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Research Article

The Effects of Blood Flow Restriction in Ergonomic Cycle Training of the Upper Limbs on Female-A Randomized Pilot Study

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Abstract

Background: Abdominal and lumbo-pelvic stability alterations may origin lower limb injuries, like for example adductor pathology in soccer players.

Objective: To compare ergonomic cycle training of the upper limbs, with and without blood flow restriction in healthy female.

Study Design: Randomized pilot study.

Methods: Twenty females were randomly assigned to the experimental (ergonomic hand-cycle training applying blood flow restriction) or control group (same training without blood flow restriction). The intervention lasted 4 weeks. The outcome measure was average power, isometric strength of biceps and triceps, power peak, relative peak power, relative average power, fatigue index and perception of effort.

Results: Experimental group showed significant improvement between weeks 0 - 4 on average power, peak power and relative average power ($p < .01$). We found significant changes ($p < .01$) in the repeated measures factor in average power, relative average power, peak power and relative peak power. There was a significant improvement following treatment compared to baseline in peak power ($p = .01$), relative peak power ($p = .03$) and relative average power ($p < .001$).

Conclusion: Blood flow restriction with ergonomic cycle training of the upper limbs can improve average power, relative average power, peak power and relative peak power.

Keywords: *Blood Flow Restriction; Female; Anaerobic Capacity; Subjective Perception of Effort; Isometric Strength*

Introduction

Blood flow restriction (BFR) is a technique used in the upper and lower limbs using a blood pressure cuff. Blood accumulation within the muscles is thus achieved, enabling a greater gain of muscle strength for performing physical exercise [1]. The safety of this technique has been described in both healthy athletes and in individuals with orthopedic and cardiovascular pathologies, such as osteoarthritis and in hypertensive patients, respectively [2]. Moreover, BFR, when used alone or in combination with low-intensity physical exercises, is effective in preventing weakness from disuse and favoring gain in strength [3].

Improvement or maintenance of strength is due to the relationship between metabolic stress and mechanical stress [4]. Metabolic stress caused by the implementation of BFR can promote adaptive muscle protein synthesis, improving cell activation and proliferation, increasing the strength and maintenance of muscle hypertrophy [3].

Low-intensity exercise, associated with BFR, has shown to be effective for the improvement of muscle strength in biceps and triceps, producing muscle adaptation similar to that produced by high-intensity exercise without occlusion [4,5]. The effects of occlusion have also been observed, when carried out prior to aerobic and anaerobic exercises on a cycle ergometer, on the performance of different sports, where it is shown to be effective in improving performance in timing tests [6,7].

An upper limb cycle ergometer is widely used in sports to evaluate the anaerobic capacity [8,9]. On the other hand, upper limb exercises using ergonomic cycles can importantly maintain the anaerobic metabolism in those subjects who, due to a physical limitation or during a rehabilitation process, require a greater development of the upper limb muscles [10,11].

Cycle ergometers have been used in the assessment of variables such as the anaerobic capacity, peak power, average power, the adapted *WinGate test* being one of the most commonly used measuring instruments [12-14].

Upper limbs exhibit a prevalence of muscles with type IIA fibers, which favors a predominance of the lactic anaerobic energy system in evaluation tests such as the adapted *WinGate test* in comparison such testing in the lower limbs [12,14,15].

The hypothesis posed by the present study was that training for the upper limbs using a cycle ergometer combined with vascular occlusion would improve the performance of physically active female to a greater extent than cycle ergometer training alone, after only 4 weeks of treatment. In addition, the peak power, average power, fatigue index, subjective effort perception and isometric strength of the biceps and triceps muscles were also evaluated. For this purpose, a randomized, single-blind, pilot study was performed in healthy female, making a comparison between cycle ergometer training for the upper limbs with and without vascular occlusion.

Methods

Participants

Participants (N = 20) were recruited from the European University of Madrid, located on the University Campus of Villaviciosa de Odón. After contacting said center's Management by e-mail, the gym users were informed of the characteristics and objectives of the present study between January and April 2019.

The inclusion criteria to participate in the study were: female aged between 18 and 40 years; being physically active; and not having any orthopedic injuries that would prevent implementation of the exercise protocol. The study excluded those female who: had a diagnosis of chronic musculoskeletal, neurological or cardio-respiratory diseases; had a diagnosis of arterial hypertension, deep vein thrombosis, or diabetes; were pregnant; and failed to sign the informed consent document.

Ultimately, 9 participants completed the study in the experimental group and 8 in the control group. Participant demographics are presented in table 1. This randomized controlled pilot study was approved by the Research Committee of the European University of Madrid (reference number: CIPI/18/029) and registered with the ClinicalTrials.gov database (reference number: NCT03618004).

This randomized pilot study has been designed and reported in accordance with the CONSORT guidelines for reporting randomized controlled trials [16].

Variables	All sample		Experimental group		Control group		P-value
Age (years)	27 (7.20)		25.1 (6.35)		28.9 (7.82)		.16 †
Height (cm.)	166.25 (7.57)		169.20 (7.55)		163.30 (6.68)		.08 †
Weight (kg)*	62.05 (9.47)		65.80 (10.61)		58.30 (6.75)		.03 †
Body mass index (kg/m^2)	22.47 (3.42)		23.11 (4.33)		21.84 (2.24)		.12 †
Number of weekly trainings	3 (1.33)		3.4 (1.57)		2.6 (0.96)		.09 †
Training duration (minutes)	57.25 (20.42)		63.5 (23.45)		51 (15.59)		.06 †
Time practicing gym (weeks)*	43.35 (49.64)		33.5 (40.95)		53.2 (57.53)		.03 †
	n	**%**	**n**	**%**	**n**	**%**	
Previous injuries in upper limbs (Yes/No)	6/14	30/70	3/7	30/70	3/7	30/70	1.00 ‡
Practice other sports (Yes/No)	10/10	50/50	5/5	50/50	5/5	50/50	1.00 ‡
Dominance (Right-handed/Left-handed)	19/1	95/5	9/1	90/10	10/0	100/0	.92 ‡

Table 1: *Descriptive analysis (means and standard deviations) of the total sample and depending on the group.*

n: Number of subjects; %: Percentage.

†: Shapiro-Wilks test.

‡: Fisher exact test.

**: Significant difference ($P < 0.05$).*

Randomization

The participants were randomized into either an experimental or control group (n = 10 per group). The randomization sequence was generated by the opaque envelope method and stored by an independent blind physiotherapist, who delivered them sequentially to the study physiotherapist, unrelated to the objectives and purposes of the study, via randomization.

Interventions

Each session of the intervention lasted 17 minutes, with 2 sessions per week, over a 4-week period. Training began by warming up on the hand bike without a training load for 5 minutes. Subsequently, 3 series of 30 seconds at full power were carried out, with 5-minute rests between them. The intensity was calculated at 0.048 kp.kg [17].

Blood flow restriction was applied to the experimental group subjects, using a 10 cm wide pressure cuff on the most proximal region of the arm. The pressure was calculated based on the subject's initial systolic pressure [18]. We chose a limit of 80% completion of sessions to define full adherence to the protocol. On the other hand, the control group did not use a pressure cuff.

Outcome measures

All outcome measures were collected by a physiotherapist who was blinded to patient allocation. It was not possible to blind the patients or physiotherapists applying the interventions.

Three assessments were carried out in this study: at the start of intervention, following the exercise program, and at the end of the 4-week follow-up period. The main outcome was average power, isometric strength, peak power, relative peak power, the relative average power and fatigue index and subjective effort.

The main outcome was average power measured using the WinGate test [18]. The equipment used was a cycle ergometer for the upper limbs (Excite® top seat, technology, Brazil). Each subject was seated, so that the center of the glenohumeral joint was aligned with the axis of the apparatus grips, with 90-degree knee flexion, the knees being aligned with shoulders and feet. The horizontal distance was adjusted so that the elbows were not at maximum extension and ensuring that participants were comfortable.

Assessment of the isometric strength of the biceps and triceps brachii was performed using a manual strength dynamometer Lafayette Manual Muscle Testing System (model 01165, USA). Strength measurement was carried out based on the protocol described by Bernardi., *et al* [12]. The subject was standing with the trunk erect, shoulders in a neutral position with arms and trunk aligned and elbows at 90 degrees flexion. The rater asked the subject to perform a maximum voluntary isometric muscle contraction in elbow flexion and extension, holding it for 5 seconds. This was repeated 3 times, with 5-minute rests between each series, the reference value being the average value obtained from the 3 repetitions.

Assessment of the peak power, relative peak power, the relative average power and fatigue index was performed in accordance with the *WinGate test* [18]. The equipment used was a cycle ergometer for upper limbs (*Excite® top seat*, technology, Brazil). Each subject was seated, so that the center of the glenohumeral joint was aligned with the axis of the apparatus grips, with 90-degree knee flexion, the knees being aligned with shoulders and feet. The horizontal distance was adjusted so that the elbows were not at maximum extension and ensuring that participants were comfortable.

Assessment of the subjective effort perception was performed using the *Borg scale CR-10* [19]. One minute after the end of the evaluation the effort perceived by the subjects was quantified from 0 to 10, 0 being the minimum and 10 being the maximum effort perceived.

Sample- size determination

A representative sample of the study sample was calculated. The magnitude of this difference was considered by calculating the effect size (d = 0.90) [17] for measuring the peak power in female. The sample size was estimated using an effect size between the experimental and control group, a power of 0.8 and level of significance $\alpha = 0.05$. The sample size needed was estimated to be 20 (10 in each group). The calculation was made using the G*Power software, version 3.1.9.4.

Statistical analysis

Statistical analysis was performed using IBM SPSS, version 21.0, for Windows. The established value of level of significance in all comparisons was $p < .05$. Homogeneity in sample distribution between the two groups was calculated using the Shapiro-Wilk test. The changes between the various evaluations were observed using the Student's t parametric test for paired samples. ANOVA of repeated measures provided the intra-subject effect and group interaction. The error rate of the significance level was controlled by the Bonferroni correction. When the Mauchly sphericity test was significant, the Greenhouse-Geisser correction coefficient was used. The partial eta-squared value was calculated as an indicator of effect size (classified as small 0.01, medium 0.06, and large 0.14) [20].

An intent-to-treat analysis has been performed in this study. The differences between groups were considered statistically significant for p < .05.

Results

Table 2 shows the descriptive statistics (mean and standard deviation) and the results of the analysis between the different evaluations for the two study groups.

Variables	Experimental group			Control group		
	T0	T1	T2	T0	T1	T2
Isometric strength of the right biceps	41.35 (4.95)	40.49 (4.21)	41.77 (4.38)	36.30 (6.00)	37.54 (5.35)	35.41 (6.08)
Isometric strength of the right triceps brachii	29.98 (6.09)	30.18 (6.06)	31.0 (6.27)	28.38 (5.51)	28.27 (5.61)	28.11 (6.47)
Isometric strength of the left biceps	40.78 (5.57)	39.71 (4.82)	42.07 (5.50)	35.75 (7.44)	36.44 (7.68)	33.81 (7.11)
Isometric strength of the left triceps brachii	30.72 (6.01)	28.21 (4.88)	29.99 (4.04)	27.84 (6.72)	27.8 (5.39)	28.21 (8.41)
Peak power	194.8 (43.18)	225.6 (75.91)	220.2 (63.31)	169.3 (45.84)	198.1 (71.31)	182.0 (67.00)
Relative peak power	3.03 (0.65)	3.44 (0.98)	3.34 (0.79)	2.89 (0.63)	3.34 (1.16)	3.12 (1.17)
Average power	160.9 (43.52)	195.0 (67.69)	190.7 (65.31)	134.3 (45.04)	170.9 (63.83)	150.8 (64.15)
Relative mean power	2.55 (0.65)	3.22 (0.85)	2.95 (0.85)	2.34 (0.64)	2.87 (1.01)	2.57 (1.09)
Fatigue index	33.0 (14.57)	29.3 (8.81)	26.8 (13.73)	36.3 (13.15)	29.8 (1.61)	32.2 (13.01)
Subjective effort perception	4.2 (1.31)	4.5 (1.71)	4.3 (0.94)	4.0 (1.24)	4.8 (1.61)	4.67 (1.06)

Table 2: *Statistical analysis means (and standard deviation) of the study variables in the baseline, post-treatment and follow-up assessments with the t-student test and effect size results.*

Outcome measures at the baseline (T0), after the three-week period of manual therapy and control interventions (T1) and after further 4-weeks as follow-up (T2).

The experimental group showed changes in average power from baseline to week 4: mean decrease of 34.10, with a 95% confidence interval for the change of -55.95 to -12.20, p-value < 0.01. Improvements were maintained after the follow-up period: mean decrease of 29.80, with a 95% confidence interval for the change of -53.70 to -5.89, p-value 0.02). There was also an improvement in peak power (mean decrease of 30.80, with a 95% confidence interval for the change of -60.20 to -1.39, p-value 0.04) and relative average power (mean decrease of 0.67, with a 95% confidence interval for the change of -0.98 to -0.35, p-value < 0.01). Similarly, at follow-up compared to baseline values (T0-T2), a significant improvement (p = 0.02) was noted in peak power (mean decrease of 25.40, with a 95% confidence interval for the change of -49.38 to -1.41, p-value 0.04) and relative average power (mean decrease of 0.40, with a 95% confidence interval for the change of -0.75 to -0.05, p-value 0.02).

The control group showed changes in average power from baseline to week 4: mean decrease of 36.60, with a 95% confidence interval for the change of -58.54 to -14.65, p-value < 0.01, now however between baseline and follow-up assessments. Although there was a significant improvement in the control group in relative average power (mean decrease of 0.53, with a 95% confidence interval for the change of -0.88 to -0.17, p-value < 0.01) after the intervention period, no significant improvements were found after follow-up compared to baseline. Table 3 shows the main statistical values (mean difference and significance) of the analysis of the three evaluations conducted in the study.

Variables	Experimental group		Control group	
	T0 - T1 MD (SD)	T0 - T2 MD (SD)	T0 - T1 MD (SD)	T0 - T2 MD (SD)
Isometric strength of the right biceps	0.86 (-0.17)	-0.42 (0.08)	-1.24 (0.20)	0.89 (-0.14)
Isometric strength of the right triceps brachii	-0.20 (0.03)	-1.02 (0.16)	0.11 (-0.01)	0.27 (-0.04)
Isometric strength of the left biceps	1.07 (-0.19)	-1.29 (0.23)	-0.69 (0.09)	1.94 (-0.26) *
Isometric strength of the left triceps brachii	2.51 (-0.41) *	0.73 (-0.12)	0.04 (0.00)	-0.37 (0.05)
Peak power	-30.8 (0.71) *	-25.4 (0.58) *	-28.8 (0.62)	-12.7 (0.27)
Relative peak power	-0.40 (0.63)	-0.30 (0.47)	-0.45 (0.71)	-0.22 (0.36)
Average power	-34.1 (0.78) *	-29.8 (0.68) *	-36.6 (0.81) *	-16.5 (0.36)
Relative mean power	-0.67 (1.03) **	-0.40 (0.61) *	-0.53 (0.82) *	-0.23 (0.35)
Fatigue index	3.70 (-0.25)	6.20 (-0.42)	6.50 (-0.49)	4.10 (-0.31)
Subjective effort perception	-0.3 (0.22)	-0.1 (0.07)	-0.80 (0.64)	-0.67 (0.54)

Table 3: *Statistical analysis of the means difference and changes between baseline, post-treatment and follow-up assessments.*

T0-T1: Outcome measures between baseline to posttreatment assessments: T0-T2: Outcome measures between baseline to follow-up assessments (T0). MD: Mean Difference; SD: Standard Deviation.

**Significant difference between improvements of the study groups (p < 0.01).*

***Significant difference between improvements of the study groups (p < 0.001).*

Differences were recorded between the three evaluations in average power ($F(1.52,27.39) = 15.03$; $p < 0.001$; $\eta^2_p = 0.45$); however, no differences were found in group interaction in terms of peak power ($F = 0.84$; $p = 0.41$; $\eta^2_p = 0.04$). There were intra-subject differences in the relative peak power ($F(2,36) = 4.73$; $p = 0.01$; $\eta^2_p = 0.20$), peak power ($F(2,36) = 6.51$; $p < 0.001$; $\eta^2_p = 0.26$) and relative average power ($F(2,36)= 14.61$; $p < 0.001$; $\eta^2_p = 0.44$). In all other variables no differences were reported in the repeated measures analysis. Differences were noted between groups in isometric strength of the right ($F(2,36)= 4.89$; $p = 0.01$; $\eta^2_p = 0.21$) and left ($F(2,36)= 4.94$; $p = 0.01$; $\eta^2_p = 0.21$) biceps, but no significant difference was reported in the other variables. Table 4 shows the results of the repeated measures analysis.

Variables	Mauchly sphericity test		Intra-subject effect			Interaction		
	W	Sig.	F	Sig.	η^2_p	F	Sig.	η^2_p
Isometric strength of the right biceps	0.83	.21	0.30	.74	0.01	4.89	.01*	0.21
Isometric strength of the left biceps	0.97	.77	0.08	.92	0.00	4.94	.01*	0.21
Isometric strength of the right triceps brachii	0.83	.21	0.27	.76	0.01	0.73	.48	0.03
Isometric strength of the left triceps brachii	0.74	.08	1.75	.18	0.08	1.40	.25	0.07
Peak power	0.84	.23	6.51	.00**	0.26	0.33	.71	0.01
Relative peak power	0.87	.32	4.73	.01*	0.20	0.11	.89	0.00
Average power †	0.68	.04	15.03	.00**	0.45	0.84	.41	0.04
Relative mean power	0.79	.13	14.61	.00**	0.44	0.33	.71	0.01
Fatigue index	0.75	.09	1.84	.17	0.09	0.31	.72	0.01
Subjective effort perception	0.82	.20	2.49	.09	0.12	1.10	.34	0.05

Table 4: *Intra-subject and inter-subject effects test results in each one of the dependent variables of the study, among the study groups.*

*†: The df corresponds to Greenhouse-Geisser test. *: p < .05. **: p < .001.*

In the pairwise comparison analysis, there was a significant improvement (p < 0.001) after intervention (T0 - T1), when comparing posttreatment and follow-up (p = .04) assessments (T0-T2), and follow-up compared to baseline (p = 0.02). In the pairwise comparison analysis at baseline (T0), T1 and T2, there was a significant improvement at posttreatment compared to baseline (T0-T1) in peak power (p = 0.01), relative peak power (p = 0.03) and relative average power (p < 0.001). Table 5 shows the results of the pairwise comparison analysis at baseline (T0), T1 and T2.

Variables	T0 - T1	T1 - T2	T0 - T2
Isometric strength of the right biceps	-0.19 (1.00)	0.42 (1.00)	0.23 (1.00)
Isometric strength of the left biceps	0.19 (1.00)	0.13 (1.00)	0.32 (1.00)
Isometric strength of the right triceps brachii	-0.04 (1.00)	-0.33 (1.00)	-0.37 (1.00)
Isometric strength of the left triceps brachii	1.27 (.08)	-1.09 (.52)	0.18 (1.00)
Peak power	-29.80 (.01) *	10.75 (.35)	-19.05 (.13)
Relative peak power	-0.42 (.03) *	0.16 (.51)	-0.26 (.28)
Mean power [a]	-35.35 (.00) **	12.20 (.04) *	-23.15 (.02) *
Relative mean power	-0.60 (.00) **	0.28 (.01) *	-0.32 (.08)
Fatigue index	5.10 (.55)	0.05 (1.00)	5.15 (.31)
Subjective effort perception	-0.55 (.31)	0.05 (1.00)	-0.50 (.17)

Table 5: *Pairwise comparison analysis (means difference and (significance)) between the three evaluations carried out in each study group.*

T0 - T1: Outcome measures between baseline to posttreatment assessments; T1 - T2: Outcome measures between posttreatment to follow-up assessments: T0 - T2: Outcome measures between baseline to follow-up assessments (T0); MD, mean difference.

** Significant difference between improvements of the study groups (p < .05).*

*** Significant difference between improvements of the study groups (p < .001).*

Compliance

Compliance was high, with 86% of patients adhering to the protocol (experimental group 90%, control group 82%). There were no significant differences in compliance between groups. Conclusions for the post-hoc per-protocol analyses did not differ from those obtained from the intention-to-treat analyses.

Discussion

Study results show how the use of the blood flow restriction technique in the upper limbs, associated with an adapted WinGate protocol, is able to significantly improve the effects on average power with respect to exercising without such restriction. The experimental group experienced superior gains in average power and peak power compared to the control group, but this did not however translate to better clinical outcomes in the long term.

Average power

Changes in the average power (relative average power/Kg) were reported for both study groups treated and evaluated following the intervention period. However, significant maintenance after follow-up was only reported for the experimental group. Based on these findings, we are able to assert that the adapted WinGate training protocol may help to maintain the relative average power regardless of a simultaneous intervention, while the values for subjective effort perception remain unchanged, resulting in an improvement of the anaerobic capacity. These findings may be explained by the fact that the anaerobic lactic system acid is the energy source used in intensity short-duration exercises [14], such as the 30-second training at maximum working power implemented according to our protocol. Hylden., *et al*. [21] using blood flow restriction therapy for low-load exercise, also reported improvements in average power in patients unable to perform high-resistance exercise or patients with persistent extremity weakness despite traditional therapy. Corvino., *et al.* [22] disclosed that endurance cycling with intermittent blood flow restriction promotes muscle deoxygenation and metabolic strain, which may translate into increased endurance training adaptations while minimizing power output and perceived exertion. Despite improvement in the average power reported in our study, there were no changes in power production, observing short-term changes but not sustained over time.

Muscle strength

Other studies reporting strength gains [23,24] used the biceps curl and bench press as an intervention for strength gains in the biceps and triceps brachii, respectively. Yasuda., *et al*. [24] described the associational relationship between strength gain and muscle hypertrophy, without any change in neural adaptation. This may explain the results of said study, as anaerobic training on a cycle ergometer does not increase strength and hypertrophy in the biceps and triceps brachii. In line with such results, other authors [25] used exercises in which the biceps and triceps brachii muscles were not prime movers, for example, the "seated shoulder press", after an intervention with vascular occlusion, without finding any improvements in the strength of either muscle.

Subjective perception of effort

This study reveals no changes in the subjective perception of effort. However, these findings contradict other studies in which significantly higher values were found for low-intensity exercise using vascular occlusion [19,26,27], for high-intensity exercise28 and for intermittent exercises with blood flow restriction compared to continuous protocols [27,28]. Only one study [29], which evaluated the heart rate when performing elbow flexion exercises associated with blood flow restriction, reported no differences between the experimental group and the control group. In terms of the subjective effort perception, two studies [30,31] related to lower limb interventions have shown results which are similar to ours. This may be due to the different methodology used in these studies, confirming the need for standardized protocols for intervention and evaluation, with the aim of gaining a better understanding and verification of the results.

The main strengths of the present study were adequate power, the methodological quality, and practically no missing data. All observers collecting outcome measures were blinded to group allocation. Significant changes have been observed after a short intervention period of only 4 weeks, changes that were maintained for a further 4-week term.

Blood flow restriction training seems to be effective for the gain of muscle strength, while high-intensity and short-duration training have proven to effectively increase the anaerobic capacity. However, when both techniques are combined, no improvements were noted in the muscle strength and anaerobic capacity variables. It should thus be noted that despite these findings, the use of this technique alone does not render poorer or lower effects, whereby time and resources can be saved in each training session.

It is essential to develop randomized clinical studies with a larger sample size taken from multicenter populations. Likewise, interventions with a higher training volume, adapting similar protocols, should be designed in order to confirm or reject the results of this study. Lastly, a more specific evaluation of the cardiovascular effects is desirable, including the assessment of blood pressure, biochemical markers and VO_2 max.

Failure to use specific muscle training to improve the isometric strength of the biceps and triceps brachii may have influenced the gain in these valences. Likewise, failure to monitor the sample in terms of diet and physical activity during research is another factor that may have directly affected the results obtained.

Limitations of the Study

The main limitation of the study is the sample size. Although many female were invited to participate, only 24 agreed to take part in this research. With the aim of minimizing this limitation, an intention-to-treat analysis was carried out.

Another limitation noted is the use of a manual pressure cuff, rather than an automatic pressure cuff, to promote blood flow restriction. Several studies [32] have reported that there may be a loss of pressure in manual cuffs during physical activity, but due to cost restrictions, an automatic model was not readily available. Also noteworthy is the reduced number of training sessions conducted (eight sessions) in comparison with other studies reaching up to 24 sessions [25].

Conclusion

Blood flow restriction techniques combined with cycle ergometer training of the upper limbs may improve peak power and average power in physically active female. Blood flow restriction associated with cycle ergometer training for the upper limbs does not significantly enhance the isometric strength of biceps and triceps brachii or improve fatigue index values, as compared to an exercise protocol using a cycle ergometer for the upper limbs alone. Randomized clinical trials should be conducted on female applying blood flow restriction focusing on muscle strength and anaerobic capacity.

Key Points

- **Findings:** Blood flow restriction techniques combined with cycle ergometer training of the upper limbs may improve peak power and average power in healthy female.
- **Implications:** This study shows as a cycle ergometer for the upper limbs, without blood flow restriction can enhance the isometric strength of biceps and triceps brachii or improve fatigue index values.
- **Caution:** Future randomized clinical trials should include a larger sample size and focusing on muscle strength and anaerobic capacity.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Contributors

E.G.M. and F.C.M. contributed to conception and design of the work, acquisition, analysis and interpretation of data, and drafting and revising the work. R.C.B. contributed to conception and design of the work, interpretation of data, critical revision of the work for important intellectual content.

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