Acute hemodynamic, metabolic, and perceptual responses to low-intensity blood flow restriction vs. conventional resistance training in overweight young adults

Respuestas hemodinámicas, metabólicas y perceptuales al entrenamiento con restricción del flujo sanguíneo versus resistencia convencional en jóvenes con sobrepeso

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Abstract

Introduction: Resistance training benefits adults with overweight, yet adherence to traditional high-intensity training (HT) is often limited by discomfort and physical strain. Low-intensity resistance exercise with blood flow restriction (LTBFR) has emerged as a viable alternative, but head-to-head evidence on acute physiological and perceptual stress in this population remains limited.

Objective: To compare acute hemodynamic, perceptual, and metabolic responses to LTBFR versus HT in overweight young adults.

Methodology: Twenty-four overweight young adults were randomized to LTBFR (n=12; 40% 1RM, 60% arterial occlusion pressure) or HT (n=12; 70% 1RM). Hemodynamic variables (heart rate, systolic and diastolic blood pressure) and perceptual measures (Rate of Perceived Exertion, Visual Analogue Scale for discomfort) were assessed pre/post a single session. Blood lactate was measured immediately post-session at baseline and after an 8-week intervention.

Results: At baseline, HT was rated significantly more demanding and uncomfortable, and evoked greater increases in heart rate and systolic blood pressure than LTBFR. Conversely, LTBFR elicited a higher diastolic blood pressure response. Both protocols initially produced comparable, significant elevations in blood lactate. Following 8 weeks, the acute post-exercise lactate response was significantly attenuated in both groups, indicating improved metabolic efficiency.

Conclusion: In overweight young adults, conventional HT imposes greater acute cardiovascular and perceptual load than LTBFR. Nonetheless, both modalities evoke robust metabolic stress and yield favorable adaptations over time. LTBFR provides these benefits with substantially lower cardiovascular strain and improved tolerability and safety, supporting its use as a physiologically potent, patient-friendly entry point for initiating resistance training in this at-risk population.

Keywords

Blood flow restriction; hemodynamic; blood lactate; overweight.

Resumen

Introducción: el entrenamiento de fuerza beneficia a jóvenes con sobrepeso, pero la adherencia al método tradicional de alta intensidad (HT) se ve limitada por incomodidad y esfuerzo. El ejercicio de baja intensidad con restricción del flujo sanguíneo (LTBFR) surge como alternativa, aunque la evidencia comparativa sobre las respuestas agudas en esta población es escasa.

Objetivo: comparar las respuestas agudas hemodinámicas, perceptuales y metabólicas del LTBFR frente al HT en adultos jóvenes con sobrepeso.

Metodología: participaron veinticuatro jóvenes con sobrepeso asignados aleatoriamente a LTBFR (n=12; 40% 1RM, 60% presión de oclusión) o HT (n=12; 70% 1RM). Previo y posterior a una sesión, se evaluaron variables hemodinámicas (frecuencia cardíaca, presión arterial sistólica y diastólica) y perceptuales (esfuerzo percibido e incomodidad). El lactato sanguíneo se midió post-sesión al inicio y tras 8 semanas de intervención.

Resultados: inicialmente, el HT fue percibido significativamente más exigente e incómodo, y generó mayores incrementos en la frecuencia cardíaca y la presión sistólica comparado con el LTBFR. En contraste, el LTBFR elevó más la presión diastólica. Ambos protocolos produjeron incrementos iniciales significativos y comparables de lactato. Tras 8 semanas, la respuesta aguda de lactato post-ejercicio se atenuó significativamente en ambos grupos, indicando mayor eficiencia metabólica.

Conclusiones: en jóvenes con sobrepeso, el HT convencional impone mayor carga cardiovascular y perceptual aguda que el LTBFR. No obstante, ambas modalidades generan estrés metabólico y adaptaciones favorables. El LTBFR aporta estos beneficios con menor tensión cardiovascular y mejor tolerabilidad, respaldando su uso como estrategia inicial potente y segura en esta población.

Palabras clave

Restricción del flujo sanguíneo; hemodinámico; lactato sanguíneo; sobrepeso.

Introduction

Overweight and obesity represent a significant global health challenge (World Health Organization [WHO], 2022), with a substantial burden also observed among young adults (GBD 2019 Risk Factors Collaborators, 2020). This demographic is at a critical juncture where the establishment of adverse lifestyle patterns can accelerate the development of cardiometabolic diseases. Conditions such as impaired glucose metabolism, dyslipidemia, and an elevated composite cardiometabolic risk are increasingly diagnosed in this age group, underscoring the urgent need for effective and sustainable exercise strategies (Reinehr, 2018).

Conventional high-intensity resistance training (HT; ≥70% 1RM) is well-established for driving muscular and metabolic adaptations (Campos et al., 2002; Kraemer et al., 2002). However, these benefits are predicated on significant physiological stress, which elicits substantial acute responses, including marked elevations in heart rate, blood pressure (hemodynamic responses), and blood lactate (Winchester et al., 2022). These physiological demands, coupled with high ratings of perceived exertion (RPE) and discomfort, can act as significant barriers for individuals with overweight who may be deconditioned or find such sessions aversive (Crewe et al., 2008; Tsirigkakis et al., 2022). This necessitates the investigation of alternative modalities that can provoke beneficial adaptations with a more tolerable acute physiological and perceptual load.

Low-intensity resistance training with blood flow restriction (LTBFR; 20–40% 1RM) has emerged as a potent alternative (Bielitzki et al., 2024). By partially occluding venous outflow, LTBFR traps metabolic byproducts, creating profound local metabolic stress (Freitas et al., 2020; Zhu et al., 2025). The acute physiological effects of this unique stimulus are a key area of investigation, as they are hypothesized to drive long-term adaptations (He et al., 2025; Zhu et al., 2025). While the chronic benefits of LTBFR are well-documented, a comprehensive comparison of its acute responses against HT remains critical. Specifically, the acute hemodynamic burden, the magnitude of the metabolic stress (via lactate), and the subjective perceptual strain are key indicators of session-by-session tolerance and safety (Macedo et al., 2025; Parkington et al., 2022). Furthermore, recent studies emphasize that perceptual responses like RPE and discomfort are not merely side effects but are crucial determinants for long-term program adherence, especially in populations sensitive to high levels of exertion (de Queiros et al., 2023).

Accordingly, the present study was designed to compare the acute physiological and perceptual stress imposed during each training session, which likely drives these long-term changes, has not yet been analyzed. Therefore, the purpose of this study was to compare the acute responses of LTBFR versus HT, specifically focusing on acute hemodynamic variables (heart rate, systolic and diastolic blood pressure, oxygen saturation), metabolic markers (blood lactate), and subjective perceptions (rating of perceived exertion and discomfort) in young adults with overweight.

Method

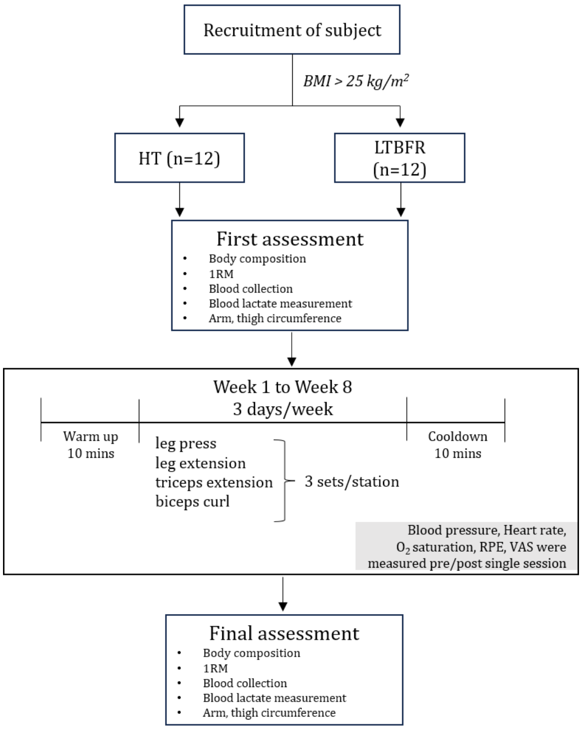
Participants

This study utilized a parallel-group, randomized controlled design to compare 8-week resistance training interventions. Twenty-four young adults with overweight (Body Mass Index (BMI) > 25 kg/m^2) were recruited and randomly assigned to either a low-intensity resistance training with blood flow restriction group (LTBFR; n=12) or a traditional high-intensity resistance training group (HT; n=12). A sample size was determined using the n4Studies tool based on 1RM leg extension data from a previous study (Ngamjarus, 2016; Shimizu et al., 2016). With an alpha of 0.05 and power of 80%, a minimum of six participants per group was required. Our recruitment of 12 per group provided sufficient power to detect meaningful differences.

All participants were recreationally active but had not engaged in structured resistance training for at least six months prior. A screening was conducted to exclude individuals with any contraindications to exercise, such as pulmonary, musculoskeletal, or cardiovascular disorders. The study protocol conformed to the Declaration of Helsinki and received ethical approval from the Human Research Ethics Committees of Walailak University (WUEC-23-084-01) and Srinakharinwirot University (SWUEC-

673012). Following a full explanation of the procedures, all participants provided written informed consent prior to participation. For any participant under the legal age of majority, written informed consent was also obtained from a parent or legal guardian. All individuals were advised of their right to withdraw from study at any time without consequence. The experimental timeline is outlined in Figure 1.

Figure 1. The outline of the time schedule of the study



Study Design and Intervention Protocols

The participants were randomly assigned to either an LTBFR group (40% 1RM, 60% AOP) or an HT group (70% 1RM) and trained three times per week. Both groups trained three times per week on non-consecutive days for eight weeks. Each 60-minute session included a standardized warm-up followed by four resistance exercises (biceps curl, triceps extension, leg press, leg extension) with equated training volume (3 sets of 12 repetitions). Participants maintained their normal dietary habits throughout the study.

- LTBFR Group: Performed exercises at 40% of their one-repetition maximum (1RM). Pneumatic cuffs were placed on the proximal portion of the limbs and inflated to 60% of the individual's estimated arterial occlusion pressure (AOP) during each set. AOP was estimated using established prediction equations incorporating blood pressure and limb circumference. Cuffs were deflated during the inter-set rest periods.
- HT Group: Performed the same exercises at 70% of 1RM without the use of cuffs.

Blood Flow Restriction (BFR) Cuff Pressure Determination

This study employed a manual BFR cuff system (B-Strong) to deliver target pressures. The pressure required to completely stop arterial flow—arterial occlusion pressure (AOP)—is individualized and depends on cuff characteristics (shape, width, length), limb size, and the person's blood pressure.

During resistance training, cuffs were inflated to 60% of the calculated AOP to balance efficacy with comfort and safety. In practice, this typically corresponded to about 70–110 mmHg for the upper arm and 110–150 mmHg for the upper thigh.

Cuff placement and width

- Upper limb: ~5 cm-wide cuffs placed as proximally as possible, with the top edge just below the deltoid near the axilla.
- Lower limb: ~10 cm-wide cuffs positioned high on the thigh, with the top edge immediately below the gluteal fold, near the groin.

Calculation of 100% AOP (mmHg) based on Loenneke et al. (2012)

- Lower body: AOP = (0.912 × systolic BP) + (0.734 × diastolic BP) + (5.893 × thigh circumference in cm) – 220.046
- Upper body: AOP = (0.667 × systolic BP) + (0.399 × diastolic BP) + (1.461 × arm circumference in cm) – 17.236

LTBFR protocol

Participants performed resistance exercises at 40% of their 1RM. The cuffs were maintained at 60% AOP during each set and deflated during the 1-minute rest period between sets.

Data Collection and Measurements

The current analysis was performed to assess the acute hemodynamic, metabolic, and perceptual responses immediately post-exercise.

- Body Composition: Body weight, fat percentage and lean mass, was determined using a bioelectrical impedance analyzer (Tanita, model UM-076).
- Hemodynamic Responses: Resting and post-exercise heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and oxygen saturation (SpO2) were assessed using an automated sphygmomanometer and fingertip pulse oximeter. Measurements were taken at baseline (pre-test) and immediately post-training (post-test).
- Blood Lactate Concentration: Capillary blood samples were collected from the fingertip before exercise (Pre-test), after the first post-test session, and after the final training session. Blood lactate concentrations were analyzed using a portable lactate analyzer (Lactate Pro 2, Arkray, Japan).
- Subjective Perceptions: Perceived exertion was assessed using the CR10 Borg Rating of Perceived Exertion (RPE) scale immediately after finishing all sessions on the first day of week. Discomfort was evaluated using a Visual Analogue Scale (VAS) ranging from 0 (“no discomfort”) to 10 (“extreme discomfort”).

Data Analysis

Data were analyzed using IBM SPSS Statistics, with statistical significance set at $p < 0.05$. Descriptive statistics are presented as mean ± standard error (SE). Prior to analysis, data were assessed for normality and homogeneity of variances using the Shapiro-Wilk and Levene's tests, respectively. A two-way repeated measures ANOVA were used to assess the main effects of the interventions. Effect sizes (ηp^2) were reported, and Tukey’s post-hoc tests were applied where appropriate. Paired t-tests were used compared to pre- and post- intervention within each group, and independent t-test were applied to compare groups at specific time points.

Results

Participants' Baseline Characteristics

The demographic and anthropometric characteristics of the participants at baseline are presented in Table 1. All 24 participants were classified as overweight based on their BMI. No statistically significant differences were observed between the LTBFR and HT groups for any variable at baseline (all p > 0.05), indicating that the randomization process resulted in two well-matched groups prior to the intervention. This similarity between groups is important for attributing subsequent training effects to the intervention protocols rather than to pre-existing group differences. The very small effect sizes observed across all baseline characteristics further support this finding, indicating that the differences between groups were negligible from a physiological perspective.

Table 1. Baseline demographic and anthropometric characteristics of participants. Data is represented as the mean ± standard error of the mean (SEM).

Characteristic	LTBFR (n=12)	HT (n=12)	p-value	95% confidence interval	Effect size
Sex (male/female)	(8/4)	(8/4)	N/A	N/A	N/A
Age (years)	20.17 ± 0.21	19.92 ± 0.23	0.652	-0.85 to 0.541	0.009
Height (cm)	171.20 ± 1.35	173.80 ± 2.06	0.535	-8.56 to 4.564	0.016
Body weight (kg)	77.28 ± 3.50	81.98 ± 6.49	0.474	-8.68 to 18.02	0.024
BMI (kg/m^2)	27.63 ± 1.03	26.98 ± 1.45	0.722	-4.33 to 3.04	0.026
Body Fat (%)	24.31 ± 2.01	22.63 ± 1.51	0.215	-4.43 to 1.053	0.069
Metabolic rate (kcal)	1624 ± 92.62	1904 ± 130.4	0.411	-187.8 to 443.7	0.028

Changes in heart rate, blood pressure, and oxygen saturation following LTBFR and HT groups

The hemodynamic responses measured 10 minutes post-exercise is presented in Table 2. After LTBFR, heart rate post-exercise (within 10 minutes) was not significantly elevated compared to baseline, suggesting a relatively rapid return towards resting cardiac demand. This indicates that the low-load BFR protocol might cause less sustained cardiovascular stress following cessation of exercise, potentially due to the lower absolute intensity. In contrast, the HT group showed a significant and substantial elevation in heart rate 10 minutes post-exercise (large effect size), indicating a greater, more prolonged cardiovascular demand and a longer recovery period from the higher-intensity resistance training. This sustained elevation may reflect the body's need to repay oxygen debt and remove metabolic byproducts from the more demanding workout.

Both LTBFR and HT protocols induced a significant and physiologically large increase in systolic blood pressure at 10 minutes post-exercise, reflecting a continued demand for increased blood flow to active muscles and sustained sympathetic nervous system activation during the early recovery phase, suggesting a robust, albeit transient, post-exercise pressor response regardless of training intensity or BFR application. However, the impact on diastolic blood pressure differed notably; while the HT group showed a significant increase, the LTBFR group demonstrated a much larger and clinically substantial elevation in diastolic blood pressure. This marked difference in diastolic response suggests the persistence of peripheral vasoconstriction unique to the blood flow restriction in LTBFR, potentially due to impeded venous return and maintained afterload, thereby imposing a distinct hemodynamic stressor compared to the more moderate effects seen in the HT protocol.

Regarding oxygen saturation, distinct recovery patterns were observed between the groups. The LTBFR group demonstrated a small but statistically significant post-exercise dip in oxygen saturation, suggesting a mild and transient imbalance between oxygen demand and supply, or a subtle impairment in gas exchange that may persist into the early recovery phase, potentially influenced by the residual effects of blood flow restriction. In contrast, the HT group maintained stable oxygen saturation levels, with no significant change from baseline. This indicates that despite the high demands of the intense training, their respiratory and circulatory systems were highly effective at preserving arterial oxygen content and delivering oxygen to tissues during the 10-minute recovery period, demonstrating efficient oxygen transport capacity without sustained desaturation.

In summary, these results suggest that while both training methods elevate post-exercise cardiovascular stress, their physiological signatures differ. HT's primary effect is a strong chronotropic response (increased heart rate), while LTBFR is characterized by a more pronounced increase in diastolic pressure and mild residual hypoxemia. Notably, the systolic pressure response was robust and comparable between both interventions.

Table 2. Heart rate, O_2 saturation, and blood pressure responses measured within 10 minutes post-exercise for the 40%1RM of low-intensity combined with 60%AOP of blood flow restriction (LTBFR) and 70%1RM of higher-intensity resistance training (HT). Data is represented as the mean ± standard error of the mean (SEM).

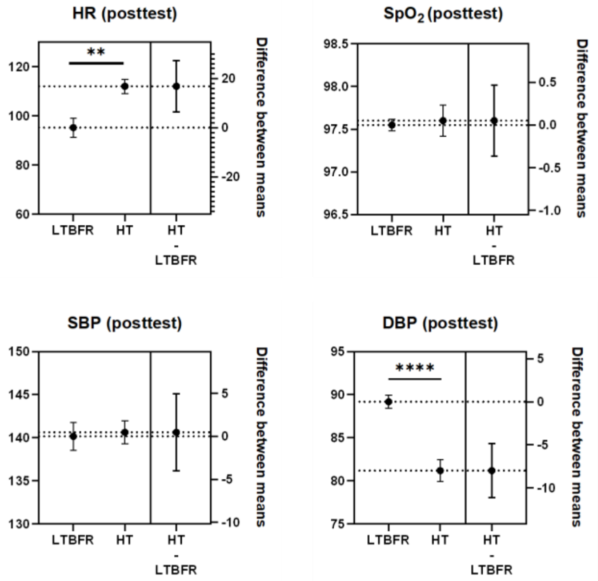
Variable	Group	Baseline (pre-exercise) [mean (SEM)]	10-min post-exercise [mean (SEM)]	p-value	95% confidence interval	Effect size
$HR_{recovery}$ (beats/min)	LTBFR	87.57 (1.33)	95.15 (3.90)	0.087	-1.254 to 16.41	0.195
	HT	88.72 (2.55)	111.9 (2.90)***	<0.0001	14.91 to 31.50	0.720
$SBP_{recovery}$ (mmHg)	LTBFR	122.9 (0.83)	140.2 (1.61)****	<0.0001	13.41 to 21.18	0.867
	HT	122.1 (0.64)	140.6 (1.32)****	<0.0001	15.35 to 21.65	0.919
$DBP_{recovery}$ (mmHg)	LTBFR	73.37 (0.41)	89.18 (0.76)****	<0.0001	13.95 to 17.66	0.960
	HT	74.22 (1.27)	81.17 (1.25)**	0.0016	3.132 to 10.77	0.521
O_2 $saturation_{recovery}$ (%)	LTBFR	97.94 (0.11)	97.55 (0.07)**	0.0083	-0.6605 to -0.1170	0.402
	HT	97.95 (0.16)	97.6 (0.18)	0.1751	-0.8786 to 0.1761	0.127

**p < 0.01, ***p < 0.001, ****p < 0.0001 indicates significant difference when compared with pre- and post-test in each group.

Hemodynamic differences at post-single session

Figure 2 compares the post-exercise hemodynamic responses between the LTBFR and HT groups. Immediately following the exercise protocols, the high-intensity training (HT) group exhibited a significantly higher heart rate compared to the low-intensity training with blood flow restriction (LTBFR) group. This distinct cardiovascular response indicates that HT placed a much greater acute demand on the heart, leading to a more substantial cardiac effort during and immediately after the training session. Despite these differences in heart rate response, both LTBFR and HT protocols resulted in similar levels of systolic blood pressure and maintained comparable arterial oxygen saturation immediately post-exercise. This suggests that both training modalities elicited a similar acute increase in the heart's pumping force and did not cause a sustained impairment in oxygen delivery. However, a notable physiological divergence was observed in diastolic blood pressure, where the LTBFR group demonstrated a significantly higher value immediately post-exercise than the HT group. This underscores a unique hemodynamic stress imposed by blood flow restriction, likely due to enhanced peripheral vasoconstriction and increased systemic vascular resistance, which could contribute to the elevated diastolic pressure observed during the early recovery phase.

Figure 2. Comparison of post-test HR, blood pressure and O_2 saturation both the 40% of 1RM of low intensity combined with 60% of AOP of blood flow restriction (LTBFR) and high intensity resistance training (HT). Data is represented as the mean ± standard error of the mean (SEM). ***p* < 0.01, *****p* < 0.0001 indicates significant difference when compared with LTBFR and HT group.

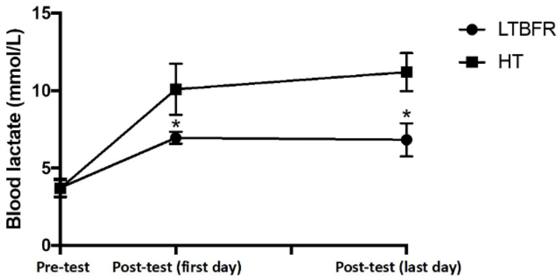


Blood Lactate Responses to LTBFR and HT

Figure 3 illustrates the blood lactate responses to the LTBFR and HT protocols. While both groups started with similar pre-test lactate levels, their responses to exercise differed significantly. Following the first session, lactate increased in both groups, but the elevation was significantly greater in the HT group (approx. 10 mmol/L) compared to the LTBFR group (approx. 7 mmol/L, $p < 0.05$). This significant difference between the groups was maintained at the final post-test measurement, with the HT group again showing a substantially higher lactate concentration than the LTBFR group ($p < 0.05$). Notably, there was no significant reduction in post-exercise lactate from the first to the last day in either group.

These findings suggest that HT inherently demands a more extensive reliance on anaerobic glycolysis to produce energy, resulting in a higher rate of lactate production and subsequent accumulation in the bloodstream. While LTBFR also induced a substantial increase in blood lactate from baseline, the lower overall lactate levels suggest a relatively reduced reliance on anaerobic pathways compared to HT, possibly due to the lower absolute workload despite the ischemic conditions. Therefore, the HT protocol imposes a more profound metabolic stress characterized by greater anaerobic contribution, as evidenced by the consistently higher blood lactate concentrations across the training period.

Figure 3. This figure shows blood lactate concentrations (mmol/L) measured at Pre-test, Post-test (first day), and Post-test (last day) in the LTBFR and HT groups. Data is represented as the mean ± standard error of the mean (SEM). $^{*}p < 0.05$ indicates a significant difference when compared with LTBFR and HT groups at the same time-point.

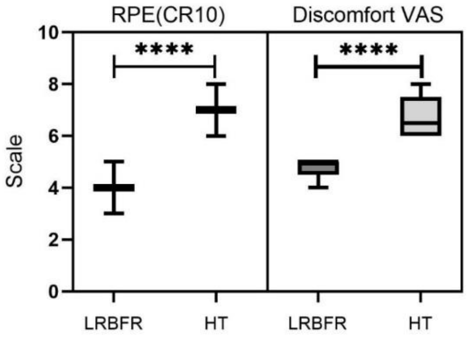


Comparison of perceived exertion and discomfort between LRBFR and HT groups

There were notable differences in the perceived exertion between the HT and LTBFR groups. The HT group reported significantly higher ratings (about 7-8) on the CR10 scale than the LTBFR group (around 4), indicating that HT was viewed as significantly more demanding ($p<0.0001$). When utilizing a visual analogue scale (VAS) to measure discomfort, a similar pattern was seen. Similarly, participants in the HT group reported significantly higher levels of discomfort (scores around 7–8) compared to those in the LTBFR group (scores around 4; $p < 0.0001$).

Figure 4 illustrates a clear physiological distinction in the experience of training intensity, demonstrating that the high-load traditional training (HT) protocol was perceived as significantly more effortful and induced a substantially higher level of discomfort compared to low-load resistance training with blood flow restriction (LTBFR). The significantly greater RPE (CR10 scale) in the HT group reflects a higher cognitive and physiological processing of internal bodily signals, indicating a more taxing and exhaustive physical demand from the high-intensity workout. Similarly, the profoundly higher Discomfort VAS scores for the HT group physiologically signify a more intense and unpleasant sensory experience, likely stemming from greater muscle fatigue, local metabolic accumulation, and overall systemic strain. Conversely, the LTBFR, despite its effectiveness in eliciting muscle adaptations, was perceived as noticeably less strenuous and uncomfortable by the participants. This suggests that LRBFR offers a distinct advantage in terms of perceived tolerability, potentially enhancing adherence and motivation for individuals who may find high-intensity training excessively challenging or unpleasant.

Figure 4 compares perceived exertion (RPE, CR10 scale) and discomfort (VAS scale) between low-load resistance training with blood flow restriction (LRBFR) and high-load traditional training (HT). Data is represented as the mean ± standard error of the mean (SEM). $^{****}p <$ 0.0001 indicates a significant difference when compared with LTBFR and HT groups



Discussion

This study aimed to compare the acute hemodynamic, metabolic, and perceptual responses between low-intensity blood flow restriction training (LTBFR) and traditional high-intensity training (HT) in young adults with overweight. Groups were well matched at baseline on demographic and anthropometric characteristics, minimizing the likelihood that pre-existing differences influenced post-exercise outcomes.

Our findings reveal that while both protocols induce significant physiological stress, they do so via distinct pathways and elicit markedly different perceptual experiences. The primary finding is that LTBFR provokes a significant metabolic and cardiovascular challenge with a substantially lower perceptual burden compared to HT, a conclusion strongly supported by recent literature investigating the unique profile of BFR training (de Queiros et al., 2023; Macedo et al., 2025; Zhang et al., 2022). This positions LTBFR as a potentially more tolerable and sustainable exercise modality for this population, holding significant promises for increasing exercise adherence and long-term health benefits in individuals who find traditional high-intensity exercise challenging, such as those in early-stage rehabilitation or deconditioned populations.

Distinct hemodynamic and metabolic signatures

Our results demonstrate that HT and LTBFR produce distinct "physiological signatures," aligning with findings from recent studies (Freitas et al., 2020; Macedo et al., 2025). HT triggered a powerful chronotropic response (significantly higher heart rate) and a greater systemic metabolic disturbance (significantly higher blood lactate) (Freitas et al., 2020; Macedo et al., 2025). This is an expected outcome, as high-intensity work demands greater cardiac output to meet systemic metabolic needs, a finding consistent with direct comparisons in the literature (Macedo et al., 2025; Viderman et al., 2025).

Conversely, LTBFR was characterized by a more pronounced pressor response, specifically a significant elevation in diastolic blood pressure (DBP) (Zhang et al., 2022). Our observation of a significantly greater DBP increase post-LTBFR is a hallmark finding in the BFR literature, recently confirmed by a meta-analysis from de Queiros et al. (2023). This response is likely attributed to an increase in peripheral vascular resistance mediated by sympathetic activation (D'Souza & Stickland, 2025; Picón et al., 2018). Interestingly, despite this intense local pressor response, the systemic lactate accumulation was significantly lower than in HT. This suggests that the metabolic stress in LTBFR is highly concentrated within the occluded muscle, creating a potent local stimulus without the same degree of systemic spillover (Miller et al., 2021). The small but significant reduction in oxygen saturation (SpO_2) post-LTBFR further supports the creation of this localized hypoxic environment, a key proposed mechanism for its effectiveness that has been detailed in recent studies on BFR and muscle oxygenation (Neto et al., 2016; Shriver et al., 2023). Notably, the robust systolic blood pressure response observed in both conditions is consistent with prior hemodynamic studies of resistance exercise performed with BFR and across different BFR application methods (Parkington et al., 2022; Winchester et al., 2022).

Beyond these systemic readouts, the distinct acute stressors induced by LTBFR are known to initiate specific molecular cascades critical for long-term vascular adaptation and metabolic health. The localized hypoxic environment created by LTBFR is a potent stimulus for the upregulation of Hypoxia-Inducible Factor-1 alpha (HIF-1α), a master regulator that promotes angiogenesis through the expression of Vascular Endothelial Growth Factor (VEGF) (Carmichael et al., 2025; Stoeltzing et al., 2003). Recent molecular insights reveal that even transient hypoxia, like that induced by BFR, is sufficient to stabilize HIF-1α, preventing its degradation and enhancing the transcription of pro-angiogenic genes, crucially including VEGF, which leads to improved capillary density and blood flow (Li et al., 2022; Volga Fernandes et al., 2022). This may provide a potential mechanistic pathway explaining how repeated bouts of LTBFR could contribute to improved vascular function. Practically, this suggests LTBFR could be a valuable tool in rehabilitation settings for populations with compromised vascular health, such as those recovering from peripheral artery disease or prolonged immobilization, where improving blood flow is a primary goal.

Furthermore, the intense local metabolic stress acts as a powerful activator of key signaling pathways. The accumulation of metabolites (e.g., lactate, inorganic phosphate) is hypothesized to stimulate the mammalian target of rapamycin complex 1 (mTORC1) pathway, a central driver of muscle protein synthesis, providing a mechanism for the well-documented hypertrophic effects of LTBFR despite low mechanical loads (Su et al., 2025). Mechanistically, this metabolic perturbation, combined with muscle fiber recruitment under ischemic conditions, leads to increased cellular swelling and osmolarity, which may act as potent activators of the mTORC1 signaling cascade crucial for muscle growth (Fry et al., 2010; Li et al., 2025). Concurrently, this metabolic challenge is known to release myokines such as interleukin-6 (IL-6) and irisin, which play crucial roles in regulating systemic glucose uptake and insulin sensitivity (Nóbrega et al., 2022; Yano et al., 2021). Studies have shown that exercise-induced accumulation of metabolites and subsequent muscle contraction can stimulate the release of IL-6, which can then act in an endocrine manner to improve whole-body glucose homeostasis (Kistner et al., 2026). Similarly, irisin, cleaved from fibronectin type III domain containing 5 (FNDC5), is highly sensitive to exercise-induced energetic stress and contributes to the browning of white adipose tissue and improved insulin sensitivity (Mohammed et al., 2025; Waseem et al., 2022). The unique combination of hypoxia and metabolic stress from LTBFR may therefore trigger a different myokine-release profile compared to the predominant mechanical stress of HT, offering a novel avenue for improving cardiometabolic health.

Perceptual responses and their practical implications

The most striking difference between the protocols was in the subjective responses, a finding that holds significant practical implications. Participants rated HT as significantly more demanding and uncomfortable, corresponding to a "very hard" exertion. Such high perceptual loads are known to be a significant barrier to long-term exercise adherence, a critical consideration in populations that may be deconditioned or exercise-averse (Suga et al., 2021). This is particularly relevant for physical education programs aiming to foster a positive view of exercise, or for fitness professionals working with clients new to exercise or those returning from injury, where discomfort can quickly lead to dropout.

In contrast, LTBFR was perceived as only "somewhat hard," representing a much more manageable level of exertion. This large disparity in perceptual load, despite both protocols creating significant physiological stress, is a cornerstone of BFR's appeal. Recent research suggests this dissociation arises because the primary drivers of perceived exertion are stimulated differently; the intense systemic stress of HT (high heart rate, high lactate) drives a high RPE, whereas in LTBFR, the stress is primarily local (Damayanti et al., 2022; Parkington et al., 2022). As highlighted by a recent meta-analysis, this allows LTBFR to "trick" the body into a state of high physiological challenge without the associated aversive feeling of whole-body exertion (Macedo et al., 2025). This unique characteristic is fundamental to its potential as a more tolerable training strategy.

Limitations and future directions

This study has several limitations. First, the modest sample size (n=12 per group) may limit statistical power, and future studies should recruit larger cohorts. Second, our findings may have limited generalizability as they are specific to young, overweight males; research in females, older adults, and other populations is needed.

Future research should also move beyond acute comparisons to investigate the long-term adaptations and clinical outcomes of LTBFR versus HT in these populations. Specifically, longitudinal studies are warranted to assess the chronic impact of LTBFR on cardiorespiratory fitness, body composition, vascular function markers (e.g., endothelial function, arterial stiffness), and metabolic health (e.g., insulin sensitivity, lipid profiles) in young adults with overweight.

Conclusions

In conclusion, this study demonstrates that LTBFR and HT elicit distinct acute physiological and perceptual responses in young adults with overweight. While HT is characterized by high systemic stress, marked by a greater heart rate and systemic lactate response, LTBFR induces a unique state of localized metabolic stress with a more pronounced diastolic pressor response. Critically, LTBFR achieves this physiological challenge with significantly lower levels of perceived exertion and discomfort. This favorable perceptual profile makes LTBFR a promising, more tolerable, and potentially more sustainable exercise alternative for individuals who may find the intensity and discomfort of traditional high-intensity training to be a prohibitive barrier to long-term adherence.

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