ORIGINAL PAPER

Physiotherapy Quarterly (ISSN 2544-4395)
2023, 31(3), 79–84

Effect of cycle ergometry on peripheral blood flow, vascular conductance, and vascular resistance in young people

DOI: https://doi.org/10.5114/pq.2023.117071

Dayane G. Gomes Guimarães[1], Andrezza S. Dias[1], Anderson I. Silva de Souza Rocha[2], Fábio T. Maciel da Silva[2], Maria do Socorro B. Santos[2,3], Amilton da C. Santos[2], Rafaela Pedrosa[1], José Heriston de M. Lima[1], Nivaldo A. Parizotto[1,3], Eduardo E. Tenório de França[1,3]

[1] Department of Physiotherapy, Federal University of Paraíba, João Pessoa, Brazil
[2] Postgraduate Program in Physical Education, Federal University of Paraíba, João Pessoa, Brazil
[3] Postgraduate Program in Physiotherapy, Federal University of Paraíba, João Pessoa, Brazil

Abstract

Introduction. The study aimed to evaluate haemodynamic changes in peripheral blood flow, vascular conductance (VC), and peripheral vascular resistance (PVR) in healthy individuals undergoing passive and active lower limb cycle ergometry.
Methods. This was a prospective, controlled, randomized study with a crossover design, in which 14 normotensive volunteers were allocated to receive: (1) assessment without intervention (control group); (2) passive lower limb cycle ergometry; and (3) active cycle ergometry of lower limbs. In the physical exercise session of the active and passive lower limb cycle ergometry protocol, the volunteers were placed in the supine position and then performed aerobic exercise for 20 minutes. Forearm blood flow was measured with a venous occlusion plethysmograph, blood pressure was evaluated with oscillometric and automatic equipment, and heart rate was monitored continuously through lead II of electrocardiogram.
Results. Active cycle ergometry was able to promote hypotension after physical exercise owing to a reduction in mean blood pressure ($p = 0.000$), with an improvement in vascular function as reflected by a reduction in PVR ($p = 0.000$) and an increase in VC ($p = 0.000$). Although the reduction in mean blood pressure in the passive cycle ergometry group was not significant, it was sufficient to promote an increase in VC ($p = 0.049$) and a reduction in PVR ($p = 0.008$).
Conclusions. A single session of 20 minutes of physical exercise with passive or active cycle ergometry of the lower limbs was sufficient to promote haemodynamic changes in normotensive individuals.
Key words: physical exercise, cycle ergometry, vascular resistance, vascular conductance, blood pressure

Introduction

Depending on the physical exercise performed, different metabolic responses and haemodynamic changes occur. Post-exercise hypotension (PEH) has been observed after performing an aerobic exercise session of different types, such as walking [1], running [2], lower limb [3] and upper limb ergometry [4].

However, there are few studies that sought to directly compare the effects of different types of aerobic exercise on the behaviour of PEH. De Fúcio Lizardo et al. [4] compared the responses to 30 minutes of lower and upper limb physical exercise on an ergometer in borderline hypertensive individuals. They concluded that the muscle mass involved in the exercise did not directly affect the magnitude of PEH, but it influenced the duration of the response, with longer hypotension after physical exercise for lower limbs.

In turn, some studies indicate that lower limb cycle ergometry, both active and passive, has been used as an adjunct in the control of the haemodynamic and biochemical functions of the human body, with the passive mode applied mainly in patients intubated in intensive care units [5, 6]. The most beneficial results of passive cycle ergometry are related to arthrokinematics owing to joint mobilization. Significant positive changes in the variables of systolic blood pressure (SBP), mean blood pressure (MBP), and heart rate (HR) in critically ill patients were observed and explained by the larger activation of the cardiovascular system of individuals submitted to exercise [7].

In the context of the known beneficial effects of active and passive cycle ergometry sessions on cardiovascular function, the present study aimed to clarify the haemodynamic changes in peripheral blood flow, conductance, and peripheral vascular resistance (PVR) in healthy individuals undergoing passive and active lower limb cycle ergometry.

Subjects and methods

Study design and participants

This was a prospective, controlled, randomized study with a crossover design. With the use of the www.randomizer.org website, volunteers were randomly allocated to the control group (who underwent only the evaluation process), the passive cycle ergometry group (Flex Motor with sensor; Cajumoro, Bragança Paulista, São Paulo, Brazil), and the active cycle ergometry group (WCT Fitness 608; Porto Alegre, Rio Grande do Sul, Brazil), with a minimum interval of 48 hours to participate in one of the groups. The randomization was to choose the order of the administration of treatments.

The study was performed at the Federal University of Paraíba, the Health Sciences Centre and the Department

Correspondence address: Eduardo Eriko Tenório de França, Department of Physiotherapy, Federal University of Paraíba, Conj. Pres. Castelo Branco III, João Pessoa, Paraíba, Brazil, CEP: 58033-455, e-mail: edueriko@hotmail.com, https://orcid.org/0000-0001-9207-2180

Received: 28.07.2021
Accepted: 22.12.2021

Citation: Guimarães DGG, Dias AS, Rocha AISDS, da Silva FTM, Santos MSB, Santos AC, Pedrosa R, Lima JHM, Parizotto NA, de França EETD. Effect of cycle ergometry on peripheral blood flow, vascular conductance, and vascular resistance in young people. Physiother Quart. 2023;31(3):79–84; doi: https://doi.org/10.5114/pq.2023.117071.

of Physiotherapy. Young adult university students of both sexes aged 18–35 years were included in the study. The following eligibility criteria were adopted: absence of chronic degenerative diseases, not showing changes in the electrocardiogram (ECG) at rest and/or during exercise, not being a smoker or ex-smoker, not consuming more than 2 doses/day of alcohol, not using medications (cardiovascular, psychotropic, or vasoactive agents), and body mass index (BMI) ≤ 30 kg/m^2. Individuals who had ingested sympathomimetics, coffee, other stimulants, or alcohol within the 24 hours preceding an evaluation, as well as those who missed one of the experimental sessions were excluded. All participants were informed about the procedures before the study commencement.

Measurements and clinical procedures

The clinical measurement was performed with the volunteer in a sitting position, after 5 minutes of rest. Blood pressure was assessed with oscillometric and automatic equipment (Dixtal® DX 2020; Manaus, Brazil). HR was monitored continuously through lead II of ECG and peripheral oxygen saturation (SpO_2) was evaluated with a pulse oximeter (Oximeter, São Paulo, Brazil).

Forearm blood flow (FBF) was measured before and after the intervention with the venous occlusion plethysmography technique. The nondominant arm was elevated above the heart level to ensure adequate venous drainage. A Silastic tube filled with mercury, connected to a low-pressure transducer, was fixed around the forearm, 5 cm distally to the elbow joint, and attached to the plethysmograph (Hokanson EC6). The sphygmomanometer cuff was placed around the wrist and upper arm. At 10-second intervals, the upper cuff was inflated above the venous pressure for a period of 10 seconds, totalling 3 cycles/waves per minute. The increase in tension in the Silastic tube reflected the volume increase in the forearm and, consequently, vasodilation. When FBF was assessed, the flow to the hand was excluded by inflating the wrist cuff to suprasystolic pressure (250 mm Hg). The signal of the blood flow wave was acquired on-line in a computer through the WinDaq DI-200 software, at the frequency of 500 Hz.

Vascular conductance (VC) was calculated with the formula:

$$VC = FBF / MBP \times 100$$

where FBF denotes forearm blood flow and MBP stands for mean blood pressure.

For PVR, the calculation was:

$$PVR = MBP / FBF$$

Pre- and post-intervention blood pressure was determined noninvasively by a finger photoplethysmography device (Finapres 2300, Ohmeda) on a beat-to-beat basis.

Intervention

In the physical exercise session of the active and passive lower limb cycle ergometry protocol, the volunteers were placed in the supine position and then performed aerobic exercise for 20 minutes; the evaluation involved Borg's effort perception index (EPI) [8]. In the passive cycle ergometry, the number of 30 revolutions per minute was adjusted, and in the active cycle, the subject was instructed to maintain the same rotation speed of the ergometer at 30 revolutions per minute. The control session took place equally, but without the practice of any type of physical activity. The individuals remained in the supine position at rest for 20 minutes. HR, arterial pressure, SpO_2, and EPI were recorded every 5 minutes during the intervention.

Experimental protocol

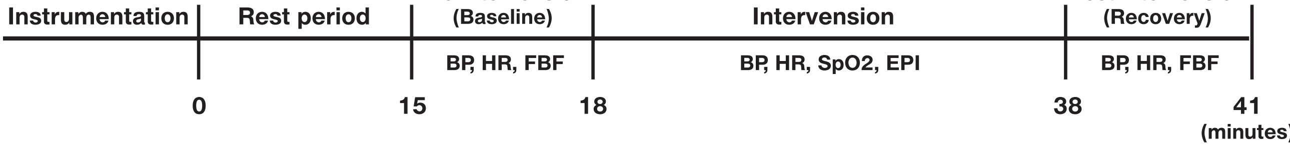
All of the studies were performed at ca. 14:00 a.m., with the subjects lying in the supine position in a quiet air-conditioned room (22–24°C). ECG leads were placed on the chest, cuffs and Silastic for FBF measurements were placed on the nondominant arm, and the finger photoplethysmography device was placed on the medium finger of the dominant arm. After a 15-minute rest period, baseline values for FBF, arterial pressure, and HR were recorded for 3 minutes. Then, the volunteer performed the aerobic exercise for 20 minutes on a lower limb cycle ergometer or a control session was carried out (the participants remained in the supine position, at rest for 20 minutes). Immediately after the end of the intervention, the haemodynamic measurements were repeated (Figure 1).

Statistical analysis

The collected data were analysed and treated statistically in the quantitative form and presented as mean and standard deviation (*SD*), as appropriate. To test the assumption of normality of data, the Shapiro-Wilk test was applied. To evaluate and compare the haemodynamic parameters before, during, and after the study protocol for the 3 sessions, the 1-way ANOVA test for repeated measures was used, with Bonferroni post-hoc correction performed depending on the data distribution. The SPSS software for Windows was employed. A 5% significance level was assumed, with a 95% confidence interval.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Research Ethics Committee of Lauro Wanderley University Hospital (approval No.: 86468218.6.0000.5183) and registered in the Brazilian Registry of Clinical Trials (No.: RBR-89QMHC).



BP – blood pressure, HR – heart rate, FBF – forearm blood flow, SpO_2 – peripheral oxygen saturation, EPI – effort perception index

Figure 1. Timeline of the experimental protocol

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

During the period from October 2018 to May 2019, 21 volunteers, young adults, were recruited (Figure 2). Three were excluded from the study because their parents were hypertensive, 2 had ingested coffee or chocolate within the 24 hours prior to the evaluation, 1 had a BMI above the limit for the study (grade 1 obesity), and 1 missed 1 of the evaluation steps without justification. Therefore, 14 volunteers were enrolled in the study.

Table 1 shows the demographic characteristics of the 14 volunteers included in the study protocol. The individuals (6 males and 8 females) were aged 22 years on average, with a mean BMI of 23.6 kg/m^2. In the same table, the baseline haemodynamic characteristics of the study participants are presented, with mean and *SD* of SBP, diastolic blood pressure, HR, and SpO_2.

Table 1. Demographic and haemodynamic characteristics of the 14 volunteers at baseline

Characteristics	Value (mean ± *SD*)
Demographic	
Age (years)	22 ± 0
Sex (male/female) (*n*)	6/8
BMI (kg/m^2)	23.6 ± 3
Haemodynamic	
SBP (mm Hg)	115.7 ± 8.5
DBP (mm Hg)	75 ± 9.4
HR (bpm)	69.9 ± 2.7
SpO_2 (%)	98.1 ± 1.1

BMI – body mass index, SBP – systolic blood pressure, DBP – diastolic blood pressure, HR – heart rate, SpO_2 – peripheral oxygen saturation

Table 2. Haemodynamic parameters and effort perception index during the interventions

Groups	MBP (mm Hg)	HR (bpm)	SpO_2 (%)	EPI
Control	82.8 ± 8.1	70.2 ± 6.2	98 ± 1	0 ± 0
Passive	82.6 ± 6.7	68.6 ± 6.8	98 ± 1	0 ± 0
Active	90.2 ± 7.8*	69.5 ± 2.8	97.7 ± 1.1	1.4 ± 1.1*

One-way ANOVA with Bonferroni post-hoc correction
MBP – mean blood pressure, HR – heart rate, SpO_2 – peripheral oxygen saturation, EPI – effort perception index
* difference in MBP for the active vs. control group and for the active vs. passive group ($p = 0.046$ and $p = 0.034$, respectively); the same for the EPI ($p < 0.001$)

Table 2 shows the mean and *SD* values of haemodynamic parameters and EPI during the 20 minutes of the study protocol (at 0, 5, 10, 15, and 20 minutes) for the 3 groups studied. A significant increase in MBP and EPI was observed for the group of active cycle ergometry when compared with the other groups.

Table 3 depicts the mean and *SD* values of MBP, FBF, VC, and PVR in the moments before and immediately after the study protocol for the 3 groups investigated. One can observe an increase in FBF ($p = 0.041$) and a reduction in PVR ($p = 0.046$) in the control group; an increase in VC ($p = 0.049$) and a reduction in PVR ($p = 0.008$) in the passive cycle ergometry group; and a decrease in MBP ($p = 0.000$), an increase in VC ($p = 0.000$), and a reduction in PVR ($p = 0.000$) in the active lower limb cycle ergometry group.

Figure 3 shows the difference between the values before and after the study protocol, presented as delta values, for the means of MBP, FBF, VC, and PVR in the control, passive cycle ergometry, and active cycle ergometry groups. A reduction can be observed in the MBP delta value (92.5 ± 6.6 to 72.8 ± 6.4, $p = 0.000$) in the active cycle ergometry group when compared with the passive cycle ergometry group and the control group. There was also an increase in the delta value of VC (6.8 ± 1.3 to 9.6 ± 1.4, $p = 0.000$) and a reduction in the delta value of PVR (15 ± 2.9 to 10 ± 1.6, $p = 0.000$) in the active cycle ergometry group compared with the passive

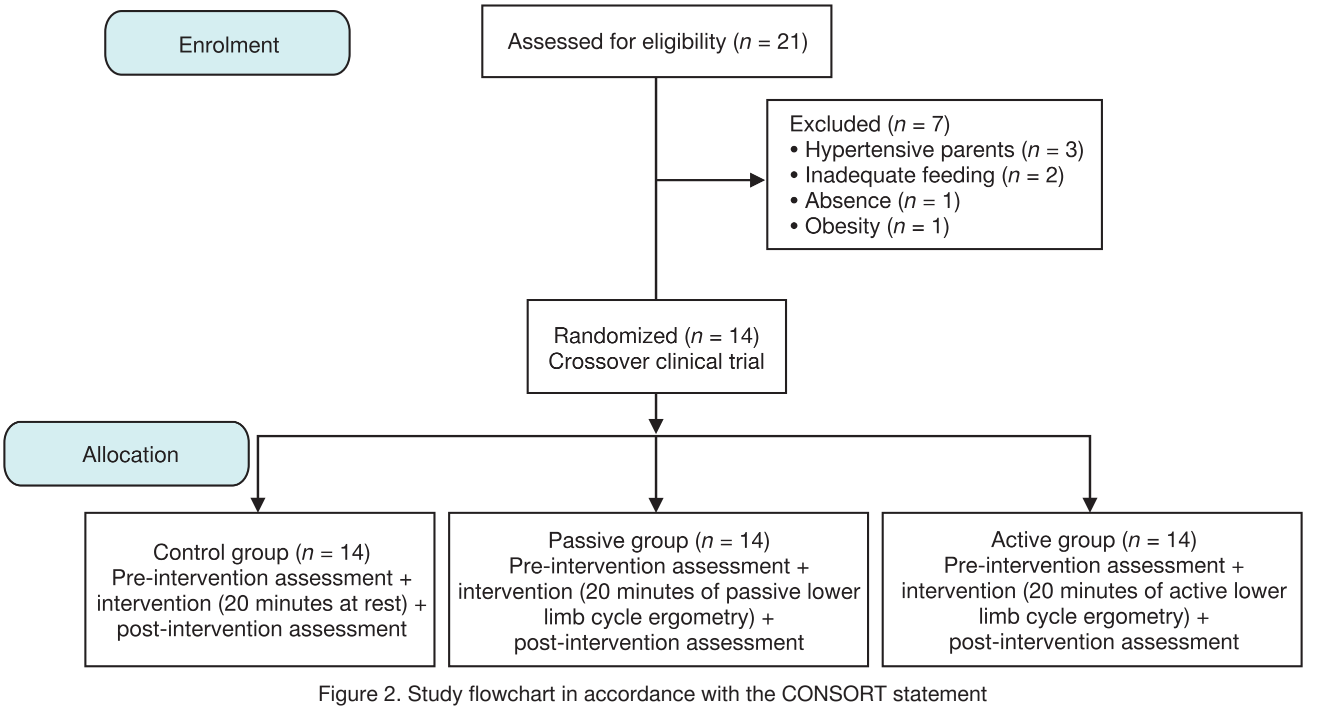
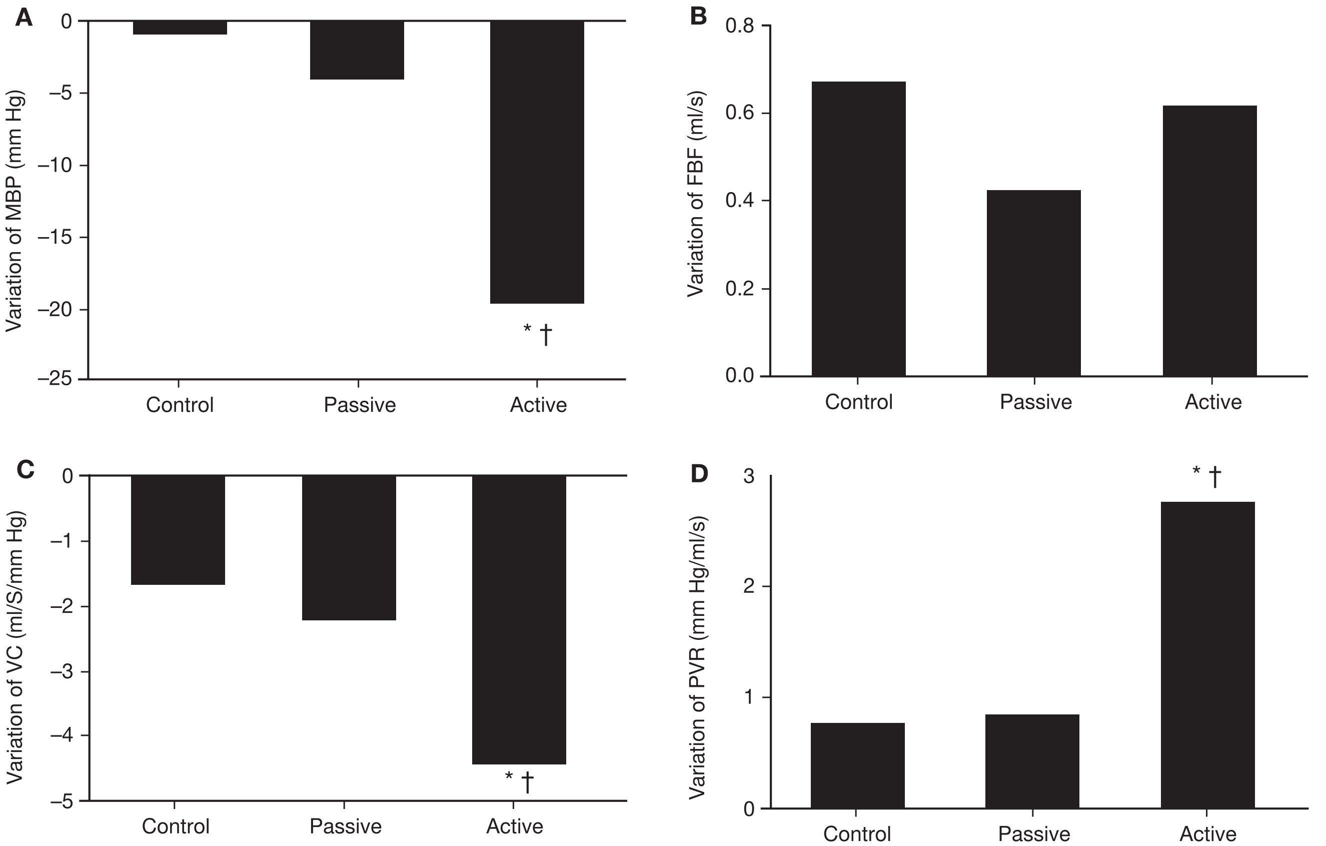


Figure 2. Study flowchart in accordance with the CONSORT statement

Table 3. Mean and standard deviation of blood pressure, forearm blood flow, vascular conductance, and peripheral vascular resistance before and after the study protocol for the 3 groups

Variables	Control			Passive			Active		
	before	after	*p*	before	after	*p*	before	after	*p*
MBP (mm Hg)	93 ± 5.9	92.2 ± 4.7	0.684	89 ± 4.7	85 ± 6.1	0.064	92.5 ± 6.6	72.8 ± 6.4	0.000*
FBF (ml/s)	6.2 ± 0.7	6.9 ± 0.7	0.041*	5.8 ± 1.2	6.2 ± 0.4	0.192	6.3 ± 1	6.9 ± 0.7	0.060
VC (ml/s/mm Hg)	6.7 ± 0.9	7.5 ± 0.8	0.079	6.5 ± 1.4	7.3 ± 0.7	0.049*	6.8 ± 1.3	9.6 ± 1.4	0.000*
PVR (mm Hg/ml/s)	15 ± 2.3	13.4 ± 1.4	0.046*	15.8 ± 3	13.6 ± 1.3	0.008*	15 ± 2.9	10 ± 1.6	0.000*

ANOVA for repeated measures with Bonferroni post-hoc correction
MBP – mean blood pressure, FBF – forearm blood flow, VC – vascular conductance, PVR – peripheral vascular resistance
* significant intra-group difference between before and after the intervention



One-way ANOVA with Bonferroni post-hoc correction
MBP – mean blood pressure, FBF – forearm blood flow, VC – vascular conductance, PVR – peripheral vascular resistance
* significant difference in the cycle ergometry active group vs. control group
† significant difference in the cycle ergometry active group vs. cycle ergometry passive group

Figure 3. Delta values of mean blood pressure, forearm blood flow, vascular conductance, and peripheral vascular resistance in the studied groups

cycle ergometry group and the control group. No significant difference was revealed in the FBF delta value when comparing the groups studied.

Discussion

The aerobic exercise session with active cycle ergometry in normotensive people promoted PEH, with an improvement in vascular function as reflected by an increase in VC and a decrease in local PVR. Although the reduction in blood pressure in the passive cycle ergometry group was non-significant, it turned out sufficient to promote an increase in VC and a reduction in PVR. The PEH found in our study may have been influenced by haemodynamic factors such as vasodilation; humoral and neural factors; the intensity, duration, and type of exercise; as well as clinical status, age, ethnicity, gender, and training status. Relaxation of the vessel wall favours a reduction in PVR and an improvement in VC.

The occurrence of the PEH phenomenon with the use of cycle ergometry was evident. PEH was observed only with the use of active cycle ergometry, which is in agreement with a study by Endo et al. [9], who also observed PEH after 60 minutes of exercise with lower limb cycle ergometry. It is important to highlight that the volunteers were normotensive and had no family history of hypertension; they also performed the exercise in the afternoon, as in the present study. Jones et al. [10] compared periods of the day and blood pressure responses after physical exercise and demonstrated the occurrence of PEH in normotensive individuals only in the afternoon. Boutcher et al. [11] did not find PEH in normotensive patients being children of hypertensive parents after 20 minutes of physical exercise on a lower limb cycle ergometer at 60% of maximal oxygen uptake. Perhaps these results are associated with the low intensity of load in the studied population.

In our study, the reduction in MBP with the use of passive cycle ergometry was not significant. This corroborates the results obtained by de Freitas et al. [12], who, evaluating the effects of passive mobilization of legs on acute haemodynamic responses in mechanically ventilated patients, also found no change in MBP. These observations can be supported by Coutinho et al. [13], who also assessed the acute effect of passive cycle ergometry of lower limbs in critically ill patients and did not reveal changes in HR or MBP, explaining this with the small haemodynamic activity in response to the lower recruitment of muscle activity in this type of exercise.

In the present study, we could observe an increase in FBF after the intervention only in the control group. The groups of passive and active cycle ergometry presented hypotensive responses after exercise associated with a significant increase in VC and a reduction in PVR.

In a study similar to ours, Boutcher et al. [11] submitted normotensive individuals to a 20-minute session of lower limb cycle ergometry, with an intensity of 60% of maximal oxygen uptake. After the physical exercise, the peak blood flow in the forearm increased by 22% and the PVR of the forearm decreased by 17% when compared with pre-exercise values. Koch et al. [14] observed that an exercise session of lower limb ergometry was able to increase FBF and reduce PVR in the active and non-active muscles. Another study, carried out in hypertensive women, showed that a cycle ergometer session of 40 minutes decreased PVR [15]. A possible mechanism is the shear stress that occurs during physical exercise in the arterial vessels. This mechanical stimulus resulting from physical exercise induces the release of vasodilating factors by the vascular endothelium, triggering an endothelium-dependent vasodilator response; the factors involve nitric oxide, the hyperpolarizing factor derived from the endothelium [16], histamines [17], and endogenous opioids [9].

When comparing the variation of haemodynamic parameters, our results showed a reduction in MBP and PVR and an increase in VC immediately after the use of active cycle ergometry compared with the passive and control groups. These findings can be related to the larger cardiovascular stress in the active cycle ergometry group, as reflected by the volunteers' EPI. Also, reduction of sympathetic discharge presented a direct association with PVR decrease and with the remodelling of resistance vessels [18]. This response may have been caused by the influence of the chemoreceptors present in the muscles, which are sensitive to the accumulation of metabolites caused by physical exercise [19] or even to the dissipation of the heat produced [20].

We also found an increase in MBP and EPI during the intervention period only in the active cycle ergometry group. Wielemborek-Musial et al. [21], using ambulatory blood pressure measurement, observed an increase of 5 mm Hg in SBP during a mean time of 12.7 hours when compared with the resting value. During this type of exercise, there is an increase in cardiac output, redistribution of blood flow, and an increase in circulatory perfusion to the muscles involved in the activity. Tension levels rise during physical exercise, predominantly static effort, with intra-arterial pressure levels above 400/250 mm Hg in young and healthy individuals without damage to health [22–24].

Our study may favour a range of investigations of vascular changes with the use of passive and active cycle ergometers in patients with vascular disorders, critically ill patients, or even elderly people who have some limitation to perform active exercise on a stationary bicycle since passive exercise with cycle ergometry was able to reduce PVR and increase VC.

Limitations

The main limitation of our study was the small size of the participant sample in the experiment.

Conclusions

The presented results indicate that in normotensive individuals, an exercise session with passive or active lower limb cycle ergometry was sufficient to promote haemodynamic changes such as a reduction of MBP with active cycle ergometry and a reduction in PVR and an increase in VC with active and passive cycle ergometry. It is possible to state that both forms of physical exercise were able to promote changes in haemodynamic parameters, which were more significant in active cycle ergometry. Moreover, a hypothesis of variations in the protocols with passive and active cycle ergometry opens to this treatment as a protagonist or adjuvant to physical therapy interventions in elderly people with disabilities, critically ill patients, and patients with vascular disorders.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Cucato GG, Da Rocha Chehuen M, Ritti-Dias RM, Carvalho CRF, Wolosker N, Saxton JM, et al. Post-walking exercise hypotension in patients with intermittent claudication. Med Sci Sports Exerc. 2015;47(3):460–467; doi: 10.1249/MSS.0000000000000450.
2. Pardono E, de Oliveira Fernandes M, Azevêdo LM, de Almeida JA, Mota MR, Simões HG. Post-exercise hypotension of normotensive young men through track running sessions. Rev Bras Med Esporte. 2015;21(3):192–195; doi: 10.1590/1517-869220152103137534.
3. Jones H, George K, Edwards B, Atkinson G. Is the magnitude of acute post-exercise hypotension mediated by exercise intensity or total work done? Eur J Appl Physiol. 2007;102(1):33–40; doi: 10.1007/s00421-007-0562-0.
4. De Fúcio Lizardo JH, Modesto LK, Campbell CSG, Simões HG. Post-exercise hypotension: comparison between different intensities of exercise on a treadmill and a cycle ergometer [in Portuguese]. Rev Bras Cineantropom Desempenho Hum. 2007;9(2):115–120.
5. Cordeiro AL, Barbosa AFN, Leitão LP, Araújo PAS, Carvalho S. Hemodynamic effects of training on cycle ergometer in patients in post operative cardiac surgery [in Portuguese]. Rev Derc. 2014;20(3):90–93.
6. Dos Santos Machado A, Pires-Neto RC, Carvalho MTX, Soares JC, Cardoso DM, de Albuquerque IM. Effects that passive cycling exercise have on muscle strength, duration of mechanical ventilation, and length of hospital stay in critically ill patients: a randomized clinical trial [in Portuguese]. J Bras Pneumol. 2017;43(2):134–139; doi: 10.1590/S1806-37562016000000170.

7. Dantas JCN, de Sá Neves J, de Andrade PHC, Martinez BP, dos Anjos JLM. Behavior of variable for active cardiorespiratory cycle ergometer use in intensive care unit [in Portuguese]. Rev Pesqui Fisioter. 2016;6(3):283–290; doi: 10.17267/2238-2704rpf.v6i3.938.
8. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377–381; doi: 10.1249/00005768-198205000-00012.
9. Endo MY, Shimada K, Miura A, Fukuba Y. Peripheral and central vascular conductance influence on post-exercise hypotension. J Physiol Anthropol. 2012;31(1):32; doi: 10.1186/1880-6805-31-32.
10. Jones H, Pritchard C, George K, Edwards B, Atkinson G. The acute post-exercise response of blood pressure varies with time of day. Eur J Appl Physiol. 2008;104(3):481–489; doi: 10.1007/s00421-008-0797-4.
11. Boutcher YN, Hopp JP, Boutcher SH. Acute effect of a single bout of aerobic exercise on vascular and baroreflex function of young males with a family history of hypertension. J Hum Hypertens. 2011;25(5):311–319; doi: 10.1038/jhh.2010.62.
12. De Freitas ERFS, da Silva Bersi RS, Kuromoto MY, de Camargo Slembarski S, Sato APA, Carvalho MQ. Effects of passive mobilization on acute hemodynamic responses in mechanically ventilated patients [in Portuguese]. Rev Bras Ter Intensiva. 2012;24(1):72–78; doi: 10.1590/S0103-507X2012000100011.
13. Coutinho WM, dos Santos LJ, Fernandes J, Vieira SRR, Forgiarini Junior LA, Dias AS. Acute effect of the use of cycle ergometer during physical therapy treatment in mechanically ventilated critically ill patients. Fisioter Pesqui. 2016;23(3):278–283; doi: 10.1590/1809-2950/15549123032016.
14. Koch DW, Newcomer SC, Proctor DN. Blood flow to exercising limbs varies with age, gender, and training status. Can J Appl Physiol. 2005;30(5):554–575; doi: 10.1139/h05-141.
15. Otsuki T, Maeda S, Iemitsu M, Saito Y, Tanimura Y, Ajisaka R, et al. Contribution of systemic arterial compliance and systemic vascular resistance to effective arterial elastance changes during exercise in humans. Acta Physiol. 2006;188(1):15–20; doi: 10.1111/j.1748-1716.2006.01596.x.
16. Portela N, Amaral JF, de Carvalho Mira PA, de Souza LV, Martinez DG, Laterza MC. Peripheral vascular resistance impairment during isometric physical exercise in normotensive offspring of hypertensive parents. Arq Bras Cardiol. 2017;109(2):110–116; doi: 10.5935/abc.20170096.
17. Lockwood JM, Pricher MP, Wilkins BW, Holowatz LA, Halliwill JR. Postexercise hypotension is not explained by a prostaglandin-dependent peripheral vasodilation. J Appl Physiol. 2005;98(2):447–453; doi: 10.1152/japplphysiol.00787.2004.
18. Marongiu [E,] Piepoli M, Milia R, Angius L, Pinna M, Bassareo P, et al. Effects of acute vasodilation on the hemodynamic response to muscle metaboreflex. Am J Physiol Heart Circ Physiol. 2013;305(9):1387–1396; doi: 10.1152/ajpheart.00397.2013.
19. Egan B, Zierath JR. Exercise metabolism and the molecular regulation of skeletal muscle adaptation. Cell Metab. 2013;17(2):162–184; doi: 10.1016/j.cmet.2012.12.012.
20. Hargreaves M, Spriet LL. Exercise metabolism: fuels for the fire. Cold Spring Harb Perspect Med. 2018;8(8):a029744.
21. Wielemborek-Musial K, Szmigielska K, Leszczynska J, Jegier A. Blood pressure response to submaximal exercise test in adults. Biomed Res Int. 2016;2016:5607507; doi: 10.1155/2016/5607507.
22. Lovato NS, Anunciação PG, Polito MD. Blood pressure and heart rate variability after aerobic and weight exercises performed in the same session. Rev Bras Med Esporte. 2012;18(1):22–25; doi: 10.1590/S1517-86922012000100004.
23. Iellamo F, Volterrani M. Effect of exercise training in essential arterial hypertension. Rev Bras Hipertens. 2010;17(2):68–71.
24. De Moraes Forjaz CL, Rezk CC, De Melo CM, dos Santos DA, Teixeira L, de Souza Nery S, et al. Resistance training for hypertensive patients: recommended or not recommended [in Portuguese]. Rev Bras Hipertens. 2003;10(2):119–124.