise. GH stimulates muscle protein synthesis, increases muscle mass, and promotes hypertrophy. It works synergistically with insulin-like growth factor 1 (IGF-1) to facilitate protein synthesis and inhibit protein breakdown, aiding muscle repair and growth. Additionally, GH enhances the proliferation and differentiation of muscle stem cells, known as satellite cells, which are critical for muscle repair and regeneration after exercise-induced damage[9]. Therefore, a growing body of evidence suggests that the principal anabolic effects of GH occur indirectly through its conversion into IGF-1 in the liver, which subsequently activates the IGF-1-Akt-mTOR pathway[10].

Additionally, BFR resistance exercises enhance muscle protein synthesis through key modifications in signaling pathways, including the activation of the mammalian target of rapamycin complex 1 (mTORC1) and the inhibition of muscle-specific atrogenes, such as Muscle RING Finger 1 (MuRF1) and atrogin-1. At the same time, BFR suppresses the myostatin pathway, which negatively regulates muscle growth, thereby promoting muscle development[7,8]. On the other hand, High-Intensity Interval Training (HIIT) is characterized by brief, repeated bursts of high to maximal exertion. The design of these exercise variables is crucial, as it makes each HIIT regimen unique in its ability to improve physical performance. While the specific signaling pathways are not fully understood, the stimuli generated by HIIT—such as hypoxia, metabolic stress, and mechanical stress—are known to promote mitochondrial, angiogenic, and cardiac adaptations, which are essential for enhancing endurance and overall athletic performance[11].

Interestingly, the physiological stimuli evoked by BFR, such as localized hypoxia and metabolic stress from increased anaerobic glycolysis and lactate accumulation, are similar to those induced by HIIT. These conditions result in elevated levels of GH, IGF-1, myokines, and reactive oxygen species. The interaction of these biochemical factors triggers adaptive pathways that are crucial for enhancing physical capabilities. Given these shared physiological effects, it is hypothesized that combining BFR with HIIT could synergistically enhance the adaptation processes, potentially leading to greater improvements in physical performance compared to HIIT alone[7]. The integration of various training modalities, such as resistance training and high-intensity interval training (HIIT), potentially combined with Blood Flow Restriction (BFR), could revolutionize traditional athletic training by more effectively targeting the biological pathways that influence muscle growth and endurance. This study aims to evaluate the effects of these combined strategies on hormonal profiles, specifically growth hormone (GH) and insulin-like growth factor 1 (IGF-1), in men. The findings could provide valuable insights into optimizing training regimens for athletes and fitness enthusiasts seeking peak performance and efficiency.

MATERIALS AND METHOD

This quasi-experimental study was conducted with a pre-test-post-test design. The statistical population consisted of young men, and were between the ages of 18 and 25. Based on previous papers and the use of G Power software It was determined that a minimum of 40 subjects were needed to achieve the sample size, which was estimated using G*power (Version 3.1.9.2) (Heinrich-Heine Dusseldorf, Dusseldorf, Germany)[12]. with a post-hoc power (1-β error probability) assumed to be 0.99[13]. From the statistical population, 40 cases were selected as a statistical sample using purposive and accessible sampling. These cases were then randomly divided into four groups: experimental (n=10 with RT), (n=10 with HIIT), (n=10 with RT+BFR) and (n=10 with BFR+HIIT). Inclusion criteria included with no known cardiovascular and cardiopulmonary diseases, musculoskeletal disorders and They should also have no

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severe chronic diseases, and a body mass index in the normal range. Individuals with a known history of deep vein thrombosis, clotting disorders, or other high-risk factors were excluded from participation to ensure safety[7,12]. and Exclusion criteria included participants who used dietary supplements, experienced exercise-related injuries or discomfort, or were absent for more than two sessions[8].

Taking into account the ethical considerations of the study, such as safeguarding the confidentiality of participants' information, employing a skilled instructor and examiner to prevent any potential harm, allowing participants the freedom to withdraw from the research at any stage, and clearly explaining the research purpose to all subjects before they begin the exercises and sign the consent form to participate. The present study was approved by the ethics committee of the Iranian Research Institute of Physical Education and Sport Sciences with: IR.SSRC.REC.1402.003 code – date of approval: March 19, 2022

Study design

The RT group included upper body exercises such as lat pull-downs, shoulder presses, biceps curls, and triceps extensions at 50% 1RM for 3 sets of 10 repetitions each. Lower body exercises (knee flexion and knee extension) were performed at 70% 1RM for 3 sets of 10 repetitions. The RT+BFR group engaged in low-intensity resistance training at 20% 1RM with blood flow restriction. They performed similar upper body exercises as the RT group, while lower body exercises utilized specially designed restrictive cuffs, completing 4 sets of 30, 15, 15, and 15 repetitions[14]. The HIIT group underwent high-intensity interval training on bicycle ergometers, while the BFR+HIIT group performed the same exercises under blood flow restriction. Before each HIIT session, both groups performed 4 sets of deep squats without additional load, but the BFR+HIIT group did so with blood flow restriction. Each training session began with a 10-minute warm-up and stretching routine, followed by a cool-down period after completing the exercises. During the last 5 minutes of each session, participants performed a cool-down comprising static movements focusing on major muscle groups, holding each position for 10 to 15 seconds and repeating each exercise 1 to 2 times[15]. Participants underwent a pretest session where measurements of the upper and lower chest, upper and lower arm, and thigh were recorded. These measurements were repeated during a posttest session two days after completing the training. Both pretest and posttest measurements were taken prior to 1RM assessments using a Gulick tape measure. To measure chest girth, participants stood with their feet shoulder-width apart and arms slightly abducted for tape positioning. Once the arms were lowered, upper chest girth was measured around the upper latissimus dorsi, and lower chest girth was measured at nipple level during normal expiration. For upper arm girth, participants stood with their arms relaxed at their sides, palms facing their thighs, and the measurement was taken at the midpoint between specific anatomical landmarks. Forearm girth was measured with palms facing forward, while thigh girth was measured in a standing position with the knee and hip flexed at 90 degrees. All measurements were taken twice and averaged, with a third measurement taken if the first two measurements differed by more than 5 mm[15]. Hormone responses (GH and IGF-1) were assessed at weeks 1 and 8, both before and after the intervention, with samples collected in the morning following an overnight fast. A medical doctor collected blood samples from a superficial forearm vein under stasis conditions. Specifically, at each time point, a 5 ml blood sample was drawn to measure GH and IGF-1 levels. These blood samples were then sent to a nearby medical laboratory for analysis[7].

Blood Flow Restriction

We adhered to Nakajima et al.'s guidelines[16] for Blood Flow Restriction (BFR) by using specialized KAATSU-cuffs on participants' legs. Initially set at 49 ± 5 mmHg, the cuffs were adjusted using alternating inflation and deflation cycles to determine each individual's optimal pressure (IOP), averaging 273 ± 33 mmHg across participants. This process, termed the KAATSU-cycle, involved starting at 140 mmHg and incrementing by 20 mmHg over at least 7 cycles. Control of pressure settings and cuff operations was facilitated by the KAATSU-Master device. Following the setup, participants in the BFR+HIIT group performed four sets of deep squats with the cuffs before beginning their High-Intensity Interval Training (HIIT) session[17].

Deep squats

The study followed KAATSU GLOBAL INC.'s recommendations for Blood Flow Restriction (BFR) exercise protocols, emphasizing three sets of deep squats with low loads, high repetitions, and short rest periods to stimulate muscular adaptations and enhance physical performance. Participants performed four sets of deep squats using only their body weight, starting with 40 repetitions and decreasing per set, with a 20-second rest between sets. All participants reached muscular or technical failure by the third or fourth set, confirming the effectiveness of the exercise intensity. Movement velocities were standardized using a metronome set at 50 beats per minute[7].

High-intensity interval training

After completing the deep squats, participants began High-Intensity Interval Training (HIIT) using bicycle ergometers (KardiomedBike, Proxomed®, Germany). The HIIT session consisted of three intervals, each lasting four minutes, separated by one-minute rest periods. The intensity of each interval was set at the second ventilatory threshold plus five percent (BFR+HIIT HR: 168 ± 14 bpm [90.5 ± 7.0% HRmax]; HIIT HR: 163 ± 15 bpm [87.2 ± 8.2% HRmax]), monitored using heart rate (HR) measured by the Polar® FT7 heart rate monitor. This intensity level was chosen

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because HIIT requires exercising above the anaerobic threshold. Participants maintained a cycling cadence between 80 to 90 rpm, consistent with the cadence used in pre-test spiroergometry[7].

Statistical Analyses

The assessment of data normality involved using the Shapiro-Wilk test. The data is reported as mean± standard deviations (SDs). Furthermore, the data was analyzed using a 2-way [4 (group) × 2 (time)] ANOVA on the SPSS statistical software (version 26). Differences in the measures were detected by using a Bonferroni post hoc test when a significant F-value was attained. Statistical significance was set at less than 0.05.

Result

The anthropometric characteristics of participants in the RT, HIIT, RT+BFR, and HIIT+BFR groups at both baseline and after eight weeks are presented in *Table 1*.

The data distribution was normal, and no significant differences were observed among the four groups at baseline.

Following eight weeks of intervention, *Table 1* demonstrates significant increases in upper chest, lower chest, right arm, left arm, left thigh, and VO_2 peak across all groups ($P < 0.05$). Notably, weight and BMI increased in the RT and RT+BFR groups compared to pre-test values, whereas these parameters decreased in the HIIT and HIIT+BFR groups ($P < 0.05$).

Table 2 further indicates a significant increase in GH and IGF-1 levels across all four groups ($P < 0.05$). Moreover, post-intervention results revealed that the RT+BFR group exhibited a greater increase in IGF-1 levels compared to the other groups ($P < 0.05$). Additionally, GH levels were significantly higher in the RT+BFR group compared to the RT and HIIT groups ($P < 0.05$).

DISCUSSION

The study's findings demonstrate that both Resistance Training (RT) and High-Intensity Interval Training (HIIT), with and without Blood Flow Restriction (BFR), significantly influence Growth Hormone (GH) and Insulin-like Growth Factor 1 (IGF-1) levels in young men. After eight weeks of training, all groups experienced significant increases in GH and IGF-1 levels ($P < 0.05$). Notably, the RT+BFR group exhibited the most pronounced rise in IGF-1 compared to the other groups, while GH levels were significantly higher in the RT+BFR group than in the RT and HIIT groups ($P < 0.05$). These results underscore the effectiveness of these training modalities in modulating hormonal responses. The increases in GH and IGF-1 levels are likely due to the physiological stress induced by these training methods, further amplified by the application of BFR.

In recent years, growing evidence has suggested that combining resistance training (RT) or high-intensity interval training (HIIT) with blood flow restriction (BFR) enhances hormonal responses, particularly growth hormone (GH) and insulin-like growth factor 1 (IGF-1).

Elevated lactate levels during intense exercise act as a potent stimulus for the anterior pituitary gland, leading to

	RT		HIIT		RT+BFR		HIIT+BFR	
	baseline	8 weeks	baseline	8 weeks	baseline	8 weeks	baseline	8 weeks
Weight (kg)	74.57±4.75	75.40±4.95^{a}	74.93±4.38	73.84±4.40^{a}	75.36±4.04	76.56±3.97^{ae}	71.35±4.34	70.20±4.24^{ad}
Height (cm)	177.88±2.94		178.85±3.39		179.94±3.23		178.92±3.26	
BMI (kg/m2)	23.55±1.27	23.82±1.39^{ae}	23.43±1.26	23.08±1.28^{a}	23.29±1.34	23.66±1.28^{ae}	22.30±1.25	21.95±1.24^{abd}
Upper chest (cm)	109.21±1.64	114.08±1.85^{acd}	111.45±2.52	111.89±2.02^{bd}	110.46±1.52	116.84±1.25^{abce}	110.32±1.93	113.62±1.69^{ad}
Lower chest (cm)	99.66±3.69	102.17±3.65^{ad}	99.88±3.18	100.43±3.24^{ad}	99.70±1.71	106.16±1.31^{abc}	100.34±3.26	102.78±3.25^{a}
Right arm (cm)	32.18±1.44	34.08±1.29^{ace}	31.94±0.94	32.34±0.91^{abd}	31.22±0.97	34.58±1.14^{ace}	31.32±0.96	32.38±1.02^{abd}
Left arm (cm)	31.20±1.41	33.17±1.14^{ac}	30.62±0.86	31.30±0.88^{abd}	30.64±1.07	33.78±1.16^{ace}	30.72±0.91	31.89±0.93^{ad}
Right thigh (cm)	55.74±2.52	57.44±2.59^{a}	56.07±2.39	56.50±2.44^{ad}	57.24±2.34	59.39±2.31^{ace}	55.39±2.12	56.40±2.37^{ad}
Left thigh (cm)	55.23±2.53	57.01±2.58^{a}	55.52±2.22	56.05±2.40^{ad}	56.72±2.20	59.39±2.31^{ace}	54.88±2.16	55.90±2.39^{ad}
Vo2peak (ml.kg- 1.min- 1)	39.63±0.71	40.21±0.474^{ae}	39.32±0.70	40.62±0.69^{a}	39.24±0.50	40.01±0.48^{ae}	39.29±0.53	41.18±0.72^{abd}

Table 1. *subject's physiological and anthropometric characteristics in two stage (baseline,8 weeks) and four groups (RT, HIIT, RT+BFR and HIIT+BFR).*

Data presented are the mean ±standard deviation. P<0.05. a: significantly different between baseline stage and 8-weeks, b: significant difference with the RT group, c: significant difference with the HIIT group. d: significant difference with the green RT+BFR group. e: significant difference with the HIIT+BFR group. (BMI: body mass index, Vo2 peak: Peak oxygen uptake)

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	RT		HIIT		RT+BFR		HIIT+BFR	
	baseline	8 weeks	baseline	8 weeks	baseline	8 weeks	baseline	8 weeks
GH (ng/ml)	5.29±0.33	5.62±0.33[ad]	5.41±0.20	5.55±0.20[ad]	5.46±0.30	6.07±0.29[abc]	5.37±0.33	5.72±0.35[a]
IGF-1 (ng/ml)	239.21±13.71	267.16±15.62[ad]	248.45±15.13	264.64±15.72[ad]	238.66±12.37	287.65±12.58[abce]	238.96±10.60	269.45±12.92[ad]

Table 2. *Subject GH and IGF-1 Levels at Two Stages (Baseline and 8 Weeks) Across Four Groups (RT, HIIT, RT+BFR, and HIIT+BFR). Data presented are the mean ±standard deviation. P<0.05. a: significantly different between baseline stage and 8-weeks, b: significant difference with the RT group, c: significant difference with the HIIT group. d: significant difference with the green RT+BFR group. e: significant difference with the HIIT+BFR group. (RT: resistance training, HIIT: high-intensity interval training, BFR: blood flow restriction, GH: growth hormone, IGF-1: insulin-like growth factor-1)*

increased GH release. GH plays a crucial role in promoting protein synthesis, muscle hypertrophy, and overall tissue growth[18]. Additionally, IGF-1 is a powerful anabolic hormone produced in response to GH, playing a vital role in muscle growth and strength enhancement. It promotes protein synthesis, stimulates satellite cell proliferation, and is essential for muscle development and tissue repair[19]. Increased GH levels enhance IGF-1 production in both the liver and muscle tissues. In the liver, GH stimulates IGF-1 synthesis, which is then released into the bloodstream to exert systemic effects. Additionally, GH triggers the local release of IGF-1 within muscle cells, supporting muscle repair and growth through autocrine and paracrine signaling[20,21]. Studies indicate that BFR during resistance exercises elevates anabolic hormones, making it a viable alternative for individuals unable to perform high-intensity exercises due to physical limitations. Research shows that BFR training induces hormonal responses comparable to or even exceeding those of traditional resistance training, making low-intensity resistance training with BFR and high-intensity interval training effective alternatives for enhancing metabolic stress and promoting muscle adaptation across various populations[22]. Moreover, comparing BFR training with traditional methods highlights its benefits, particularly for the elderly. BFR enhances muscle mass and strength, prevents atrophy, improves cardiopulmonary function, aids recovery from injuries and surgeries, and addresses degenerative diseases. Its mechanisms include increased muscle fiber recruitment, activation of protein synthesis pathways, hormone secretion, and pressure-induced cell swelling[23]. A recent study by Muhammed Öniz and his team (2024) demonstrated that a brief HIIT program causes significant changes in GH levels due to the time main effect, suggesting that HIIT can effectively regulate hormones and improve athlete performance when applied correctly. However, individual responses may vary depending on specific conditions[25]. Similarly, Bartłomiej Ptaszek et al. (2023) explored interval training combined with occlusion and cooling and found a significant time-dependent increase in IGF-1 levels. They suggested that adding occlusion and local cryotherapy to interval training enhances its effectiveness[25]. Pehzaan Sarfabadi and his team (2023) showed that low-intensity BFR training and high-intensity resistance training (HI-RT) significantly improve lower-limb muscle strength and power in long-jumpers[26]. Further research, such as Júlio Cesar Gomes Silva's systematic review (2019), highlights the acute and chronic benefits of aerobic exercise combined with BFR, including neuromuscular and metabolic adaptations, increased energy expenditure, and hemodynamic improvements[27]. Haruhito Takano et al. (2005) suggested that metabolic byproduct accumulation and hypoxia-induced nerve stimulation during low-intensity BFR resistance exercise likely trigger GH and GH-releasing hormone secretion[28]. Additionally, a study by Masoumeh Ahmadi Jirandeh et al. (2023) found that incorporating BFR into high-intensity TRX training significantly enhances IGF-1 levels, muscle strength, lean body mass, and anaerobic power in active females[29]. In contrast to these findings, Kacin and Strazar (2011) observed that while BFR improves local muscle endurance, its long-term benefits on hypertrophy and strength are less pronounced compared to high-intensity resistance training. BFR training effectively enhances muscle endurance and vascular adaptations due to metabolic stress and improved oxygen delivery. However, for maximal hypertrophy and strength development, higher mechanical tension (as seen in HIRT) is essential. While BFR can serve as a complementary or alternative strategy, particularly for individuals unable to perform heavy lifting, its hypertrophic and strength effects remain secondary to traditional high-load resistance training[30]. Similarly, Jeremy P. Loenneke (2015) concluded that varying BFR pressures alters acute muscular responses, but higher pressures do not necessarily amplify these effects, suggesting traditional high-intensity training may offer comparable benefits[31]. Other studies highlight the safety concerns of BFR. Li Yinghao (2021) found that optimal cuff pressures are critical for desired outcomes, as higher pressures may not always yield better results[12]. Anthony K. May (2022) demonstrated that both BFRT and HLRT produce similar improvements in muscle strength and size, with strength gains primarily attributed to neurological adaptations rather than hypertrophy[32]. However, BFR training is associated with risks, such as numbness, dizziness, subcutaneous hemorrhage, and rhabdomyolysis.

For individuals with conditions like hypertension or thoracic outlet syndrome, adverse effects may include central retinal vein occlusion and Paget–Schroeder syndrome[33]. Research by Dahan da Cunha Nascimento (2022) also highlights that BFR users, particularly anabolic steroid users, face increased risks of thrombotic complications, including stroke and pulmonary embolism, due to factors like hypercoagulability and vascular hypertrophy[35].

While the study highlights the effectiveness of RT and HIIT with BFR in modulating GH and IGF-1 levels, further research is needed to assess the long-term effects on muscle hypertrophy, strength, and overall health. The variability in individual responses and safety concerns emphasize the importance of carefully designed protocols. Future studies should focus on optimizing BFR parameters and exploring the molecular mechanisms behind hormonal adaptations, particularly for populations with physical limitations or chronic conditions, to enhance BFR's therapeutic potential.

Study strengths and limitations

The strength of our study was that we performed two types of high-intensity exercise and compared them with and without the use of BFR. This study has several potential limitations. First, the quasi-experimental design and lack of a placebo or control group may limit the internal validity and prevent clear causal inferences. Second, although participants were randomly assigned to groups, the sample size was relatively small (n = 10 per group), which may reduce statistical power and increase the risk of Type II error. Third, the short intervention period (8 weeks) may not reflect long-term hormonal or performance adaptations. Fourth, the study was conducted exclusively on healthy young men, which limits the generalizability of the findings to women, older individuals, or clinical populations. Finally, the absence of blinding for participants and assessors may have introduced some degree of measurement bias.

CONCLUSIONS

In this study investigating the effects of Resistance Training (RT) and High-Intensity Interval Training (HIIT) with and without Blood Flow Restriction (BFR), it was found that both training modalities significantly modulate Growth Hormone (GH) and Insulin-like Growth Factor 1 (IGF-1) levels in young men, with the RT+BFR group showing the most pronounced hormonal responses. These results highlight the potential of combining BFR with RT and HIIT to enhance anabolic hormone release, which plays a crucial role in muscle growth and overall health improvement.

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