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Effects of isometric training with and without blood flow restriction on handgrip strength in adults

Efectos del entrenamiento isométrico con y sin restricción del flujo sanguíneo sobre la fuerza de prensión manual en adultos

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Abstract
Handgrip strength is a marker of health and performance, with prospective associations with mortality. Blood Flow Restriction (BFR) training allows for the induction of adaptations with low mechanical stress; however, its added effect on isometric hand/forearm tasks is uncertain and may depend on load prescription. The aim of this study was to evaluate the effects of a six-week isometric program with and without BFR on handgrip strength. A 6-week clinical trial (3 sessions/week) was conducted in 18 physically active males aged 20 to 40 years, assigned to training with BFR (n=10) and without BFR (n=8). Volume and effort were kept constant between groups. The dependent variable was maximal grip strength (dynamometry). Data were analysed using mixed linear models with group, time, and their interaction effects. The results showed that both groups improved after the intervention, with no evidence of additional benefit with BFR (group × time not significant; difference in differences = 0.56 kgf, 95% CI −2.09 to 3.21). Although the BFR group showed higher absolute values at Pre and Post-intervention (difference in Post-intervention 8.07 kgf; 95% CI 0.12–16.02), the change trajectories were parallel. The hand effect was small (~1.9 kgf) and not significant, with no interactions. Conclusion: In active males, a six-week isometric program improves handgrip, but adding BFR does not provide an additional gain with the exercise prescription used.
Keywords: vascular resistance; dose–response relationship; muscle strength; metabolic stress; exercise.

Resumen
La fuerza de prensión manual es un marcador de salud y rendimiento, con asociaciones prospectivas con mortalidad. El entrenamiento con restricción del flujo sanguíneo (RFS) permite inducir adaptaciones con bajo estrés mecánico, sin embargo, su efecto añadido en tareas isométricas de mano/antebrazo es incierto y puede depender de la prescripción de la carga. El objetivo del estudio fue evaluar los efectos de un programa isométrico de seis semanas con y sin RFS sobre la fuerza de prensión manual. Se llevó a cabo un ensayo clínico de 6 semanas (3 sesiones/semana) en 18 varones físicamente activos con edades entre los 20 a 40 años, asignados a entrenamiento con RFS (n=10) y sin RFS (n=8). Se mantuvieron constantes el volumen y el esfuerzo entre grupos. La variable dependiente fue la fuerza de presión máxima (dinamometría). Los datos se analizaron mediante modelos lineales mixtos con efectos de grupo, tiempo y su interacción. Los resultados mostraron que ambos grupos mejoraron tras la intervención, sin evidencia de beneficio adicional con RFS (grupo × tiempo no significativo; diferencia en diferencias = 0,56 kgf, IC95% −2,09 a 3,21). Aunque el grupo con RFS mostró valores absolutos superiores en Pre y Post-intervención (diferencia en Post-intervención 8,07 kgf; IC95% 0,12–16,02), las trayectorias de cambio fueron paralelas. El efecto de la mano fue pequeño (~1,9 kgf) y no significativo, sin interacciones. Conclusión: en varones activos, un programa isométrico de seis semanas mejora la prensión manual, pero añadir RFS no proporciona una ganancia adicional con la prescripción de ejercicio empleada.
Palabras clave: resistencia vascular; relación dosis-respuesta; fuerza muscular; estrés metabólico; ejercicio.

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Introduction

Lower muscular strength, quantified by handgrip strength (HGS), is associated with a higher risk of mortality (Díaz-Cortés et al., 2024; Hughes et al., 2017). In the PURE study (Leong et al., 2015), each decrease of 5-kg in HGS was associated with a 16% increase in all-cause mortality, with grip strength being a stronger predictor of overall and cardiovascular mortality than systolic blood pressure. Muscular strength is a fundamental physical quality not only for sports performance but also as a cornerstone of health across the lifespan (Suchomel et al., 2018; Zhuang et al., 2020). Its preservation and development are associated with a lower incidence of chronic diseases and greater longevity (Artero et al., 2012; Volaklis et al., 2015). In this context, HGS stands out as a reliable indicator of overall muscular strength and as a predictive marker of health, including functionality in older age, with direct implications for training and rehabilitation (Cronin et al., 2017; McGrath et al., 2022).

Within this context, various training strategies have been proposed to optimize the development of muscular strength. One of the most studied in recent years is blood flow restriction training (BFR), which consists of applying external pressure at the proximal part of the trained limb (arm or thigh) in order to partially restrict venous return during exercise while maintaining reduced arterial flow (Dech et al., 2022; Takarada et al., 2000). Under these hypoxic and high metabolic stress conditions, increased recruitment of motor units and anabolic signaling have been observed. This may explain why low loads (≈20–50% 1RM) or isometric contractions with BFR can induce improvements in strength and hypertrophy, sometimes comparable to high-load protocols (Hughes et al., 2017), although this equivalence is not consistent throughout the literature (Muñoz et al., 2022; Wortman et al., 2021). Its application to the forearm and hand muscles, directly involved in HGS, is feasible and has been explored (Hughes et al., 2017; Wortman et al., 2021). Since effectiveness and safety depend on the applied stimulus, it is recommended to individualize pressure according to the percentage of BFR pressure determined for each limb and to standardize the reporting of parameters and adverse events (Hughes et al., 2017).

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Compared with traditional training, high loads (~70% 1RM) remain the standard for maximizing strength, whereas low loads (~30–50% 1RM) performed close to or until failure can achieve similar hypertrophy after several weeks (Hughes et al., 2017). However, the greatest strength gains are typically observed with high loads (Hughes et al., 2017; Wortman et al., 2021). In this context, adding BFR to low loads appears to produce significant gains in strength and hypertrophy with less joint stress, which has driven its adoption in musculoskeletal rehabilitation (for example, post-surgical cases or osteoarthritis) (Hughes et al., 2017; Wortman et al., 2021), but also in athletes. In healthy athletes, significant strength improvements have been observed in approximately 78% of studies, increases in muscle size in about 50%, and improvements in performance markers in around 75% (Wortman et al., 2021). Nevertheless, the proposed mechanisms (ischemia/hypoxia, metabolic stress, anabolic signaling, increased recruitment of fast-twitch fibers) remain largely hypothetical and require more pragmatic and specific identification (Hughes et al., 2017). Uncertainties also persist regarding optimal implementation, especially in well-trained athletes and in specific tasks such as handgrip strength (Wortman et al., 2021).

The aim of this study was to evaluate the effects of a six-week isometric training program with BFR, applied to the musculature involved in HGS in physically active adults aged 20–40 years, and to compare it with an equivalent isometric program without BFR while maintaining constant volume and effort. Our hypothesis was that the increase in HGS from pre- to post-intervention would be greater with BFR than in the non-BFR group. The results could offer coaches and clinicians a low-mechanical-stress option when high loads are not feasible (pain, early return to training, competitive congestion), as well as basic guidelines for individualization and monitoring (pressure adjustment, effort control, tolerability).

Materials and Methods

Study design

A randomized and comparative clinical trial with two groups (BFR vs. non-BFR) was conducted, with a six-week intervention and three sessions per week. Assessments were performed at week 0 (pre-intervention) and week 6 (post-intervention) to compare

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pre- to post-intervention changes between groups. Random assignment (1:1) was carried out at the individual level; blinding of participants and evaluators was not possible due to the nature of the intervention. Informed consent was obtained from all participants. Confidentiality and anonymous data processing were guaranteed in accordance with the Declaration of Helsinki.

Participants

Initially, 21 male volunteers were recruited from the population of Amposta (Spain). Three participants dropped out for personal reasons or injuries unrelated to the study, resulting in a final sample of 18 men aged between 20–40 years. Table 1 presents the inclusion criteria.

Table 1. Defined inclusion criteria

Having more than 3 years of experience in strength training.
Having no injuries that would prevent the participant from following the study protocol.
Being at least 18 years old.
Being able to attend all training sessions included in the protocol.

Participants were randomly divided into two groups: a BFR group (n = 10) and a non-BFR group (n = 8). Baseline anthropometric characteristics of participants are presented in Table 2. The primary analysis was planned using a linear mixed model (LMM) to evaluate the group × time interaction in HGS. Since G*Power does not include LMM calculations, the a priori sample size calculation was approximated using a repeated-measures ANOVA (within–between interaction; 2 groups × 2 measurements). Assuming $\alpha = 0.05$, $1-\beta = 0.80$, a pre–post correlation of $\rho = 0.70$, and a moderate-to-large expected effect size ($f = 0.28$), the required sample size was N = 18 (≈9 per group).

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Table 2. Baseline anthropometric characteristics of participants

	BFR group (n = 10)	Non-BFR group (n = 8)
Age (years)	26.10 ± 5.45	23.50 ± 2.20
Height (cm)	176.70 ± 5.06	172.63 ± 3.25
Body mass (kg)	80.16 ± 9.66	72.53 ± 8.34
BMI (kg/m²)	25.59 ± 2.65	24.28 ± 2.51
Years of experience	8.80 ± 2.15	5.25 ± 1.75

Note. BFR = blood flow restriction; BMI = body mass index.

Experimental Procedure

A familiarization session with the dynamometer and the isometric protocol was conducted. Subsequently, two assessments were performed: pre-intervention (week 1) and post-intervention (week 8). Training sessions were carried out three times per week (Monday, Wednesday, and Friday) during the six weeks between the two assessments, within a time slot maintained by each participant. Participants were instructed to avoid intense upper-limb exercise in the 24–48 h prior to testing and to refrain from consuming caffeine or alcohol in the 24 h prior to the assessments. All sessions were supervised by the principal investigator and a PhD in Physical Activity and Health Sciences, who verified exercise technique, time under tension using a metronome/stopwatch, and recorded adherence (percentage of sessions completed) and adverse events (classified as mild/moderate/severe and their relationship with the intervention).

Intervention

Warm up (both groups). Wrist, elbow, and shoulder mobility exercises (~5 min), followed by 2–3 submaximal grip contractions (30–50% effort; 3–5 s) to standardize prior activation.

Common training protocol (both groups). Isometric exercises targeting the intrinsic and extrinsic musculature of the hand and forearm. Each session included the three exercises in the order indicated, with 10 s rests between repetitions and 30 s between

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exercises. Progression was applied from week 4 by increasing the duration of repetitions in the fist plank and hanging exercises.

- Weeks 1–3
  - *Wall push*: 10 sets × 5 s isometric contractions at 100% maximal voluntary contraction (MVC).
  - *Fist plank*: 5 sets × 20 s.
  - *Bar hang*: 5 sets × 20 s.
- Weeks 4–6
  - *Wall push*: 10 sets × 5 s isometric contractions at 100% MVC.
  - *Fist plank*: 5 sets × 20 s.
  - *Bar hang*: 5 sets × 20 s.

Exercise intensity was monitored using the Borg CR-10 scale (Borg, 1998) to standardize the effort/fatigue state prior to measurements and ensure consistent conditions between sessions. Ratings were recorded at the end of the final set of each exercise, targeting a 6–8/10 range to ensure sufficient stimulus without compromising technique.

BFR group: a commercial elastic band (Nyamba, 5 kg) was applied circumferentially to the most proximal portion of the upper limb (proximal forearm), which is considered a valid tool to induce BFR (Passos et al., 2024). Dosage was standardized according to limb circumference. After measuring the circumference at rest, the band was marked to achieve 25% BFR during weeks 1–3 and 30% during weeks 4–6 (target length = 0.75 × C and 0.70 × C, respectively) on the first wrap. The second wrap was used only for fixation without adding tension. As a complementary perceptual control, perceived tightness (0–10) was recorded, targeting 6–7/10 (this scale was used only as verification due to its limited reliability across sessions (Bell et al., 2019)). After each placement, distal perfusion was checked (capillary refill <2 s, normal coloration and sensation), and the band was removed between exercises. The session was stopped in case of any sign of intolerance. This circumference-based dosage aligns with recent methodological proposals for BFR (10–30% of limb perimeter) and avoids relying exclusively on perceived tightness (Aniceto & Da Silva Leandro, 2022).

Non-BFR group: the same protocol was followed without the elastic band.

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Measurement procedures

Handgrip strength (HGS) was assessed using a Takei Hand Grip dynamometer (Takei, Japan), an instrument with demonstrated validity and reliability compared with reference devices (Trajković et al., 2024). Participants performed three maximal isometric contractions per hand, with standardized rest (~60–120 s). The highest value in kilograms of force (kgf) was recorded. The test was performed before and after the intervention (week 1 and week 8). Posture was standardized; when the aim is maximal clinical comparability, the ASHT position is recommended (seated, elbow at 90°, neutral wrist). Both hands were measured, and participants remained seated using the same chair for each measurement. The wrist was positioned at 15–30° extension and 0–15° ulnar deviation. The second handle position was suggested for calibration, although some protocols recommend adjusting it to maximize participant comfort (Farmer et al., 2019).

Statistical analysis

Normality was assessed using the Kolmogorov–Smirnov test and inspection of Q–Q plots of the residuals. When necessary, the dependent variable was transformed (e.g., log or square-root transformation) to stabilize variance and approximate normality (Field, 2017). The effect of the intervention was evaluated using linear mixed models (LMM) with Group (BFR vs. non-BFR), Time (pre-, post-intervention), and their group × time interaction as fixed effects, and a random intercept for each participant to account for intra-individual dependency (West et al., 2014). Model selection was performed using likelihood ratio tests between nested models, estimated by maximum likelihood (ML) when comparing fixed effects and by restricted maximum likelihood (REML) when evaluating the random-effects structure. The final model was reported using REML estimation (Kuznetsova et al., 2017). In the presence of a significant interaction, simple effects were calculated (between-group comparisons at each time point and within-group changes), with Holm–Bonferroni adjustment for p-values. Results are presented as estimated marginal means (EMMs) with standard errors (SE) or 95% confidence intervals (95% CI), and effect sizes (standardized mean difference; SMD, Hedges' d) with the following interpretation: <0,2 trivial; 0,2–0,6 small; 0,6–1,2 moderate; 1,2–2,0 large;

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>2,0 very large (Hopkins et al., 2009). The significance level was set at α = 0.05. All analyses were conducted using JASP (version 0.18.3.0) (Linear Mixed Models module).

Results

A total of 72 HGS observations were analyzed (18 participants × 2 time points × 2 hands). Table 3 presents the descriptive statistics for handgrip strength (kgf) by group, time point, and hand, together with the within-subject change (Δ post–pre). Descriptively, HGS increased in both groups after six weeks. The BFR group showed higher values compared with the non-BFR group at both pre- and post-intervention assessments**.** The magnitude of change was similar in the left hand, while the right hand showed greater improvement in the BFR group.

Table 3. Handgrip strength (kgf) by group, time point, and hand. Values are expressed as mean ± SD; Δ post–pre = within-subject change. BFR (n = 10); Non-BFR (n = 8).

Group	pre-intervention right hand	pre-intervention left hand	post-intervention right hand	post-intervention left hand	Δ post-pre right hand	Δ post-pre left hand
BFR	51.50 ± 8.12	49.71 ± 7.76	54.74 ± 8.05	52.85 ± 7.66	3.24 ± 0.86	3.14 ± 0.88
Non-BFR	44.04 ± 6.61	42.16 ± 9.31	46.25 ± 6.84	45.21 ± 9.23	2.21 ± 0.94	3.05 ± 1.33

Note. BFR = blood flow restriction. Δ was calculated for each participant and hand as $\Delta_i = post_i - pre_i$; the SD of Δ corresponds to the standard deviation of these individual changes.

A linear mixed model (LMM) was fitted with fixed effects of group (BFR vs. non-BFR) and time (pre- vs. post-intervention), and a random intercept for participant (ID), estimated using REML with Satterthwaite correction for the degrees of freedom. A significant effect of time was observed *($F(1, 15.5) = 32.15$; $p < .001$)*, and a group effect

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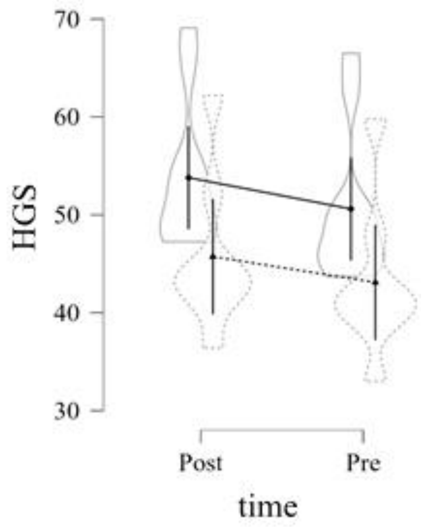
close to statistical significance *($F(1,16) = 4.43$; $p = .051$)*. No group × time interaction was detected *($F(1,5.2) = 0.30$; $p = .589$)*, indicating no additional gain attributable to BFR in the pre- to post-intervention change. In point estimation, the difference-in-differences (BFR − Non-BFR) was 0.56 kgf *($SE \approx 1.03$; $p \approx .586$)*.

Figure 1. Estimated marginal means (EMM ± 95% CI) of handgrip strength (kgf) by group and time point (both hands combined).



The estimated marginal means (EMMs) of handgrip strength (HGS, kgf) for both hands were as follows: BFR pre-intervention (solid line) = 50.61 [45.80–55.41] and post-intervention = 53.80 [48.92–58.67]; Non-BFR (dashed line) pre-intervention = 43.10 [37.65–48.56] and post-intervention = 45.73 [40.28–51.19] (Table 4). Figure 1 illustrates the overall increase from pre- to post-intervention in both groups and the parallel pattern of the slopes, which is consistent with the absence of a group × time interaction.

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Table 4. Estimated marginal means (EMM) of handgrip strength (kgf) by group × time with 95% confidence intervals (95% CI).

Group	Time	EMM	SE	95% CI Lower	95% CI Upper
BFR	post	53.80	2.49	48.92	58.67
Non-BFR	post	45.73	2.78	40.28	51.19
BFR	pre	50.61	2.49	45.80	55.45
Non-BFR	pre	43.10	2.78	37.65	48.56

Note. BFR = blood flow restriction.

Between-group difference at post-intervention was 8.07 kgf *(SE = 3.73; 95% CI 0.12 to 16.02; p = .042)*. At pre-intervention, the difference was 7.51 kgf *(SE = 3.78; 95% CI −0.55 to 15.57; p = .061)*. The difference-in-differences estimate was 0.56 kgf *(SE = 1.03; 95% CI −2.09 to 3.21; p = .586)*, consistent with the non-significant interaction.

LMM analysis was repeated including the factor hand (right/left) and all interactions, while maintaining a random intercept for participant, estimated using REML with Satterthwaite corrections. A significant main effect of time was observed *(post > pre; p < .001)*, and the group effect approached statistical significance *(p ≈ .05)*. The hand effect was small *(right = 1.9 kg higher than left; p ≈ .060)* and did not reach statistical significance. No significant interactions were detected for group × time, group × hand**,** time × hand, or the three-way interaction *(all p > .05)*. The EMMs by group × time × hand showed the same pattern observed in the main model: similar pre–post improvements in both groups and both hands, with no evidence of an additional effect attributable to BFR (see Figure 2).

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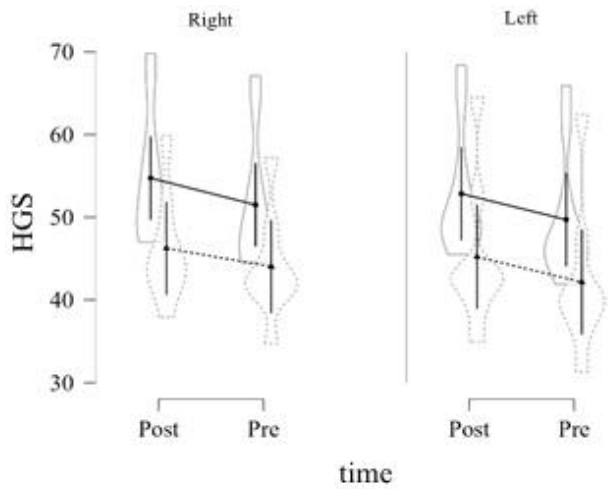
Figure 2. Estimated marginal means (EMM ± 95% CI) of handgrip strength (kgf) by group **(**BFR: solid line; Non-BFR: dashed line**),** time point **(**pre-, post-**),** and hand **(**panels**).**



Discussion

The aim of this study was to compare the effects of an isometric training program with and without blood flow restriction (BFR) on handgrip strength (HGS). The main findings showed that both groups improved after six weeks of intervention, but the BFR group did not result in additional gains compared with the non-BFR group. Although the BFR group showed higher absolute values at both pre- and post-intervention**,** this reflects baseline differences rather than a specific effect of BFR on the improvement. The hand effect was small and did not modify the conclusions. Overall, these results do not confirm the hypothesis of superiority of BFR for increasing HGS in this context**.**

Both groups increased HGS after six weeks, a pattern consistent with the early adaptations expected from a supervised isometric training program, including improved intra- and intermuscular coordination and increased neural efficiency. In protocols including BFR, the metabolic stress stimulus under local hypoxia may further enhance the response despite the use of low loads (Hughes et al., 2017). This combination of mechanisms (mechanical tension + metabolic stress) has been described as a plausible mechanism for strength and muscle mass gains with BFR, without requiring high loads (Pearson & Hussain, 2015). From the perspective of the scientific evidence, reviews and meta-analyses indicate that BFR training increases strength compared with its equivalent low-load training without BFR in clinical contexts, although in terms of maximal strength

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it generally remains below high-load training. Nevertheless, both approaches (with and without BFR) produce significant improvements with training frequencies and durations comparable to those used in our study, reinforcing that the time effect observed is consistent with the literature (Hughes et al., 2017; Pearson & Hussain, 2015).

Although the BFR group showed higher absolute means than the non-BFR group at both pre- and post-intervention, this pattern reflects a baseline imbalance favoring the BFR group rather than a specific effect of BFR. When modeling the group × time interaction with a random intercept for participants, the difference-in-differences estimate was small and non-significant, indicating that being higher at post-intervention does not imply an additional gain attributable to BFR. This interpretation is consistent with the available literature: BFR often outperforms low-load training without BFR in clinical contexts, but in terms of maximal strength it does not match high-load training, and its advantage depends on test specificity (dynamic vs. isometric) and load prescription, which may attenuate differences when analyzing pre–post changes in isometric tasks such as HGS (Lixandrão et al., 2018). Furthermore, the mechanisms attributed to BFR (e.g., metabolic stress under local hypoxia) do not guarantee a strength advantage compared with well-progressed isometric training in already active individuals, particularly when mechanical tension and training frequency are similar between groups (Pearson & Hussain, 2015). Finally, the dosage used (perceived BFR based on limb circumference with an elastic band**)** is methodologically plausible, but current guidelines recommend individualizing pressure using percentage of arterial occlusion pressure (%AOP) to reduce interindividual under- or overdosing; the absence of such individualization may dilute a potential differential effect of BFR (Patterson et al., 2019). In contrast to our findings, a systematic review in the lower limb reported that BFR combined with neuromuscular electrical stimulation may improve quadriceps strength and mitigate muscle mass loss during immobilization, although with greater fatigue and heterogeneous protocols (Carbajo-Mateos et al., 2025). Overall, the absolute between-group differences observed at post-intervention should be interpreted as level differences rather than additional effects, and the adjusted analysis supports the absence of superiority of BFR in improving HGS in this protocol.

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Several methodological factors may have attenuated a potential differential effect: (i) dose and duration (six weeks of isometric training), sufficient to induce neural improvements in both groups; (ii) an active population, with a smaller relative margin for improvement compared with clinical populations where BFR shows moderate effects versus low-load training; (iii) pressure prescription based on limb circumference using an elastic band, whereas methodological guidelines recommend individualization by %AOP (≈40–80%) and consideration of cuff width/material to standardize the hemodynamic stimulus; the lack of individualization may lead to under- or overdosing and dilute differences; and (iv) the isometric nature of both the training and measurement, where the main contribution of BFR—metabolic stress under hypoxia—does not always translate into advantages over mechanical tension when volume and effort are equated (Hughes et al., 2017; Patterson et al., 2019). Together, these factors may explain why BFR did not provide an additional improvement in this specific protocol, despite its demonstrated utility in other scenarios with more standardized prescriptions and populations with greater potential for adaptation.

In our analysis, the right hand was on average ≈1.9 kg stronger than the left, a small and non-significant effect, with no interactions with group or time; that is, the pre–post improvement was parallel in both hands. This pattern is expected when the training stimulus is symmetrical and isometric in nature, where early gains largely depend on neural adaptations and coordination rather than asymmetric structural changes, meaning that no additional advantage of one hand over the other would be expected under the same protocol and perceived effort (Hughes et al., 2017; Lixandrão et al., 2018).

These adaptive pathways (mechanical tension + metabolic stress in the case of BFR) are well described as primary and additive mechanisms, but they do not necessarily imply differential lateral effects when the stimulus is equalized between sides (Pearson & Hussain, 2015). Moreover, evidence on BFR indicates comparable improvements in isometric strength across different testing modes when properly applied, supporting the suitability of HGS as an outcome measure, and no consistent pattern of dominance-related asymmetry under BFR in balanced protocols has been established (Patterson et al., 2019). Finally, meta-analytic literature emphasizes that test specificity (dynamic vs. isometric) and stimulus prescription may modulate the magnitude of strength outcomes, but do not

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provide evidence of a systematic hand effect in this context. In our study, with volume and effort equated and no hand × group × time interactions, the most coherent interpretation is the absence of meaningful lateral modulation of the training response (Lixandrão et al., 2018).

This study presents several limitations. The sample size was small and included only physically active males, limiting generalizability. Participants and evaluators were not blinded, introducing potential performance and measurement bias. There was a baseline imbalance favoring the BFR group; although the linear mixed model (group × time) addresses this analytically, some uncertainty regarding small effects remains. The duration (six weeks) may have been insufficient to observe more pronounced divergences. BFR dosing was performed using an elastic band (circumference-based perceived BFR), a proxy that does not guarantee individualization based on %AOP, potentially leading to interindividual under- or overdosing. Other relevant outcomes (e.g., hypertrophy, functional performance, pain) were not assessed. Although participants were instructed to control external activity and avoid caffeine/alcohol prior to assessments, residual variability in these exposures cannot be ruled out.

Among the strengths of this study are the randomized parallel-group design, systematic supervision of training sessions, standardization of warm-up and exercises, prior familiarization with the dynamometer, and the recording of adherence and adverse events. Analytically, a linear mixed model with Satterthwaite correction was employed, reporting EMMs and 95% confidence intervals, which improves transparency and interpretability of the effects. Additionally, control of training volume and perceived effort between groups strengthens the specific comparison of the BFR component.

Future trials should include larger samples and more diverse populations (e.g., women, clinical patients), alternative durations and dosing strategies, and instrumental individualization of pressure (%AOP) with control of cuff width and material. It would also be relevant to compare dynamic versus isometric tasks and expand outcome measures (e.g., hypertrophy, function, pain). Exploring moderators (baseline level, dominance, tolerability) and responder profiles, as well as implementing assessor blinding and preregistration of analyses, would further strengthen future research.

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From a practical perspective, in contexts of low mechanical stress (pain, early return to activity, competitive congestion), an isometric program such as the one applied here can improve HGS within six weeks. Under the dosage used, adding BFR did not show an additional advantage compared with the same protocol without BFR. In practice, it is recommended to standardize effort using the Borg CR-10 scale, ensure proper technique and timing through supervision, and—if BFR is used—individualize pressure whenever possible, verify distal perfusion, and monitor tolerability. A deeper understanding of the mechanisms discussed may help develop optimal training programs that maximize morphological adaptations, with potential applications in clinical, rehabilitation, and sports settings.

Conclusions

A six-week isometric training program improves handgrip strength (HGS); however, no superiority of blood flow restriction (BFR) was observed compared with an equivalent protocol without BFR under the dosing used. The approach appears feasible and well tolerated, but studies with greater statistical power and pressure individualization based on percentage of arterial occlusion pressure (%AOP) are needed to determine whether small additional effects of BFR may exist in this context.

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