Blood Pressure Behavior in Healthy Youngs after Mixed Cycle Ergometer (Upper and Lower-Limbs) or Bike Cycle Ergometer Sessions: An Experimental Study

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Abstract: ***Background**: The blood pressure (BP) effects of aerobic exercise performed on a cycle ergometer are widely studied. However, little is known about mixed cycle ergometers (cycle ergometers where you exercise lower and upper limbs simultaneously).**Objective**: To evaluate the BP effects after two protocols of continuous aerobic exercise performed on a bike cycle ergometer and a mixed cycle ergometer. **Methods**: Seventy-five healthy normotensive young people (male and female) aged 21.4±2.8years, 1.72±0.08m, 67.2±13.1kg, and 22.4±3.6kg/m^2 participated in an experimental study. They were divided randomly into three groups of 25 participants each. The experiment consisted of a single session of continuous aerobic exercise, with a 30-minuteduration; the intensity of ~65% HRMax adapted and Borg Scale, in 2 protocols: 1) Bike Cycle Ergometer Protocol (P-Bike); 2) Mixed Cycle Ergometer (P-Mixed); a 3) Control Protocol (P-Control) without exercise. BP measurements were taken before, immediately after, and 15, 30, and 45 minutes after the protocols. **Results**: At the end of the experimental protocols, both experimental protocols showed similar rises in SBP, P-Bike: Δ+13, P-Mixed Δ+10.3 mmHg, and DBP showed a rise, P-Bike Δ+6.5 mmHg, P-Mixed Δ+0.9 mmH compared to CS (p<0.05). At 15 minutes, SBP and SBP returned to baseline. After a few moments, the BP diminishes but without significance. **Conclusions**: The BP increased after both exercise protocols by the same magnitude, returning to baseline after a few moments. These findings support the mixed cycle ergometer's safe prescription in low-to-moderate intensity.***

Keywords: Aerobic exercise, Blood Pressure, Acute responses

1. Introduction

Increased blood pressure (BP) is considered an independent risk factor for diverse cardiovascular conditions (James et al., 2014), and it is estimated that more than one billion people worldwide have high blood pressure (HBP) (Patel, Ordunez, 2016), which is regarded as a relevant cardiovascular chronic disease. HBP treatment comprises of antihypertensive drugs and lifestyle modifications like diet, tobacco and alcoholism cessation, stress modulation, and physical exercise (James, 2014; Nascimento et al., 2017).

Aerobic exercise is a well-established intervention for preventing and treating HBP (Cornelissen and Smart, 2013; James et al., 2014), and individuals may clinically benefit from post-exercise hypotension after these exercises, such as walking-running (Dimeo F. et al., 2012), aquatic exercise (Cunha et al., 2018), bike cycle ergometer (Rondon et al., 2002). Relatively to cycle ergometer, although several studies have evaluated the BP effects after sessions with cycle ergometers for lower limbs (bike cycle ergometer) in different ages (Forjaz et al., 1998;Rondon et al., 2002; Cunha et al., 2021) and even upper limbs (Almeida et al., 2010), at least in our knowledge, there are no studies with aerobic exercises performed in mixed cycle ergometer that cycle upper and lower-limbs at the same time.

Our group studied the acute autonomic responses of young males that carried out an aerobic exercise session performed on a mixed-cycle ergometer. The session consisted of 30 minutes of low-to-moderate intensity, where they continuously cycled upper and lower limbs. They identified that heart rate (HR), and indexes such as SDNN, had no differences during and after the session compared to a traditional bike protocol (Souza et al. 2013).

Exercise on a bike cycle ergometer produces acute changes in the vascular system, resulting in vasodilation of the lower limbs, leading to blood flow redistribution for active muscle areas, generating vasoconstriction in the upper limbs, an increase in the stroke volume, and cardiac output (Guimarães et al., 2014). Cycling upper and lower limbs, as in mixed cycle ergometers, will likely produce similar responses but with major vasodilation and lower peripheral vascular resistance (PVR), which may result in different cardiovascular responses.

Exercise performed on a cycle ergometer has been proposed as having physiological benefits such as improving cardio-respiratory fitness (Zanget al., 2022), muscle endurance (Veldema et al., 2019), metabolic control (Madsen et al., 2015), promoting weight loss (Reljicet al., 2020), glucose reduction (Madsen et al., 2015), BP reduction (Rondon et al., 2002), and is also recommended due to lower risk of injuries related to the potential risk of falls (Stemplewski et al., 2012)for specific populations, such as the elderly.

To the best of our knowledge, there are no studies assessing BP after aerobic sessions that perform efforts of both the lower and upper limbs at the same time. Therefore, this study aimed to evaluate the effects of BP after two continuous aerobic exercise protocols performed on a bicycle cycle ergometer and a mixed cycle ergometer.

2. Methods

This is an experimental cross-sectional study usinga randomized design developed in an Exercise Physiology Laboratory. The study conformed to the provisions of the Declaration of Helsinki and was approved by the Research Ethics Committee of the Goiania Emergency Hospital (195.225). All subjects read and signed the informed consent form before participating in the study.

Study sample

Seventy-nine healthy young male and female university students were randomized, and fourwere excluded from the analyses because they did not complete the entire protocol. The final sample consisted of 75 participants (n=75). The inclusion criteria were being diagnosed with normal arterial BP according to the Eight Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Arterial Pressure (James et al., 2014); aged 18 to 30 years; pre-study SBP ≤ 130 mmHg and DBP ≤ 85 mmHg; and no practice exercise (any exercise) for at least three months. The exclusion criteria were the Body Mass Index (BMI)≥30kg.m^2; fever and any infectious diseases; diabetes; cardiovascular disease or any history of the cardiovascular event; renal disease; active smoking; orthopedic impairments; or physical or mental limitations that prevent exercising.

Study procedures

The study protocol included two visits to our laboratory before starting protocols, at least 48hours apart. On visit 1, the study procedures were explained to potential participants, and their questions were answered. Those who agreed to participate signed a formal consent form. At this same visit, the patients' medical histories were taken.

On visit 2, clinical and physical assessments were carried out. The participants were randomized (www.randomization.org) into three protocols (n=25/protocol): 1) P-Bike-Bike Cycle Ergometer; 2) P-Mixed -Mixed Cycle Ergometer ; 3) P-Control-Control Protocol.

Protocols

All protocols were held at 10 am under similar conditions. The intensity of the exercise protocols was calculated according to the adapted formula for bike exercise (Cunha, 2013) as follows: HR for exercise = % intensity x (HRmax) -10% of the final result; HRmax is estimated by age (220-age). In addition to HR, the Subjective Effort Scale (Borg, 1974) was employed. To achieve the prescribed intensities in each protocol moment, the participants cycled with individual rotations per minute based on the prescribed HR zone and the Borg scale. No additional overload was used on the ergometers. The HR was monitored continuously during exercise protocols (Polar, RS800cx, Kempele, Finland). The intensity was supervised individually bya specific researcher, who was responsible only for this. All participants were informed not to drink coffee on the experiment day, to avoid alcohol intake 48hours before, and not to exercise.

Bike cycle ergometer Protocol (P-Bike): The P-Bike session was carried out on a common cycle ergometer for lower limbs (Aerobike R7, Goiania, Brazil) in the seated position in the exercise physiology laboratory. It was a continuous session of dynamic cycling and aerobic exercise with duration of 30 minutes, starting witha2-minutewarm-up period, a main 26-minuteexercise period, and a 2-minutecooldown period. The intensities were ~45% HRmax during warm-up, 65% HRmax during the main period, and 55% HRmax during cooldown.

***Mixed cycle ergometer Protocol (P-Mixed)*:** The P-Mixed session was carried out on a mixed cycle ergometer, a machine similar to a conventional stationary cycle ergometer but adapted to cycle both upper and lower-limbs at the same time, in the seated position (Aerobike R11, Goiania, Brazil), in the exercise physiology laboratory. It was a continuous session of dynamic cycling and aerobic exercise with duration of 30 minutes, starting in a 2-minutewarm-up period, a main 26-minute exercise period, and a 2-minutecooldown period. The intensities were ~45% HRmax, during warm-up; 65% HRmax during the main period; and 55% HRmax during cool down.

Control Protocol (P-Control): The P-Control was held in environmental conditions similar to the experimental sessions in the exercise physiology laboratory for ~30minutes, but in the P-control, no exercise was performed. During this session, participants remained seated or standing as desired and were allowed to drink water, go to the bathroom, and talk.

Blood pressure Measurements

The BP measurements were taken in a seated position using an internationally validated semi-automatic BP monitor (Omron 705-CP, Matsusaka, Japan) following the techniques as described in the Eight Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Arterial Pressure (James et al., 2014).

For all sessions, BP was measured after 10 minutes seated in a chair at rest, pre-exercise, or control, and immediately (Min 0), 15 minutes (Min 15), 30 minutes (Min 30), and 45 minutes (Min 45) post-exercises or control. The BP was measured twice at each moment, with one minute between them, and the mean value of BP was used.

Statistical analysis

We performed the Shapiro-Wilk test to assess the normality of the distribution of numerical data. The BP was analyzed between the groups at the pre-exercise time and with the control session by one-way ANOVA. Delta (Δ) was calculated by subtracting the BP value after the protocol from the BP pre-protocol (Δ=Post-Pre). The data were described as mean ± standard deviation, and all analyses were performed using the Statistical Package for Social Sciences (SPSS v21), considering significant p<0.05.

3. Results

Seventy-five participants completed the protocol procedures, and Table 1 summarizes their main characteristics. There is no variance among protocol participants based on their characteristics, evidencing sample homogeneity. Resting BP measured during sample selection indicates normotension.

Table 1: Study participants' main characteristics

	P-Control (n=25)	P-Bike (n=25)	P-Mixed (n=25)	p
Age (years)	21 ± 2.9	20.5 ± 2.5	20.8 ± 2.2	NS
Body weight (kg)	62.6 ± 11.9	62.6 ± 10	67.5 ± 11	NS
Height (m)	1.73± 0.09	1.70± 0.08	1.73 ± 0.08	NS
BMI (kg/m^2)	22 ± 3.6	22.4 ± 2.5	22.4 ± 2.6	NS
Resting SBP (mmHg)	107 ± 8	112 ± 11	110 ± 12	NS
Resting DBP (mmHg)	68 ± 5.7	70 ± 7.1	67.8 ± 4.4	NS

Mean± SD; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure. NS=No Significance.

The pre-exercise BP between protocols did not differ for systolic BP (SBP): P-control =108±8;P-bike = 111±11;P-Mixed = 114±12 mmHg, p=0.151.Immediatelly after the exercise, the SBP increased significantly in all exercise protocolscompared to P-Control (P<0.001), and comparing the pre-moment, the P-bike presented: Δ+13 mmHg, P-Mixed Δ+10.3 mmHg, without significance among exercise protocols.At Min 15, the SBP returned to the same level of P-Control in both exercise protocols. In theaftermoments, there was adecrease in SBP for both protocols, greater in the P-mixed (Min 30: Δ-2.8 vs. Δ-5.3mmHgand Min 45: Δ-3.3 vs. Δ-4.9mmHg for P-Bike and P-Mixed, respectiverly), but both without significance(Table 2).

Table 2: The kinetics of the systolic blood pressure (SBP) after aerobic cycle ergometer protocols and control

Moment	SBP			
	P-Control (n=25)	P-Bike (n=25)	P-Mixed (n=25)	p inter
Pre	108.2±8	111.6±11	114.2±10	0.151
Min 0	107.9±8.9 (Δ-0.3)	124.6±10(Δ+13)*	124.5±9(Δ+10.3)*	<0.001
Min 15	107.2±9.3 (Δ-1)	111.7±11(Δ+0.1)	109.9±11(Δ-4.3)	0.419
Min 30	107.4±8.6 (Δ-0, 8)	108.8±13(Δ-2.8)	108.9±13(Δ-5.3)	0.898
Min 45	109.6±8.2 (Δ+1.4)	108.3±12(Δ-3.3)	109.3±11(Δ-4.9)	0.911

** SBP variation in relation to the Pre point, intragroup (p<0.05).*
Values expressed in means ± standard deviation
P-Control = Control Protocol; P-Bike = Bike Protocol; P-Mixed = Mixed-Protocol cycle ergometer.

The pre-exercise BP between protocols did not differ for diastolic BP (DBP): P-Control = 68±5; P-Bike = 70±8; P-Mixed = 69±5 mmHg; p=0.586. Immediatelly after the exercise, the DBP increased significantly in all exercise protocols compared to P-Control (P<0.001), and comparing the pre-moment, the P-Bike increased more Δ+6.5 mmHg than the P-Mixed Δ+0.9 mmHg, but without significance. At Min 15, the SBP returned to the same level of P-Control in both exercise protocols, maintaining similar results until the end (min 45). See table 3.

Table 3: The kinetics of the diastolic blood pressure (DBP) after aerobic cycle ergometer protocols and control.

Moment	DBP			
	P-Control (n=25)	P-Bike (n=25)	P-Mixed (n=25)	p inter
Pre	68.4±5	70.3±6	68.9±5	0.586
Min 0	69.3±5 (Δ+0.9)	76.8±6(Δ+6.5)*	71.6±5(Δ+0.9)	<0.001
Min 15	69.3±6 (Δ+0.9)	70.2±6(Δ-0.1)	70±6(Δ+0.9)	0.868
Min 30	68.7±5(Δ+0.3)	69.2±7(Δ-1.1)	68.4±6(Δ+0, 3)	0.919
Min 45	71.4±6(Δ+3)	70.6± 6(Δ+0.3)	68±5(Δ+3)	0.150

** DBP variation in relation to the Pre point, intragroup (p<0.05).*
Values expressed in means ± standard deviation
P-Control = Control Protocol; P-Bike = Bike Protocol; P-Mixed = Mixed-Protocol cycle ergometer.

4. Discussion

Our study focused on changes in the BP in healthy university students immediately after two different aerobic cycle ergometer protocols, the P-bike, a conventional bike ergometer session, and the P-Mixed, a mixed cycle ergometer that cycles lower and upper limbs at the same time. The main finding of this study was that the low-to-moderate intensity aerobic exercises performed in both cycle ergometers increased SBP immediately after each session similarly and to a small magnitude, returning to the same level as the control protocol at min 15 (Chen C, Bonham, 2010). There was BP reduction in the after moments without significance, but interestingly, with a greater reduction in P-Mixed. Other interesting data was relative to a DBP that increased significantly immediately after P-Bike.

The SBP and DBP increased in response to aerobic cycle ergometer demand in both protocol situations, but it was a safe rise of small magnitude. Furthermore, BP levels returned to the baseline compared pre-exercise levels and the control session, within 15 minutes after the exercise sessions. All exercises will increase SBP (Almeida et al., 2010; Del Rosso et al., 2016; Cunha et al., 2018; Cunha, 2021) during and for most parts, immediately after, but DBP increases in many exercises did not occur (Cunha et al., 2021). The BP is physiologically a product of cardiac output and peripheral vascular resistance (Beevers et al., 2001), and the cardiac output is determined by the stroke volume and heart rate (Beevers et al., 2001).Any change in one or more of these parameters logically affects BP. It is noteworthy that, though statistically significant, the rise in BP in our study was within the acceptable range (James et al., 2014).

The BP increase immediately after exercises shown in our study can be justified for acute physiological adaption due to increased energy demand, increased heart rate, and stroke volume, which will increase cardiac output (Beevers et al., 2001). These findings are consistent with those from other studies using anaerobic cycle ergometer in a protocol, sample size, and intensity similar to ours (Forjaz et al. 1998) and also with hypertensive older adults in aerobic and anaerobic exercises, such as strength exercise (Cunha et al., 2021), aquatic exercise (Cunha et al., 2018), and also, cycle ergometer (Rondon et al., 2002; Cunha et al., 2021). None of these studies reported a marked decline in BP immediately after exercise (Min 0).

The DBP increased immediately after the session only in P-Bike.A physiological mechanism justifies this response. The DBP is directly related to peripheral vascular resistance (PVR) (Beevers et al., 2001), which is controlled by an increasing (vasoconstriction) or decreasing (vasodilation) vessel contraction based on each body area and its metabolic demand, redistributing blood flow for active muscle areas. Differences in active muscle mass size may also account for the differences in energy demand (Beevers et al., 2001; Almeida et al., 2010). When cycling on a mixed cycle ergometer with lower and upper limbs together simultaneously, there is more muscle mass working compared to a bike that uses only lower limbs, so the vessel vasodilatation will be higher in these active areas to increase blood flow, lowering the PVR and the DBP responses, as seen immediately after P-Mixed. Relative to BP response to muscle mass involved in the exercise, Almeida et al. (2010) studied the BP in young people after two incremental ergometric protocols using bikes and arm-cranking, and the DBP declined only after the bike cycle ergometer session, but not in the arm-cranking session, reinforcing that larger muscle groups presented more vasodilation and reduced PVR, impacting the DBP reduction.

In the after moments, there was a decrease in SBP for both protocols, greater in the P-mixed (Min 30: Δ-2.8 vs. Δ-5.3mmHg and Min 45: Δ-3.3 vs. Δ-4.9mmHg for P-Bike and P-Mixed, respectively), but both without significance. A classic study with a cycle ergometer in young people found similar results toours. They submitted a group of young individuals to a 30-minute bike cycle ergometer session in different intensities, and they did not observe any BP fall in SBP for all intensities. Unlikeours, Almeida et al. (2010) found an SBP reduction after a bike and arm-cranking session, but for DBP, there was a reduction only after the bike. Although there was no Post-Exercise Hypotension (PEH) in the present study, there was a greater reduction in P-Mixed, probably derived from mass muscle size, generating more physiological adaptation, production of nitricoxide, and better control of cardiovascular variables like cardiac output (Beevers et al., 2001). Many factors influence the PEH and can help to understand the absence of significant PEH. This phenomenon is related to many variables, such as age, BP state, exercise type, duration, and intensity (James et al., 2014;Forjaz et al., 1998; Cunha et al., 2021).

Furthermore, these data further did not support that post-exercise hypotension (PEH) occurs in young people until 45 minutes after both aerobic cycle ergometer protocols. Nevertheless, our study showed that mixed cycle ergometers should be safe because BP changes were not risky and did not bring about an unfavorable rise in BP levels, which is quite significant for different clinical populations. However, it should be noted that aerobic exercise can be carried out in different modalities and types of exercise. Cycle upper and lower limbs can adapt to the cardiovascular system and many other physiological variables.

5. Study Limitations

The study's main limitation is the conduction in a laboratory setting, making it difficult to perceive the reality in the local environment where these people practice exercises.

6. Conclusion

A significant increase in blood pressure was found immediately after both aerobic ergometer protocols, but it was a safe increase of a small magnitude. The P-Bike has increased the PAD. BP returned to baseline within 15 minutes and remained stable until 45 minutes after exercise. At 30 and 45 minutes, there was a decrease in SBP, greater in P-Mixed but without significance. These findings support the mixed cycle ergometer's safe prescription in low to moderate intensity. Therefore, there is a need for studies that aim to evaluate different audiences, ages, and diseases with measurements for a longer time, which will contribute to a better understanding of the mixed cycle ergometer.

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