

Acute responses of isometric handgrip exercise combined with blood flow restriction in the elderly

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Abstract

This study aimed to investigate the influence of isometric handgrip exercise under different blood flow restriction times on acute responses related to safety and effectiveness in the elderly. Eleven physically active elderly people (70.1±7.1 years) were subjected to three protocols (P1-1m), (P2-30s) and (P3-Control) of isometric handgrip contraction. Hemodynamic markers (SBP, DBP and HR), hematological markers (D-dimer, fibrinogen, APTT and ultrasensitive CRP) and Surface Electromyography (sEMG) of the *flexor digitorum superficialis* and *extensor digitorum communis* muscles were analyzed. The hemodynamic variables showed no significant difference $p < 0.05$ between the moments before, immediately after, after 15 minutes, and after 30 minutes. The hematological variables showed no significant difference $p < 0.05$ between the pre- and post-30 minute time points. The sEMG variables showed a significant difference of $p < 0.01$ at the beginning, middle and end of each series and between the complete series for both muscles analyzed. In line with the aim of this study, we can accept the hypothesis that the P1-1m, P2-30s and P3-Control protocols are safe. However, we reject the hypothesis that the BFR protocols result in greater muscle activation compared to the protocol without BFR.

Key Words: handgrip; blood flow restriction; thromboembolism; electromyography; elderly.

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Resistance training is widely recognized for its beneficial effects on health, including its ability to reduce adverse complications for the elderly, since the decline of physiological systems increases the risk of various diseases such as hypertension, obesity, sarcopenia and osteoporosis.¹⁻³ The American College of Sports Medicine (ACSM) recommends prescribing exercises with intensities between 60% and 80% of one Repetition Maximum (1RM) to promote significant adaptations.³ However, this approach can represent a challenge for this population, due to joint limitations, physical frailty or comorbidities common in this age group.¹ In this context, Blood Flow Restriction (BFR) training associated with light loads (around 30% of 1RM) has emerged as a promising alternative.⁴ This method uses pneumatic cuffs to partially restrict blood flow during exercise, inducing a hypoxic environment that stimulates the recruitment of type II fibers,⁵ favoring hypertrophy and

muscle strength gain safely and with less joint overload.⁶ Frailty is a distinct, multidimensional, and potentially reversible clinical condition that reflects the decline of physiological and adaptive capacities in older adults, increasing the risk of adverse health outcomes. This condition requires early assessment and personalized interventions, with a strong emphasis on tailored physical exercise, nutritional support, and educational strategies. Dionyssiotis *et al.*⁷ highlight the importance of specific rehabilitative interventions for frail older adults, including individualized exercise programs, neuromuscular stimulation, and detailed functional assessments. For geriatric rehabilitation to be effective, it is essential that professionals are trained to identify and manage frailty through integrated approaches. In this context, Maccarone *et al.*⁸ emphasize the need to train professionals with geriatric competencies to develop appropriate care and rehabilitation strategies for this population.

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Despite the benefits, the safety of BFR training in the elderly requires attention.⁹ Studies have warned of potential risks associated with inappropriate use of the technique,^{9,10} especially in relation to time under restriction, as prolonged exposure can increase the risk of thrombosis and vascular dysfunction.⁹⁻¹¹ In addition, flow restriction can lead to elevations in blood pressure, which requires caution in elderly people with hypertension or a predisposition to cardiovascular disease.^{11,12} Thus, the adoption of well-defined and supervised protocols is essential to ensure the integrity and well-being of this population.

At the same time, Isometric Handgrip Exercise (IHE) has stood out as a reliable marker of general health and functionality in the elderly.^{13,14} Studies have shown that handgrip strength is positively correlated with autonomy, functional capacity and life expectancy.¹⁵ Current literature has suggested isometric handgrip exercise as a promising strategy in the management of hypertension, especially due to its short duration (approximately 11 minutes per session) and the possibility of performing it with portable devices.¹⁶ However, its application as therapy has limitations, since handgrip promotes muscle adaptations restricted to the small muscle mass recruited. Thus, its use is recommended as a complement to, rather than a substitute for, conventional forms of exercise.¹⁶ The combination of IHE with blood flow restriction represents an innovative approach, which at thesis potentiate the neuromuscular effects and promote beneficial hemodynamic responses with minimized risk in this population.^{17,18}

In view of the above, this study aims to investigate the acute responses of isometric handgrip exercise combined with blood flow restriction under different times in the elderly. Specifically, it seeks to understand the hemodynamic and neuromuscular changes resulting from this practice, providing evidence that can contribute to the development of safer and more effective training protocols for this population.

Materials and Methods

Study design

This was an experimental study lasting a total of four weeks. In the first week, screening procedures were carried out: anamnesis, application of the International Physical Activity Questionnaire (IPAQ) - short version and Venous Thromboembolism Risk Questionnaires (VTRQ), physical assessment, and calculation of the Ankle-Brachial Index (ABI). All participants were assessed by a cardiologist. This study was approved by the ethics committee of the Catholic University of Brasilia (CEP - 5.847.173). After signing the Informed Consent Form (ICF), the participants were randomized to three different protocols: i) P1-1min: exercise with blood flow restriction (BFR) for 1 minute; ii) P2-30s: exercise with BFR for 30 seconds; iii) P3-control: exercise without BFR for 1 minute.

Participants

The sample was selected at the *Centro de Convivências do Idoso (CCI)* at UCB, and included 11 elderly people,

70.1±7.1 years old, living in the federal district, physically active, with low thromboembolic risk and cleared for exercise by their cardiologist (Table 1). The exclusion criteria were: uncontrolled hypertension, rheumatological diseases, history of VTRQ, severe varicose veins, diabetes mellitus, use of anticoagulants.

Instruments and assessments

Questionnaires

The volunteers completed an anamnesis and the questionnaires, initially using the IPAQ short version and then the VTRQ questionnaire. The researcher remained available to answer any questions during the process.

With regard to the VTRQ questionnaire, the risk was calculated based on the answers, assigning 1 to 5 points to each item. The total score obtained made it possible to classify the incidence of deep vein thrombosis and the respective level of risk.

Ankle-brachial index

The test was carried out in a controlled environment, with a temperature of 22°C and relative humidity of 70%, according to Kawamura¹⁹ The volunteers rested for five minutes in the supine position before the measurements were taken. Blood Pressure (BP) was measured on the arms and legs using automatic cuffs (BP3AC1, Microlife, Shenzhen, China), positioned approximately 2 cm above the cubital fossa and 2 cm above the malleoli, respectively. The measurements were taken simultaneously, starting with the right side and then the left.

ABI was calculated as the ratio between Ankle Systolic Blood Pressure (SBP) and Arm SBP ($ABI = \text{Ankle SBP} / \text{Arm SBP}$). Based on the result, the volunteers were classified as: Normal ABI (0.91 to 1.30) or altered ABI (<0.90 or >1.30).

Intervention

Isometric handgrip exercise

Over the next three weeks, the participants underwent (handgrip) sessions. Initially, a protocol based on 4 sets with 2 minutes of isometric contraction and 1 minute of rest was

Table 1. Characterization of the sample.

Variable	Mean±SD
Age (years)	70.1±7.1
Body mass (kg)	70.3±14.4
Heights (cm)	156.8±5.9
MIVC (kg)	9.5±4.4

MIVC, maximum voluntary isometric contraction; Kg, kilograms; cm, centimeters.

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tested, according to Goessler *et al.*¹³ However, due to the volunteers' difficulty in maintaining the contraction for 2 minutes, the protocol was adapted, based on the work of Sousa *et al.*²⁰ The alternative protocols consisted of 8 sets, with a 1-minute interval between them. The P1-1min and control protocols performed 8 sets with 1 minute of contraction and 1 minute of rest, while the P2-30s protocol performed 8 sets with 30 seconds of contraction and 1 minute of rest. The workload was set at 30% of the Maximum Voluntary Isometric Contraction (MVIC). The P1-1 min protocol totaled 16 minutes under restriction and the P2-30 protocol totaled 11 minutes under restriction.

Arterial occlusion pressure

The arterial occlusion pressure was determined to individualize the intensity of the BFR during exercise. The value was calculated as 130% of the pre-exercise SBP for each session, according to the methodology validated by Lorenz *et al.*²¹ This approach allowed standardizing BFR pressure independently in relation to limb or cuff size, ensuring greater precision and safety in applying the protocol.

Physiological and laboratory assessments

Blood collection

The blood collection procedure was carried out by the Sabin Laboratory team in a controlled environment, following strict biosafety protocols. Samples were taken at two points: pre-exercise (before the session) and post-exercise (30 minutes after the session).

The volunteer was placed in a comfortable chair and given instructions on the procedure. The puncture site was then antiseptically cleaned with 70% alcohol and the sample was collected using a vacuum tube system. Two 4 mL tubes with EDTA were collected for analysis of the following hemostasis markers: D-Dimer; APTT (Activated Partial Thromboplastin Time); ultrasensitive CRP and Fibrinogen.

Blood pressure and heart rate

BP and Heart Rate (HR) were measured using the oscillometric method, using an automatic device (Arteris, Cardiosistemas Coml. Indl. Ltda, Brazil, São Paulo), duly adjusted to the circumference of the volunteer's arm. The cuff was positioned approximately 2 cm above the cubital fossa and the following hemodynamic parameters were recorded: SBP, DBP and HR. Measurements were taken at four different times: pre-exercise, immediately after exercise, 15 minutes post-exercise and 30 minutes post-exercise, following the guidelines of the American Heart Association (AHA).²² This procedure allowed for a systematic and standardized analysis of hemodynamic responses at different post-exercise recovery intervals.

Maximal voluntary isometric contraction

After pre-exercise blood pressure measurement, the volunteer was positioned on a chair, keeping their feet flat on the floor, their arm close to their torso and their elbow flexed at 45°, in accordance with the guidelines of the American Society of Hand Therapists (ASHT). The assessment was carried out on the dominant arm using a digital

dynamometer (Hand Dynamometer SS25L, Biopac Systems, Santa Barbara, California) in isometric mode.

The volunteers were instructed to perform a maximum sustained contraction for 5 seconds after the verbal command «Attention, now!». Three attempts were made, with an interval of 120 seconds between each. The greatest force recorded between the three attempts was taken into account. Before each test, the dynamometer was calibrated to ensure accurate measurements.

Surface electromyography

Surface Electromyography (sEMG) was assessed using a Biopac electromyograph (MP30B-CE, Biopac Systems, Santa Barbara, CA). Two surface electrodes with silver sensors were positioned at a distance of 20 mm over the *Flexor Digitorum Superficialis* (FDS) and *Extensor Digitorum Communis* (EDC) muscles, following the longitudinal direction of the muscle fibers.¹⁶ Data analysis was based on the average Root Mean Square (RMS) of the acquired signals.

The RMS peak obtained during MVIC was used to normalize the sEMG signal. For signal acquisition, the raw sEMG signals were recorded by the Biopac system with a sampling rate of 2000 Hz and 1000x gain, using two digital filters: high-pass (30 Hz) and low-pass (500 Hz). During the exercise, to help the volunteers, a screen was positioned with a visual indicator representing the levels of force, it was possible to position the cursor on a point representing 30% of the MVIC, and they were verbally instructed to maintain the contraction throughout the series.

A specific routine was developed to extract the data. The data was processed using Biopac Student Lab Pro software (v. 3.7.7). For each series, the average RMS values of a one-second window were extracted at four moments: beginning, middle, end and complete. The software provided the values in Volts, which were then converted to millivolts and tabulated for statistical analysis.

The positioning of the electrodes followed the guidelines of Perotto.²³ For the EDC muscle, the volunteer was positioned with the hand in pronation, allowing the evaluator to palpate the posterior region of the forearm between the middle and upper third with the thumb positioned over the ulna and the middle finger over the radius, the midpoint between these structures was marked with the index finger. In the case of the FDS muscle, positioning required the volunteer to keep the hand supine. The evaluator, holding the participant's wrist, aligned the index finger with the biceps brachii tendon, marking the location of the electrodes ulnar to this point. The reference electrode was attached to the olecranon of the contralateral arm, completing the measurement circuit.

Statistical analysis

The normality of distribution was checked using the Shapiro-Wilk test, while the homogeneity of variances was assessed using the Levene test. Continuous data was expressed as mean + Standard Deviation (SD).

The hemodynamic and hematological variables were subjected to two-way ANOVA for repeated measures in order

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to assess possible interactions between the experimental groups and the different assessment times. A significance level of $p \leq 0.05$ was adopted and, in cases where the sphericity of the data was violated (tested by the Mauchly test), the Greenhouse-Geisser correction was applied. When statistically significant differences were detected, Sidak's post-hoc test was used to identify the specific contrasts. The ANOVA results are presented with the respective F values, degrees of freedom (gl) and p-value.

As for the Electromyography (sEMG) variables of the FDS and EDC muscles, the data did not meet the assumptions of normality and homogeneity, as indicated by the Shapiro-Wilk and Levene tests. The Friedman non-parametric test was then used, the results of which were described by the X^2 value, degrees of freedom (gl) and p-value. When significant differences were found, the post-hoc pairwise comparison was applied to identify the variations between the groups and times assessed.

The Fatigue Index (FI) was calculated as the ratio between the final RMS value and the initial RMS ($FI = \text{RMS_FINAL} / \text{RMS_INICIAL}$), and the difference between the groups was analyzed using the Friedman test. All the statistical analyses were carried out using IBM SPSS software (version 21.0), while the graphs were drawn up using Microsoft Excel (version 2016).

Results

The two-way ANOVA for repeated measures showed no significant effects of the different protocols (P1-1min;

P2-30s; P3-control) on the hemodynamic variables [$f(2,340, 35.094)=0.689$; $p > 0.05$], nor of the different times assessed (pre, immediately post, 15 and 30 minutes after exercise) [$f(1,087, 32.608)=0.957$; $p > 0.05$] (Table 2, Figure 1).

Similarly, the results of the repeated measures ANOVA for the hematological variables showed no significant effects between the protocols [$f(6, 31.094)=0.915$; $p > 0.05$] and between the times (pre and post) [$f(3,36.158)=6.346$; $p > 0.05$] (Table 3, Figure 2).

With regard to electromyographic activity, for the FDS muscle, the Friedman test showed significant differences in the mean RMS values between the start, middle and end times [$x^2(71)=257.897$; $p < 0.001$]. However, multiple comparisons did not reveal statistically significant differences between these moments within the same protocol ($p > 0.05$). In addition, there were significant differences between the complete series [$x^2(23)=59.067$; $p < 0.01$], without, however, showing relevant differences in the multiple comparisons ($p > 0.05$).

Similar results were observed for the EDC muscle, with significant differences in the mean RMS values between times [$x^2(71)=212.733$; $p < 0.01$] and between sets [$x^2(23)=60.109$; $p < 0.01$], but without significance in multiple comparisons ($p > 0.05$).

The fatigue index, calculated by the ratio between the mean RMS values at the start and end of each set, showed no significant differences between the groups [$x^2(2)=1.256$; $p > 0.05$], with values close to 1, suggesting low muscle fatigue.

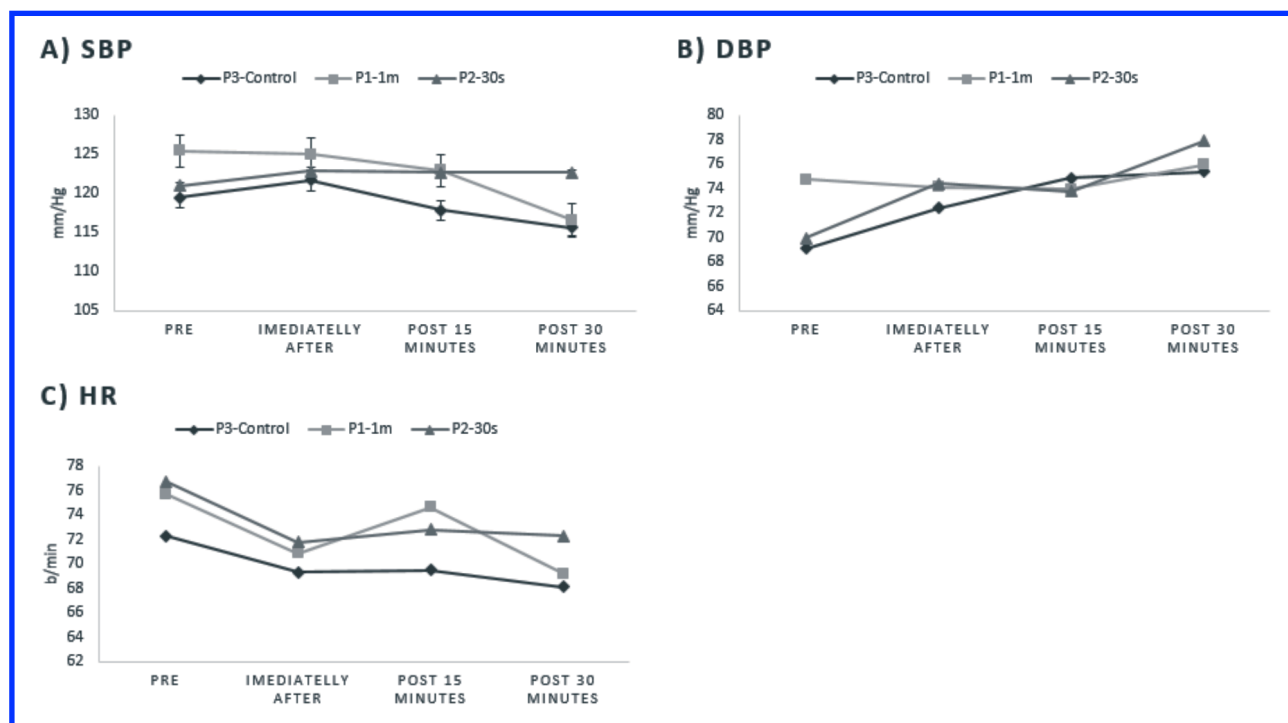


Figure 1. Behavior of hemodynamic variables. SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; mmHg, millimeter of mercury; BPM, beats per minute.

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Discussion

The absence of significant differences in hemodynamic variables (SBP, DBP and HR) between the protocols with and without BFR suggests that its application, even for short periods, does not impose additional acute cardiovascular overload on the elderly. These findings corroborate previous studies that reinforce the safety of the method when applied with moderate intensity and adequate monitoring, as indicated by Patterson *et al.*⁹

The isometric nature of the exercise may explain the hemodynamic stability observed, since this type of activity tends to cause less pronounced cardiovascular responses, an important aspect for the safety of SRF in the elderly.²⁴ In addition, physiological changes related to ageing, such as reduced baroreflex sensitivity and lower sympathetic responsiveness, may have attenuated these responses. With regard to hematological variables, the data obtained indicates no significant changes in coagulation and

Table 2. Descriptive statistics for hemodynamic variables.

Variable	Group	Mean	Standard deviation
SBP pre (mmHg)	Control	119.45	14.48
	1 min	125.45	22.57
	30 seg	121.00	11.51
SBP Immediate post (mmHg)	Control	121.64	9.76
	1 min	125.00	12.28
	30 seg	122.82	15.46
SBP after 15 (mmHg)	Control	117.82	10.27
	1 min	122.91	9.26
	30 seg	122.64	12.52
SBP after 30 (mmHg)	Control	115.64	8.76
	1 min	116.59	7.49
	30 seg	122.64	15.79
DBP pre (mmHg)	Control	69.09	11.18
	1 min	74.73	16.29
	30 seg	69.91	11.46
DBP immediate post (mmHg)	Control	72.36	10.88
	1 min	74.09	10.05
	30 seg	74.36	13.81
DBP after 15 (mmHg)	Control	74.82	10.07
	1 min	73.95	9.83
	30 seg	73.77	8.98
DBP after 30 (mmHg)	Control	75.36	11.39
	1 min	75.95	8.00
	30 seg	77.86	12.39
HR pre (bpm)	Control	72.27	11.15
	1 min	75.73	12.78
	30 seg	76.73	12.39
HR immediate post (bpm)	Control	69.27	10.00
	1 min	70.82	13.08
	30 seg	71.77	16.47
HR after 15 (bpm)	Control	69.45	10.90
	1 min	74.64	15.02
	30 seg	72.77	17.84
HR after 30 (bpm)	Control	68.09	10.52
	1 min	114.18	144.94
	30 seg	72.27	14.75

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; mmHg, millimeter of mercury; BPM, beats per minute.

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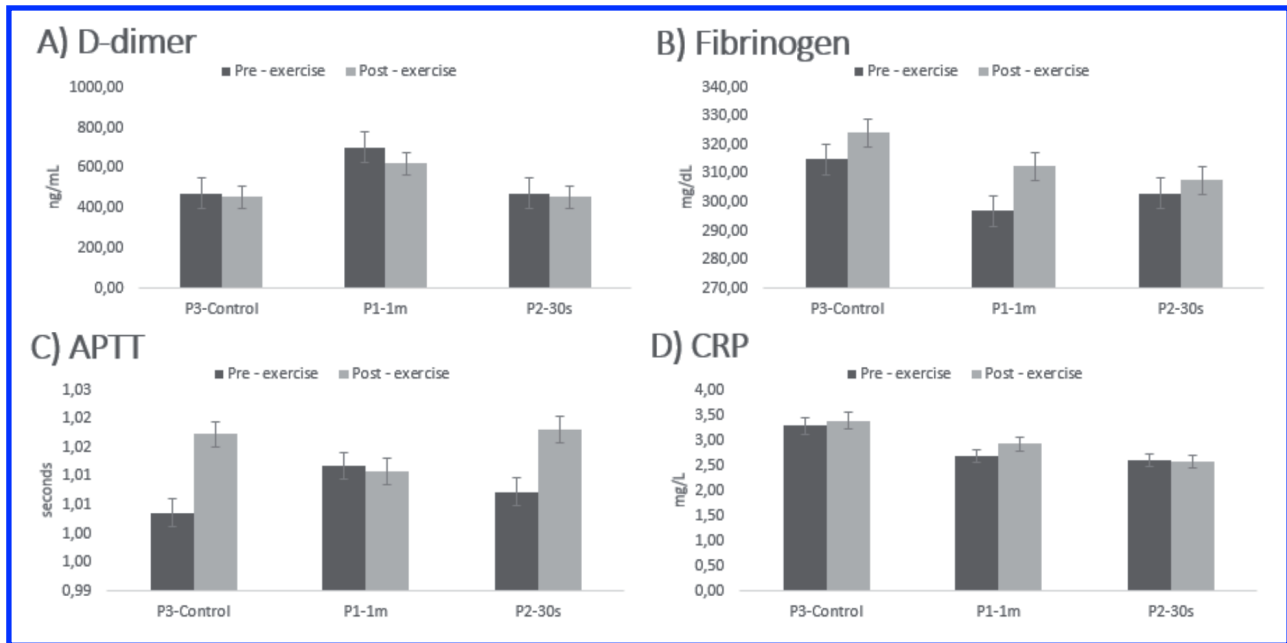


Figure 2. Behavior of hematological variables. APTT, active partial thromboplastin time; CRP, C-reactive protein; ng/mL, nanogram per milliliter; mg/dL, milligram per deciliter; mg/L, milligram per liter.

Table 3. Descriptive statistics for hematological variables.

Variable	Group	Mean	Standard deviation
D-dimer pre (ng/mL)	Control	471.55	227.93
	1 min	700.36	702.54
	30 seg	472.00	232.13
D-dimer post (ng/mL)	Control	452.91	216.79
	1 min	621.18	558.37
	30 seg	452.55	200.66
Fibrinogen pre (mg/dL)	Control	314.91	73.51
	1 min	296.91	39.99
	30 seg	303.00	59.45
Fibrinogen post (mg/dL)	Control	324.18	70.32
	1 min	312.55	54.38
	30 seg	307.73	66.85
APTT pre (seconds)	Control	1.00	0.09
	1 min	9.74	28.94
	30 seg	1.01	0.09
APTT post (seconds)	Control	1.02	0.10
	1 min	1.01	0.12
	30 seg	1.02	0.10
CRP pre (mg/L)	Control	10.12	24.57
	1 min	2.68	2.56
	30 seg	2.60	2.96
CRP post (mg/L)	Control	10.68	26.23
	1 min	2.92	2.87
	30 seg	2.57	2.87

APTT, active partial thromboplastin time; CRP, C-reactive protein; ng/mL, nanogram per milliliter; mg/dL, milligram per deciliter; mg/L, milligram per liter.

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inflammation markers. Combined with previous studies, these findings guarantee the safety of the method even in an elderly population, known for its greater susceptibility to thromboembolic events and exacerbated inflammatory processes.²⁵ The slight reduction in d-dimer levels and the stability of fibrinogen and APTT values suggest that the protocols used did not trigger pro-coagulant responses. Similarly, the absence of significant variations in ultrasensitive CRP shows that the protocols did not provoke an acute systemic inflammatory response, reinforcing the safety of BFR even in more vulnerable populations.^{9,25,26} Electromyographic analysis revealed significant variations in the RMS values of the FDS and EDC muscles over time and between the series, but no statistical differences in the multiple comparisons. This indicates that, despite the temporal changes in muscle electrical activity, the protocol used was not sufficient to induce significant muscle fatigue. Previous studies have reported intermittent variations in muscle activity during repetitive protocols, but without clear patterns of fatigue.²⁷ Furthermore, the absence of significant differences highlights the importance of considering individual variability and the physiological characteristics of muscles when interpreting the results of electromyography studies. As suggested by Koo and Li.²⁸ Such resistance to fatigue can be attributed to the characteristics of the muscles analyzed, which are involved in endurance tasks and may be more tolerant of prolonged effort.²⁹

In addition, the fatigue index remained stable between the protocols, reinforcing the hypothesis that the intensity of the exercise was not enough to cause significant changes. The lack of significance in the multiple comparisons may also be related to individual variability and the physiological characteristics of the muscles, aspects that should be considered when interpreting electromyographic data.³⁰

Conclusions

In line with the aim of this study to investigate the influence of isometric handgrip exercise under different blood flow restriction times on acute responses related to safety and effectiveness in the elderly, we can accept the hypothesis that the P1-1m and P2-30s protocols are safe for the elderly.

However, we reject the hypothesis that BFR protocols result in greater muscle activation compared to the protocol without BFR. We also rejected the hypothesis that the P1-1m protocol would potentiate the hypotensive effect compared to the P3-Control protocol. Finally, we accepted the hypothesis that the P2-30s protocol results in similar responses to the P3-Control protocol under a shorter exercise time.

Despite the promising results, the lack of significant differences may be associated with the small sample size, reducing statistical power and making it difficult to identify subtle effects on hemodynamic, hematological and electromyographic markers. Another limitation found was the homogeneity of the sample.

Future studies should consider larger, homogeneous samples to evaluate the chronic effects of EIPP with BFR on inflammatory and coagulation markers, since prolonged adaptations may differ from the acute responses observed

in this study. In addition, it would be relevant to expand the analysis to include other markers related to the hemostatic system, such as thrombomodulin levels, which may offer a more comprehensive view of the impacts of BFR training in elderly populations. Finally, it is important to evaluate the combined impact of different pressures and restriction times to determine best practices in the use of this method. These results reinforce the potential of acute isometric exercise with BFR as a safe intervention in specific populations, providing a solid basis for clinical and scientific application, with no evidence of immediate risk to coagulation or inflammation.

List of abbreviations

ACSM, American College of Sports Medicine
IHE, Isometric Handgrip Exercise
BFR, Blood Flow Restriction
IPAQ, International Physical Activity Questionnaire
VTRQ, Venous Thromboembolism Risk Questionnaires
ASHT, American Society of Hand Therapists
APPT, Activated Partial Thromboplastin Time
CRP, C-Reactive Protein
FDS, *Flexor Digitorum Superficialis*
EDC, *Extensor Digitorum Communis*
sEMG, surface electromyography
ABI, Ankle-brachial index
SBP, Systolic blood pressure
DBP, Diastolic blood pressure
HR, Heart Rate

Contributions

Thailson Fernandes da Silva conceived the idea presented and prepared the manuscript, and wrote the article; Leandro Lima de Sousa, Carlos Ernesto Santos Ferreira conceived the idea presented and prepared the manuscript, and critically reviewed it for intellectual content; Johnatan Campos Sousa Leite, Lucas de Souza Martins, Robson Conceição Silva contributed substantially to the conception of the article; all authors read and approved the final edited manuscript.

Conflict of interest

The authors declare no conflicts of interests.

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Ethics approval and consent to participate

This study was approved by the ethics committee of the Catholic University of Brasília (CEP - 5.847.173). All pa-

tients participating in this study signed a written informed consent form for participating in this study.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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