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POST-EXERCISE HYPOTENSION AFTER MAXIMAL INTENSITY EXERCISE AND THE EFFECT OF BEETROOT ON BLOOD PRESSURE RESPONSE: A RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Purpose: We investigate the effects of a running exercise session until exhaustion on the post-exercise pressure response and to see if beetroot changes this response. Materials and Methods: Normotensive recreational male street runners (39.2 ± 8.6 years, n= 17) performed two running to exhaustion at 80% of VO_2 max: 1-preceded by intake of 140mL of beetroot juice (BET); or 2-control drink (CON). Measurements of blood pressure (BP) were performed at rest, immediately after exercise and every 10 min during 60 min recovery after exercise. Nitrite, malondialdehyde and total antioxidant capacity were measured before, 2 hours after ingestion of drinks and after exercise. Results: The BP decreased in both procedures at 60 minutes post-exercise in relation to the pre-exercise moment: systolic BP (BET: 108.9 ± 8.0 to 95.4 ± 5.1, p <0.05; CON: 109.4 ± 8.5 to 93.4 ± 5.3, p <0.05); diastolic BP (BET: 76.8 ± 6.2 to 66.4 ± 1.5 p <0.05; CON: 75 ± 65.4 to 65.5 ± 1.0, p <0.05), with no difference between procedures. Conclusion: Exercise until exhaustion promotes a significant reduction in BP, but intake of a single dose of beetroot juice before exercise does not promote additional effects on the post-exercise hypotensive response in recreational runners. Trial registration number and date of registration: RBR-9ydn4bn, June 09, 2022.

Key words: Post-Exercise Hypotension. Beetroot Juice. Exercise until exhaustion.

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RESUMO

Hipotensão pós-exercício após exercício de intensidade máxima e efeito da beterraba na resposta pressórica: ensaio clínico randomizado

Objetivo: Investigamos os efeitos de uma sessão de exercício de corrida até a exaustão na resposta da pressão arterial pós-exercício e se a beterraba altera essa resposta. Materiais e métodos: Corredores recreacionais do sexo masculino, normotensos (39,2 ± 8,6 anos, n=17) realizaram duas corridas até a exaustão a 80% do VO_2 máximo: 1 - precedida pela ingestão de 140 mL de suco de beterraba (BET); ou 2 - bebida controle (CON). Medições da pressão arterial (PA) foram realizadas em repouso, imediatamente após o exercício e a cada 10 minutos durante 60 minutos de recuperação após o exercício. Nitrito, malondialdeído e capacidade antioxidante total foram medidos antes, 2 horas após a ingestão das bebidas e após o exercício. Resultados: A PA diminuiu em ambos os procedimentos 60 minutos após o exercício em relação ao momento pré-exercício: PA sistólica (BET: 108,9 ± 8,0 para 95,4 ± 5,1, p < 0,05; CON: 109,4 ± 8,5 para 93,4 ± 5,3, p < 0,05); PA diastólica (BET: 76,8 ± 6,2 para 66,4 ± 1,5, p < 0,05; CON: 75 ± 65,4 para 65,5 ± 1,0, p < 0,05), sem diferença entre os procedimentos. Conclusão: O exercício até a exaustão promove uma redução significativa na PA, mas a ingestão de uma única dose de suco de beterraba antes do exercício não promove efeitos adicionais na resposta hipotensiva pós-exercício em corredores recreativos. Número de registro do ensaio e data de registro: RBR-9ydn4bn, 09 de junho de 2022.

Palavras-chave: Hipotensão pós-exercício. Suco de beterraba. Exercício até a exaustão.

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INTRODUCTION

The practice of physical exercise reduces blood pressure (BP) both chronically (Börjesson et al., 2016) and after a single session (Cardoso Jr et al., 2010) a phenomenon known as post-exercise hypotension (PEH).

This hypotensive effect can endure for several hours (Marques-Silvestre et al., 2014). This phenomenon has been demonstrated after dynamic aerobic exercises at moderate and constant intensity (between 50 and 80% of VO_2 max) (Laterza et al., 2007), which is the form usually adopted by people who practice running or walking exercises (Silva et al., 2017).

However, the participation of non-athletes in street running events has grown in recent years around the world, so it has been common for these people to perform running exercises until exhaustion in training and recreational competitions, a different form of exercise that has been consolidated by the potential to promote PEH (García-Pinillos et al., 2017).

Exercise until exhaustion can inhibit PEH, because of increased production of catecholamines and greater sympathetic activity in this type of exercise (Halliwill et al., 2013).

This is particularly important for the recreational runner population, because this population has an average age over 40 years old, precisely period in which the incidence and prevalence of hypertension increases (Buford, 2016).

However, the pressure response after these exercise sessions practiced until exhaustion is still little studied.

A systematic review showed that beetroot is able to improve the tolerance and performance of recreational athletes (Van De Walle, Vukovich, 2018).

Interestingly, in addition to improving performance, beetroot also promotes a reduction in BP in the first hours after intake, a temporal behavior similar to PEH (Ashworth, Bescos, 2017).

The nitrate present in beetroot and its transformation into nitric oxide (NO) is the mechanism that explains the beneficial effects of beetroot both in increasing performance (Nyakayiru et al., 2017) and in BP reduction (Webb et al., 2008).

It is possible to hypothesize that beetroot can modify the pressure response after this exercise, leading to a greater vasodilator response, greater reduction in blood pressure after exercise or mitigate the possible hypertensive effect of an exercise performed until exhaustion.

Therefore, the aim of this study was to investigate the effects of a running exercise session until exhaustion on the post-exercise pressure response and to see if beetroot changes this response.

MATERIALS AND METHODS

Participants

The study was carried out with 17 recreational male street runners, aged 39.2 ± 8.6 years. Normotensive runners were chosen because the pressure response after exercise until exhaustion is not well known, which could be a hypertensive response, and consequently unsafe for hypertensive patients.

The sample size was calculated as proposed by Eng (2003), based on the study by (Christofaro, Casonatto, 2008) with normotensive men in which an aerobic exercise session promoted a systolic PEH of 8.2 mmHg, which resulted in an effect size of 1.60, for an alpha error of 5% and sampling power of 95%, the minimum sample for this study would be 6 participants.

Runners were recruited from the environments in which they performed their training. Inclusion criteria for participants were: pre-exercise pressure values lower than 130/85 mmHg (Barroso et al., 2021), to have been running for at least one year and had been training uninterruptedly for at least three months, with a minimum of three weekly running sessions and two days of other complementary physical activities, in addition to training in order to participate in long-running running competitions, do not have chronic degenerative diseases, no smokers e no made continuous use of any medication. Subjects who do not participate in all experimental procedures or had gastrointestinal discomfort with beetroot juice or control drinks were excluded.

Ethical Considerations

The study was submitted to the Human Research Ethics Committee of the Health Sciences Center (CCS), being approved under protocol Nº 0640/16. All subjects who participated in the research signed the free and informed consent form, according to resolution 466/12 of the National Health Council.

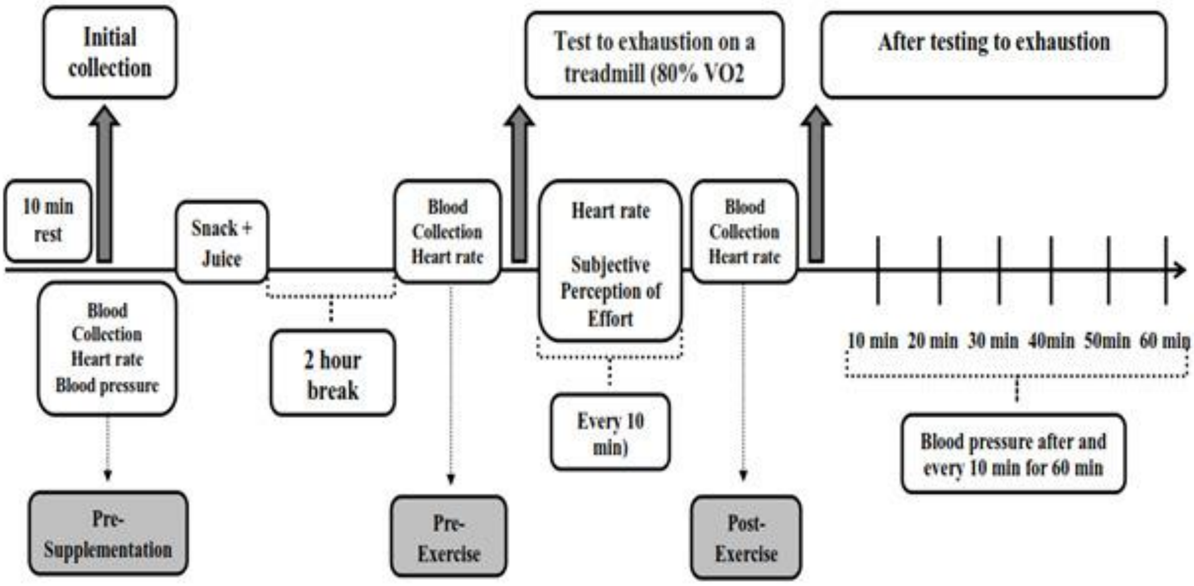

Figure 1 - Design of the experimental procedure.

Study design

This was a randomized, double-blind, placebo-controlled clinical trial with cross over. Initially, a test was performed to determine aerobic capacity (3,200 meters).

Two procedures were performed with running to exhaustion preceded by intake of beetroot juice or control drink randomly by researcher not involved with the study (www.randomizer.org).

The supplementation was performed two hours before exercise on a treadmill at 80% VO_2 max. Heart rate and subjective perception of effort were taken every 10 minutes during the exercise.

Blood pressure was measured at rest, immediately after exercise and every 10 minutes for one hour after exercise. Blood samples were taken before ingestion of beetroot juice or control drink, 2 hours after ingestion of beetroot juice and after exercise until exhaustion. Consort 2025 was adoped (https://www.consort-spirit.org/).

Preparation for exercise procedures

The volunteers were instructed to suspend physical exercise 48 hours before the test that determined aerobic capacity and anaerobic threshold, as well as before experimental sessions. They were instructed not to ingest nutritional supplements, foods that are sources of antioxidant vitamins and rich in NO_3 during the study in order to ensure the exclusion of any effects associated with food on the experimental procedure.

In addition, refrain from consuming caffeine and alcoholic beverages 6 and 24 h, respectively, before each trial, and from using oral antiseptics throughout the experiment, as these are known to eradicate the oral bacteria that are necessary for conversion from NO_3^- to NO_2^- (Govoni et al., 2008).

Food consumption was assessed before the start and during the study using the 24-hour food record (Gibson, 1990).

Food intake was monitored the day before and on the day of the experimental sessions with beetroot juice and control. The individuals were instructed to maintain their usual eating patterns.

Supplementation protocol

The subjects arrived at the laboratory for at least 8 hours fast and had a standardized breakfast (sandwich with cheese) containing 55.9 g of carbohydrates, 14.3 proteins and 9.4 g of fat. The sandwich was accompanied by 140 ml of beetroot juice or control drink, ingested two hours before the test until exhaustion.

An experimental drink was commercial beetroot juice (Beet It Sport, James White Drinks, Ipswich, UK), 98% concentrated beetroot juice and 2% lemon juice. Two 70 ml bottles of the juice were used, for a total consumption of 140 ml according to the dose adopted by (Wylie et al., 2013). Ingestion was performed two hours before exercise.

The control drink had a color similar to beetroot juice and consisted of a juice with artificial grape flavor without antioxidants and without nitrate, developed for specific research purposes (Aliança Premier, Vinícola Nova Aliança, Flores da Cunha-RS, Brazil). The athletes consumed 10 ml/kg/day, and each 200mL of the drink had an energy value of 140kcal and 33g of CHO.

Test until exhaustion

Initially a determination of the maximum aerobic capacity was made, by means of a test following the protocol proposed by (Weltman et al., 1987) (3200m in the shortest possible time).

A week later, the experimental sessions started. Following the order previously established in the randomization, the athletes performed a running exercise until exhaustion at 80% of VO_2 max, with supplementation of beetroot or a control drink, with a difference of one week between each procedure on a treadmill (Moviment, São Paulo, Brazil) in an air-conditioned environment, with temperature between 22 and 25ºC and air humidity around 65%, controlled by thermohygograph (TFA HT-7429, São Paulo, Brazil). To control the intensity, a Polar cardiofrequency meter, model RS800CX (Polar Electro® Oy, Kempele, Finland), to record heart rate every 10 minutes. Borg's effort perception scale (Borg, 1982) used to obtain the sensation of effort of the athletes during this race. The criterion for interrupting the test was the inability to keep up with the determined speed, even in the face of verbal stimulus from the researchers. The result was given in minutes and seconds of running.

Blood pressure

It was measured at rest, immediately at the end of the exercise and every 10 minutes during the 60 minutes period. It was measured by the auscultatory method using an aneroid sphygmomanometer Welch Allyn (WELCH ALLYN INC, Nova York, EUA) previously calibrated against a column of mercury following the VI Brazilian Guidelines on Hypertension (Sociedade Brasileira de Cardiologia/Sociedade Brasileira de Hipertensão/Sociedade Brasileira de Nefrologia, 2010).

All measurements were made in a sitting position. At the end of the exercise, the subjects were asked to sit down immediately and remained in this position for 60 minutes when blood pressure was monitored every 10 minutes.

Biochimical analysis

Malondialdehyde (MDA) - The oxidant activity of malondialdehyde (MDA) was quantified by the reaction of thiobarbituric acid with the products of decomposition of hydroperoxides, according to the method described by Ohkawa, Ohishi and Yagi (1979).

Total Antioxidant Capacity (TAC) - The total antioxidant capacity (TAC) was quantified in plasma via the 2,2-diphenyl-1-picrylhydrazyl free radical sequestering activity by the method described by Brand-Williams, Cuvelier and Berset (1995).

Plasma Nitrite - Concentrations of plasma nitrite was determined by the Griess reaction that quantifies the nitrite in the sample through the diazotization reaction forming a pink-colored chromophore. The reagent will be prepared using equal parts of 5% phosphoric acid, 1% sulfanilamide in 5% phosphoric acid, 0.1% dihydrochloride-ethylenediamine-N (1-Naphtyl) (NEED) and distilled water. Nitrite / nitrate detection shall be followed by the addition of 500 µL Griess reagent to 500 µL of the plasma. After 10 minutes, the absorbance was measured in a spectrophotometer (Biospectro SP-22, Curitiba, Brazil) at a wavelength of 532nm. The nitrite concentrations were calculated by extrapolation to a standard curve of NaNO2 and the data expressed in micromoles (Green et al., 1981).

Statistical Analysis

The data were expressed as mean and standard deviation from the mean. After testing the data for normality and homogeneity using the Shapiro-Wilk and Levine tests, the two-way ANOVA test was used for repeated measures to verify differences in BP, nitrite concentrations, MDA and TAC in the different protocols. The analyzes were performed using SPSS software version 26 (IBM SPSS, Chicago, IL, USA), adopting significance of $p<0.05$.

RESULTS

All runners trained at least three times a week, with 50% practicing five times a week, 40% six times a week and 10% three times a week. All performed complementary activities in addition to running training, being these, weight training (70%) or cycling (30%).

As shown in table 2, they were eutrophic, and had VO_2 max above the limits considered excellent for health purposes, according to the American Heart Association (Fletcher et al., 2013), but well below the aerobic capacity of top level athletes, which characterizes them as recreational athletes.

They presented average values of arterial pressure considered excellent, according to the Brazilian Society of Hypertension (Barroso et al., 2021).

In the evaluation made before each session of the experimental procedures, they were shown with initially similar values for resting blood pressure, nitrite and TAC.

Table 1 - Baseline characteristics of the study subjects (n=17).

Characteristics		M±SD	
Age (years)		39.2±8.6	
BMI (kg/m^2)		23.6±2.1	
Body fat (%)		24.1±3.8	
RHR (bpm)		55.8 ± 8.4	
VO_2 máx (ml/kg/min)		55.2±6.1	
Training time (years)		12.1±8.5	
Training frequency (days/week)		5.2±0.9	
Weekly volume (km)		63.3±12.6	
Work (hours/day)		74±1.1	
Sleep (hours/day)		7.1±0.5	
ESE-BR		4.4±2.5	
	Beetroot juice	Control	P-value
SBP (mmHg)	108.9 ± 8.0	109.4 ± 8.5	0.77
DBP (mmHg)	76.8 ± 6.2	75 ± 1.7	0.35
Nitrite (μM)	13.6 ± 7.8	12.3 ± 7.9	0.49
MDA (μM)	3.9 ± 0.2	4 ± 0.2	0.008
TAC (%)	23.3 ± 8.8	21.2 ± 9.8	0.24

Legend: BMI – body mass index; RHR – resting heart rate; VO2máx: maximum volume of oxygen; ESS-BR – Epworth Sleepiness Scale – Brazil (Bertolazi et al., 2009); SBP – systolic blood pressure; DBP – diastolic blood pressure; MDA – malondialdehyde; TAC – total antioxidant capacity. Data are show as mean ± standard deviation.

Figure 2 illustrates the plasma concentration of nitrite in the pre and post-exercise.

The concentration of nitrite after ingestion of beetroot juice had a significant post-exercise increase compared to the control group ($p=0.035$).

Before exercise and after the supplementation of beetroot juice, there was an increase in the concentration of nitrite, although this increase was not significant between the pre and post-exercise period ($p=0.240$)

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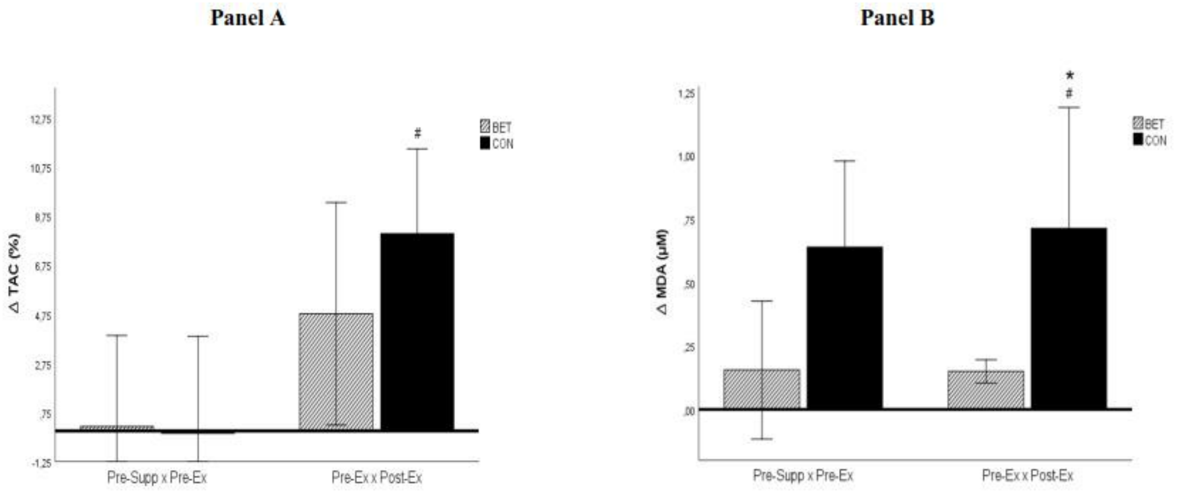

Figure 2 - Delta values for nitrite concentration before and after an exercise session. Data are show as mean ± standard deviation. Pre-Supp x Pre-Ex: difference between the time before exercise and beetroot supplementation or control condition that occurred 2 hours before; Pre-Ex x Post-Ex: difference between the moment before exercise and the moment immediately after exercise; BET: beetroot juice; CON: control drink; *indicates statistical difference between procedures. There was a statistical difference between the groups (p=0.035).

Plasma concentrations of MDA and TAC in response to experimental procedures are shown in figure 3. Beetroot juice prevented an increase in lipid peroxidation caused by the exercise session, since the MDA was increased at the end of the exercise of the control procedure, both in relation to the value before the exercise of this same procedure and in relation to the after the procedure with beetroot intake. Meanwhile, the MDA values have not changed within the juice intake procedure.

On the other hand, beetroot did not intervene in the antioxidant capacity, since there was an increase of 20.6% and 37.7% in the antioxidant activity from the pre to the post-exercise moment in the procedures with juice and placebo, respectively. However, this increase was significant only in the control procedure (p=0.001). There was no difference between procedures post exercise (p=0.571).

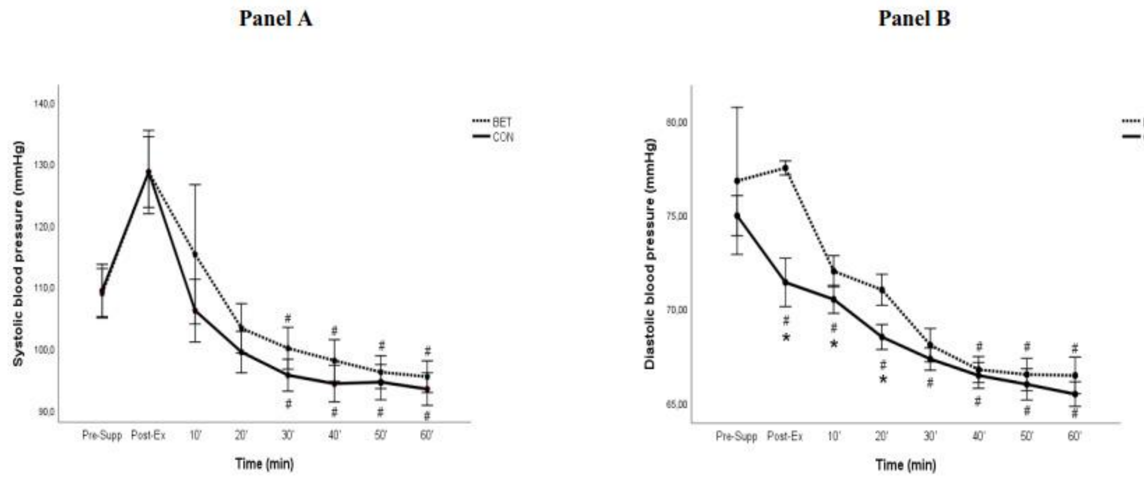

Figure 3 - Delta values for MDA e TAC before and after an exercise session. Data are show as mean ± standard deviation. Pre-Ex: difference between the time before exercise and beetroot supplementation or control condition that occurred 2 hours before; Post-Ex: difference between the moment before exercise and the moment immediately after exercise; BET: beetroot juice; CON: control drink; MDA: malondialdehyde; TAC: total antioxidant capacity *indicates statistical difference between procedures;

#indicates statistical difference in relation to the pre-exercise moment. There was a statistical difference between the procedures for malondialdehyde (p=0.004).

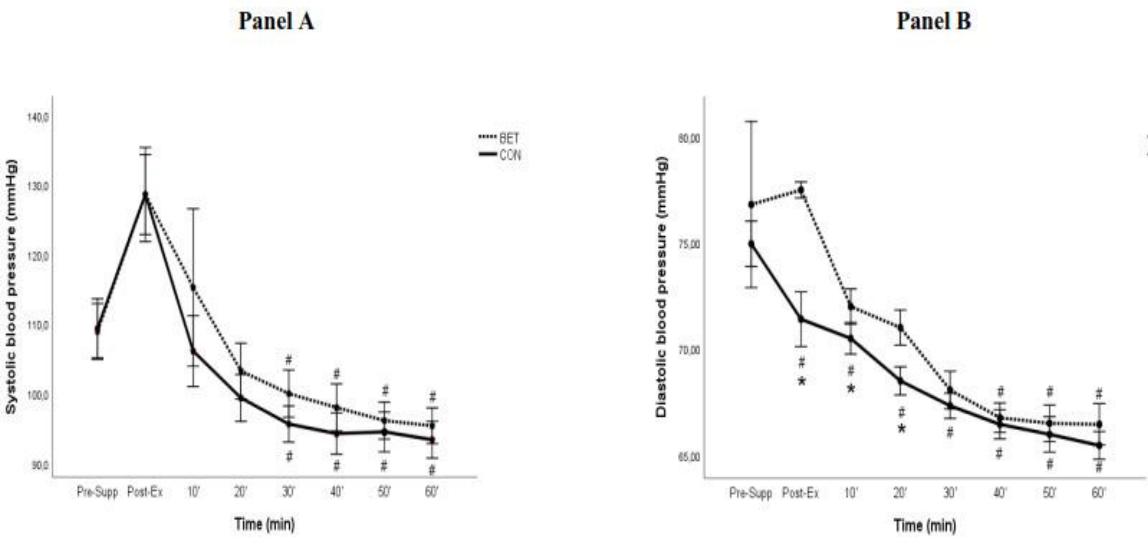

Figure 4 - Systolic and diastolic blood pressure after exercise, immediately exercise and every 10 minutes after exercise. Data are show as mean ± standard deviation. Pre-Supp: pre-supplementation; Post-Ex: immediately post-exercise; BET: beetroot juice; CON: control drink; *indicates statistical difference between procedures; #indicates statistical difference in relation to the pre-exercise moment. There was a statistical difference between groups for diastolic blood pressure (p=0.023).

SBP and DBP are shown in figure 4. Both procedures resulted in a significant reduction in SBP from 30 minutes after exercise. The procedures resulted in a significant reduction in SBP 60 minutes after exercise in relation to the pre-supplementation values, that is, before exercise (BET: 108.9 ± 8.0 to 95.4 ± 5.1, p<0.05; CON: 109.4 ± 8.5 to 93.4 ± 5.3, p<0.05).

However, there was no significant difference in SBP between BET and CON conditions after the exercise session.

The exercise without supplementation was able to promote the reduction of the DBP from the moment immediately post-exercise in relation to the pre-exercise, while the procedure with the ingestion of beetroot juice was only able to promote a significant reduction 40 minutes after the exercise.

However, at 60 minutes after exercise in relation to the pre-supplementation time, both procedures significantly reduced the DBP (BET: 76.8 ± 6.2 to 66.4 ± 1.5 p <0.05; CON: 75 ± 65.4 to 65.5 ± 1.0, p<0.05).

Despite the apparent better diastolic hypotensive response in the control procedure, this is only because the pre-exercise values were lower in this condition.

DISCUSSION

Despite the demanding demand for exercise to the maximum effort, this study showed that a running until exhaustion session is able of promoting the phenomenon of PEH, so that the post-exercise hemodynamic response is safe in this population. On the other hand, despite the beetroot vasodilator potential, our data showed that this food does not modify the post-exercise pressure response.

Continuous exercise of constant and moderate intensity has been reported as promising to promote PEH (Carpio-Rivera et al., 2016).

The literature has shown that exercise protocols with intensity between 50% and 80% of HRMax, resulted in reductions of 18 to 20 mmHg in systolic BP and from 7 to 9 mmHg for diastolic BP (Kelley, Kelley, 2000).

This data is particularly important in recent years, that a new profile of exercise practitioners has emerged around the world, which are recreational runners. Whereas in the past people were instructed to practice moderate intensity exercise for the prevention and treatment of high blood pressure (Barroso et al., 2021) and chronic illnesses (Haskell et al., 2007). Currently, a large and growing portion of the population has been practicing street racing with their training and competitions until exhaustion.

Our study showed that the benefits that had already been demonstrated of moderate exercise in the post-exercise pressure response also extend to high intensity exercises, at least when the runner population is normotensive.

If this physiological pressure response also occurs in hypertensive patients, it is something that cannot be guaranteed from the data of the present study.

On the other hand, from the results of the present study, which show a safe blood pressure response for normotensive individuals, we have ethical evidence to move forward in studies with recreational runners who have arterial hypertension.

In the present study, we cannot determine with all the scientific rigor that exercise until exhaustion also promotes PEH, because in our study there was no control group. So, we propose that in the next studies, with hypertensive or normotensive, a control session be added without exercise, in order to better methodologically determine PEH.

The increase in nitrite is seen in all studies with beetroot supplementation (Kelly et al., 2013; Raubenheimer et al., 2017; Wylie et al., 2013). In fact, this increase is the marker that indicates the success of the supplementation protocol. Although, despite the increase in plasma nitrite that also occurred in our study, there was no effect on the post-exercise blood pressure response.

Beetroot has been extensively studied in the context of improving physical performance (Domínguez et al., 2017; Olsson et al., 2019), but recently the acute hypotensive effect has also been investigated due to the fact that nitric oxide has vasodilating properties, so that it promotes the reduction of blood pressure. This reduction in resting blood pressure a few minutes or hours after ingestion has been shown in meta-analyzes and systematic reviews (Bahadoran et al., 2017; Bonilla Ocampo et al., 2018; Siervo et al., 2013).

However, so far only two studies have investigated the effects of beetroot on PEH. Amaral et al., (2019) when investigating the additional effects of beetroot juice intake on PEH in postmenopausal hypertensive women, concluded that a single dose of beetroot juice was not able to promote significant changes in PEH, even with an increase in the salivary nitrate concentration. However, in addition to the population difference with our study, the exercise of menopausal women consisted of a continuous and moderate exercise session, while our study was up to 80% VO_2 max exhaustion.

On the other hand, Bezerra et al., (2019) when conducting a study with obese men who had a high cardiovascular risk profile, observed that a single dose of beetroot juice promoted a 5.3 mmHg reduction in SBP for 6 hours after a moderate intensity aerobic exercise session. Meanwhile, exercise with a control drink reduced only 3.8 mmHg, and this reduction was not significant. Similarly, in the previous study, the exercise protocol was different from the protocol used in our study.

The only study that showed the effect of beetroot after exercise until exhaustion was Buhl and Rodrigues (2017), who investigated the chronic supplementation of beetroot juice in healthy individuals, who practice physical activity.

The participants underwent a 5 km running test on a treadmill before and after 7 days of supplementation, but no significant change was observed in SBP and DBP. In this study, a chronic and non-acute effect of beetroot was measured.

An important aspect to be taken into account in the present study is that the individuals were normotensive. In a literature review with meta-analysis, Bahadoran et al., (2017) concluded that individuals with higher BP values show a more pronounced decrease after supplementation with beetroot juice, while PEH is more discreet in those who start exercise with pressure values close to normal. In addition, individuals with some pathology (such as hypertension, overweight, obesity) may benefit more than healthy individuals.

The present study showed that beetroot was able to prevent the increase in MDA, thus preventing lipid peroxidation.

Probably, the increase in MDA in this procedure induced the body to cause an antioxidant capacity. Thus, beetroot was able to prevent oxidative stress caused by exercise, by increasing the concentration of nitrite, but possibly blocked the body's antioxidant response. However, no improvement in total antioxidant capacity was observed.

Howatson et al., (2010) also demonstrated a reduction in MDA in healthy individuals with ingestion of cherry juice for 5 days.

It is known that physical exercise can promote oxidative stress, based on the production of reactive oxygen species. This oxidative stress produced is related to the duration and intensity of the exercise (Souza Jr. et al., 2005).

It should be noted that the present study was carried out with a single dose of beetroot juice, followed by an exercise session, which is an agent promoting lipid peroxidation (Cruzat et al., 2007).

In addition, studies showing increased antioxidant activity are chronic, with supplementation of some food for several days.

Although the results show that beetroot does not improve PEH, one of the limitations of our study is the absence of a control condition without exercise, which does not allow determining whether an exercise session until exhaustion is able to promote PEH, as occurs in moderate intensity exercises.

Anyway, both procedures resulted in a reduction in BP. In the procedure with beetroot juice there was systolic PEH of 13.5 mmHg and diastolic of 10.3 mmHg, while in the procedure without beetroot juice, systolic PEH of 16 mmHg and diastolic of 9.5 mmHg was observed, so that these data stimulate the realization of studies with the control condition to better determine the exercise potential until exhaustion to promote PEH.

Although the NO_3-NO_2-NO pathway is the most likely mechanism for the hypotensive effect of beetroot, further studies are needed to assess whether other substances are unrelated.

This study showed that exercise until exhaustion did not prevent PEH of runners. This is particularly important because the number of runners has increased a lot in recent years. As the participants in the study were normotensive, then beetroot was not shown to be necessary to mitigate any inadequate blood pressure response to exercise until exhaustion.

However, we still do not know the pressure response after exercise until exhaustion in hypertensive patients, so we recommend investigations with this public and the testing of the effect of the beetroot, in case the post-exercise pressure response in these hypertensive patients who practice running until exhaustion does not show so much physiological as in the normotensive individuals of the present study. It is also suggested to carry out studies with chronic supplementation to assess whether beetroot juice is able of increasing the body's antioxidant defense and promoting additional effects on PEH.

In conclusion, exercise until exhaustion is safe and beneficial for runners, because promotes a significant reduction in blood pressure, but intake of a single dose of beetroot juice before exercise does not promote additional effects on the post-exercise hypotensive response in recreational runners. We strongly recommend checking these outcomes in a population of runners who have hypertension.

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Federal University of Paraiba.

CONFLICTS OF INTEREST

The authors report no conflict of interest.

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