Can blood pressure decrease after maximal exercise test predict the blood pressure lowering effect of aerobic training in treated hypertensive men?

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What is known about this topic

- Significant correlations have been reported between the reductions in blood pressure observed after a maximal exercise test and after a period of aerobic training in healthy individuals.
- Blood pressure decrease observed after a maximal exercise test may be used to predict the blood pressure lowering effect of aerobic training in hypertensives.

What this study adds

- The decrease in blood pressure observed 30 min after a maximal exercise test was not associated with the blood pressure reduction induced by aerobic training in treated hypertensive men.
- The blood pressure reduction observed 30 min after a maximal exercise test cannot be used to predict hypertensives responders or non-responders to the blood pressure lowering effect of aerobic training.

Abstract

The acute decrease in blood pressure (BP) observed after a session of exercise (called post-exercise hypotension) has been proposed as a tool to predict the chronic reduction in BP induced by aerobic training. Therefore, this study investigated whether post-exercise hypotension observed after a maximal exercise test is associated to the BP-lowering effect of aerobic training in treated hypertensives. Thirty hypertensive men (50±8 years) who were under consistent anti-hypertensive treatment underwent a maximal exercise test (15 watts/min until exhaustion), and post-exercise hypotension was determined by the difference between BP measured before and at 30 min after the test. Subsequently, the patients underwent 10 weeks of aerobic training (3 times/week, 45 min/session at moderate intensity), and the BP-lowering effect of training was assessed by the difference in BP measured before and after the training period. Pearson correlations were employed to evaluate the associations. Post-maximal exercise test hypotension was observed for systolic and mean BPs (-8 ± 6 and -2 ± 4 mmHg, all $P<0.05$). Aerobic training reduced clinic systolic/diastolic BPs (-5 ± 6/-2 ± 3 mmHg, both $P<0.05$) as well as awake and 24h mean BPs (-2 ± 6 and -2 ± 5 mmHg, all $P<0.05$). No significant correlation was detected between post-exercise hypotension and the BP-lowering effect of training either for clinic or ambulatory BPs (r values ranging from 0.00 to 0.32, all $p > 0.05$). Post-exercise hypotension assessed 30 min after a maximal exercise test cannot be used to predict the BP-lowering effect of aerobic training in treated hypertensive men.

Keywords: Aerobic exercise; Maximal Exercise Test; Post-Exercise Hypotension; Clinic Blood Pressure; Ambulatory Blood Pressure; Hypertension.

INTRODUCTION

Hypertension is an idiopathic chronic disease, affecting 31% of adults worldwide, and indirectly responsible for about 14% of the all-cause deaths [1]. Although pharmacological treatment decreases blood pressure (BP), rates of BP control are still low (approximately 30%) [2], and a better control may be obtained by its association with aerobic training (AT) [3–5]. Strong evidence shows that AT reduces clinic and ambulatory BPs in hypertensives [6] with the magnitude of reduction being similar to the pharmacological treatment [7]. Therefore, AT is recommended for hypertension treatment [3–5], but approximately 25% of the hypertensives may not respond to AT with BP decrease [8], being important to find tools to detect these non-responder patients.

A single session of aerobic exercise induces an acute and long lasting decrease in BP during the post-exercise period that has been called post-exercise hypotension (PEH) [9–11]. It has been proposed that PEH may be used to predict the chronic BP-lowering effect of AT [10, 11]. Therefore, for clinical application, it would be useful if PEH after a maximal exercise test, a procedure already used in the pre-training screening of hypertensives [3, 12], could predict the BP-lowering effect of AT.

Some studies reported strong correlations between the BP decrease observed after a maximal exercise test and the BP reduction obtained after a period of AT in healthy individuals [13, 14]. However, this association was not found in patients with chronic kidney disease who were receiving antihypertensive drugs [15], suggesting that it might not happen in treated hypertensives, which needs to be checked. Additionally, the studies reporting significant associations have employed the same initial BP to calculate both, PEH and the BP-lowering effect of AT [13, 14]. This procedure might result in a mathematical coupling known as regression to the mean that is a well-known experimental pitfall, and can lead to spurious significant correlations [16, 17]. Thus, a more robust experimental design is still needed to confirm the association.

Therefore, the present study investigated the association between PEH after a maximal exercise test and the BP-lowering effect of AT in hypertensive men receiving antihypertensive medication and used different initial BPs to calculate PEH and the BP-lowering effect of AT.

METHODS

This study employed secondary data from a randomized controlled trial designed to compare the BP-lowering effects of morning and evening AT in treated hypertensive men. The main results were published elsewhere [18]. The study was approved by the Research Ethical Committee of the School of Physical Education and Sport (no. 966.072) and registered in the Brazilian Clinical Trials platform (RBR-7q7pz7). All patients signed a written consent form before enrollment.

Subjects

The patients were recruited through printed and digital media. As study's criteria, patients should: i) be male; ii) age between 30 and 65 years old; iii) present hypertension and be taking antihypertensive medications with classes and doses constant for at least the last 4 months; iv) have resting systolic/diastolic BP ≤ 160/105 mmHg; v) present neither chronotype (i.e. scores between 41 and 59 in the Horne and Ostberg morningness-eveningness questionnaire); vi) not be taking β-blockers or dihydropyridine calcium channel blockers; (vii) be nonactive (practicing < 150 min/week of physical activity according to the International Physical Activity Questionnaire); and viii) not have physical limitations to perform aerobic exercise. The patients were excluded if they presented: i) obesity at stage 2 or higher (i.e. body mass index ≥ 35 kg/m^2); ii) diabetes with complications or in use of insulin; iii) hypertensive target-organ damage; iv) other cardiovascular diseases besides hypertension; and v) electrocardiogram abnormality at rest or during an exercise test.

Preliminary Exams

To check accomplishment to the study's criteria, the patients underwent preliminary evaluations. They were interviewed regarding their health history, medication use and physical activity practice, and answered the Horne and Ostberg's morningness-eveningness [19] and the International Physical Activity [20] questionnaires. They underwent a clinical exam performed by a physician, and their body mass and height were measured. Their BP was measured three times after 5 min of seated rest on two different occasions. Finally, blood and urine samples were collected to evaluate the presence of secondary hypertension and target-organ damage according to the Brazilian Guideline for Hypertension [3].

Procedures

Before and after 10 weeks of AT, the patients who fulfilled the study's criteria attended to the laboratory for two different visits conducted with an interval of at least 48h. One visit was dedicated to evaluate PEH by measuring BP before and at 30 minutes after a maximal exercise test. The other visit was used to evaluate the chronic BP-lowering effect of AT by measuring clinic and ambulatory BP. After the training period, the visits were conducted at least 48 hours after the last training session.

Assessment of PEH after the maximal exercise test

Maximal exercise test was conducted in a temperature controlled (20-22ºC) laboratory between 7 and 9 a.m. The patients were instructed to have a light meal two hours before, to avoid caffeinated beverages and smoking in the testing day, and to avoid alcoholic drinks and vigorous physical efforts in the previous 24 hours. The test was carried out on a cycle ergometer (Lode Medical Technology, Corival, Groningen, Netherland) with a ramp protocol of 15 watts increment each minute until the patients were unable to keep pedaling frequency at 60 rpm. The test was preceded by a 3-min warm-up at 30 watts and followed by a 5-min cool-down period pedaling at 30 watts. During the test, auscultatory BP (Unitec, São Paulo, Brazil) was measured every two minutes, electrocardiogram (EMG System, 030110/00B, São Paulo, Brazil) was continuously recorded, and breath-by-breath oxygen consumption (VO_2) was continuously analyzed by a metabolic card (CPX Ultima, Medical Graphics Corporation, St. Paul, MN). VO_2peak was considered as the highest value achieved during exercise in means of 30s. For 10 min before and 30 min after the test, the patients rested seated on a comfortable chair. At the end of each of these moments, BP was measured three times with an interval of 1 min, and the mean value was calculated. The measures were taken by an experienced evaluator, using the auscultatory method and a mercury column sphygmomanometer (Unitec, São Paulo, Brazil). PEH was calculated by the difference between the BP measured after (at 30 min) and before the maximal exercise test conducted before the training period.

Assessment of the effect of AT on clinic and ambulatory BPs

Before and after the training period, in a visit different from the maximal test, clinic BP was measured using the auscultatory method and a mercury column sphygmomanometer (Unitec, São Paulo, Brazil). The measurements were performed 3 times after 5 min of seated rest and with an interval of 1 min between the measures. The mean of the three measures was considered as the clinic BP. In the same day, an oscillometric ambulatory BP monitor (Spacelabs Healthcare, 90207, USA) was positioned on the non-dominant arm of the patients, and they left the laboratory being instructed to perform their normal daily activities and to come back to the laboratory after 24h. The monitor was programmed to take measures every 15 min for 24 hours, and the patients were instructed to avoid physical efforts during the monitoring. Additionally, they should record their daily activities and take notes regarding the time of sleeping and awaking. In the monitoring conducted after the training period, the patients were asked to keep the same daily activities as in the pre-training monitoring. For analyses, only records that presented at least 85% of the measures valid were considered. Twenty-four hour, asleep and awake BP were calculated, respectively, by the average of all measures taken during whole monitoring period, the period that the patient reported to be sleeping and the period that he reported to be awake. The clinic BP-lowering effect of AT (Δclinic BP) was determined by the difference in clinic BP measured after and before the training period, while the ambulatory BP-lowering effect of AT (Δambulatory BP) was determined by the difference in 24-h, awake and asleep BP assessed after and before the training period.

AT protocol

AT was performed on cycle ergometer (CEFISE, Biotec 2100, Campinas, Brazil), 3 times per week for 10 weeks. Training duration and intensity progressed along the training period. Exercise duration increased from 30 to 45 min in the first two weeks of training and this duration was maintained until the end of the training period. Exercise intensity was set at the heart rate of the anaerobic threshold during weeks 1 to 4 and increased progressively to achieve 10% below the heart rate of the respiratory compensation point at weeks 9 and 10. The maximal exercise test conducted before the training period was used to establish the anaerobic threshold and the respiratory compensation point according to literature criteria [21]. During the training sessions, heart rate was monitored (POLAR 800cx, Kempele, Finland) to keep intensity within the desirable range.

Statistical Analysis

Since this study used a database from a bigger study [18], sample size was originally calculated for the main variable of the bigger study and accepted by convenience for this investigation. Normality of data was evaluated by Shapiro-Wilk test. Paired t-test were used to confirm the occurrence of PEH (pre- vs. post-maximal exercise test) and the effect of AT (before vs. after training). Pearson correlations and linear regressions were used to analyze the association between PEH and the clinic and ambulatory BP-lowering effect of AT. The analyses were performed in SPSS software (SPSS for windows; IBM, Chicago, IL). Data were expressed in mean ± standard deviation, and the level of significance adopted was $p \leq 0.05$.

RESULTS

A total of 68 patients signed the informed consent form to participate. After checking for the study criteria, 32 were excluded. Therefore, 36 patients were enrolled in the experimental protocol, but during the training phase, 6 patients dropped out. Thus, 30 patients finished the study´s protocol and had their data analyzed (Figure 1).

[FIGURE 1 ABOUT HERE]

The sample was composed by middle-aged hypertensive men, taking different types of antihypertensive drugs, mostly as monotherapy (Table 1). Maximal exercise tests were interrupted by fatigue in all patients.

[TABLE 1 ABOUT HERE]

Adherence to training sessions was 96 ± 4%. VO_2peak increased significantly after AT (VO_2peak = 21.4 ± 3.3 vs. 23.1 ± 4.2 $mL.kg^{-1}.min^{-1}$, p = 0.04), while weight did not change (88.6 ± 13.3 vs 88.3 ± 13.0 kg, p = 0.21).

Maximal exercise test promoted PEH, significantly reducing systolic and mean BPs, but not diastolic BP (Table 2). AT decreased clinic systolic, diastolic, and mean BPs (Table 3). Considering ambulatory BP, AT significantly reduced 24h and awake mean BPs; tended to reduce 24h and awake diastolic BPs; and did not significantly change 24h, awake and asleep systolic BPs nor asleep diastolic and mean BPs (Table 3).

[TABLE 2 AND 3 ABOUT HERE]

Considering the main objective of the study, no significant association was observed between the systolic or diastolic BP changes observed after the maximal exercise test (PEH) and the changes in clinic or ambulatory BPs observed after AT (Table 4, Figure 2).

[TABLE 4 AND FIGURE 2 ABOUT HERE]

DISCUSSION

This study investigated the association between PEH assessed 30 min after a maximal exercise test and the chronic BP reduction induced by AT in treated hypertensive men using an experimental design that overcame previous limitations. The existence of such association would have supported the use of BP reduction observed after a maximal exercise test as a clinical tool to identify those hypertensives who would mostly respond to AT with BP reduction. However, contrary to this expectation, the main finding of the present study was that there was no association between PEH assessed 30 min after a maximal exercise test and either the clinic or the ambulatory BP reduction induced by 10 weeks of AT.

In the present study, maximal exercise test induced PEH, decreasing systolic BP by -7.6 ± 5.7 mmHg, which is in accordance with the previous studies that also reported PEH after maximal exercise tests in health individuals [13, 14]. Additionally, as expected, AT increased VO_2peak as previously reported [18], and promoted significant reductions in clinic systolic/diastolic BPs (-4.6 ± 6.4 / -1.8 ± 3.2 mmHg) as well as in some parameters of ambulatory BP (24h and awake mean BPs, -2.1 ± 4.9 and -2.3 ± 6.0 mmHg, respectively). These BP reductions were lower than those reported in a recent meta-analysis [6], but may have clinical importance since a -5 mmHg decrease in clinic systolic BP may be associated with a reduction of 14% in the risk of death from stroke and 9% from coronary heart disease [22].

Regarding the use of PEH after a maximal test to predict the BP-lowering effect of AT, the present findings do not support this application in treated hypertensive men as no significant association was observed between the acute and chronic responses of BP to aerobic exercise. This absence of association was also reported in patients with chronic kidney disease [15], but differs from prior findings of strong associations reported in healthy individuals [13, 14]. Some factors may be raised to explain the discrepancy among the studies. First, the time after the maximal exercise test when PEH was assessed may influence the association. The previous studies that have reported significant associations assessed PEH at 7 [14] and 60 min [13] after the maximal exercise test, while the present study assessed PEH at 30 min, a midpoint between these periods, which suggests that the time of measurement may not have been the reason for the absence of association. However, a recent review conducted by our group [23] reported that in many studies the greatest PEH happened after 30 min of recovery, being possible that the use of other specific times points or the greatest reduction in BP after the exercise test could reveal a different result from using the assessment at 30 min of recovery. Nevertheless, this time point was employed in the present study based on the previous studies that have employed maximal exercise tests and on the feasibility in clinical routine, where a long-term assessment after a maximal exercise test is difficult. Another possible reason for the difference in the results of the present study in comparison with those that found significant correlations is the use of antihypertensive medication that may affect the relationship between the acute and the chronic responses of BP to exercise. Along this line, a recent meta-analysis concluded that PEH is less evident in patients receiving anti-hypertensive drugs [9], while the BP-lowering effect of AT is greater in patients receiving medication [24, 25]. Finally, an important explanation, as cited before, may be the mathematical approach adopted in the previous studies [13, 14] that considered the same initial BP for calculating both PEH and the BP-lowering effect of AT, which may have caused spurious significant correlations [16, 17].

The absence of association (i.e. a null result) between PEH assessed 30 min after a maximal exercise test and the BP-lowering effect of AT might seem an inconsequential finding. However, it may have important clinical impact considering the readiness to generalize the positive previous results obtained in healthy individuals [13, 14] to other populations. Therefore, despite the importance of maximal exercise test to guide AT for hypertensives, the findings of the present study do not support the use of the BP response measured after this test to identify responder and non-responders to AT among treated hypertensives. Therefore, other tools should be identified for this specific purpose. Along this line, in pre-hypertensives, PEH after a submaximal session of aerobic exercise (30 min at 65% of VO_2 peak) has been reported to be associated with the BP-lowering effect of AT [26], however, this relationship needs to be tested in treated hypertensives by future research.

Finally, we would like to highlight some of the strengths and limitations of the present study. The assessment of PEH and the BP-lowering effect of AT using different initial BP values reduces the chances for mathematical bias. Additionally, as all patients were under consistent anti-hypertensive treatment for 4 months or more, their clinical condition was stable, reducing any possible influence of medication changes. On the other hand, the results are limited to the study cohort's characteristics. Inactive middle-aged men under antihypertensive treatment were investigated. So, results cannot be generalized to women, physically active patients, other age groups, and untreated patients. These specific populations need to be studied in the future. Additionally, maximal tests were conducted in the morning. As BP presents daily variations, results could be different if tests were conducted at other times of day, which also should be tested in the future. As discussed before, PEH was assessed at 30 min after the maximal exercise test, and future research should test other times points and the association with the greatest PEH. Finally, a lack of statistical power due to a small sample may be a concern. However, the previous studies [13, 14] that revealed strong correlations used samples smaller than the present study (i.e. 12 and 23 subjects) for these calculations. In addition, if the sample size for this study had been calculated *a priori* based on the data of these studies and considering an alpha error of 5% and a power of 90%, the smaller number needed would be 20 subjects.

In conclusion, although a maximal exercise test generates PEH and AT decreases clinic and ambulatory BPs in medicated hypertensive men, these acute and chronic BP changes were not correlated. Thus, in this population, BP response assessed 30 min after a maximal exercise test cannot be used to predict the chronic BP-lowering effect of AT.

Data Availability Statement

Additional data will be provided by the corresponding author on reasonable request.

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Acknowledgements

The authors thank the volunteers for participating.

Author Contributions

LA and LCB collaborate to the study design, collected data, carried out the statistical analysis, contributed to the interpretation of results, and drafted the initial manuscript; TP, RF, RR collected data, and revised the manuscript; GS, AA, DMJ were responsible for patients clinical evaluation and follow-up, and revised the manuscript; JH contributed to the interpretation of results and revised the manuscript; CF designed the study, get grants for the study, supervised data collection, contributed to the interpretation of results and revised the manuscript. All authors gave final approval of the manuscript version submitted for publication.

Funding information

This study was supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP 2014/216676-6), Programa de Excelência Acadêmica (PROEX 88882.327719/2019-01), Conselho

Nacional de Desenvolvimento Científico e Tecnológico (CNPq 304436/2018-6), and Coordenação de Aperfeiçoamento Pessoal de Nível Superior–Brasil (CAPES, financial code 001).

Ethical Approval

All patients signed a written consent form. The study from which data of the present investigation was derived was approved by the Research Ethical Committee of the School of Physical Education and Sport (no. 966.072) and registered in the Brazilian Clinical Trials platform (RBR-7q7pz7), and its procedures followed the standards proposed by the Helsinki Declaration.

Competing Interest

The authors declare no competing interests.

Figure 1 – Study Flowchart.

Figure 2 – Associations between the changes clinic and ambulatorial systolic (SBP), mean (MBP) and diastolic (DBP) blood pressures assessed after a maximal exercise test (Δ after Max test) and after a period of aerobic training (Δ after AT).

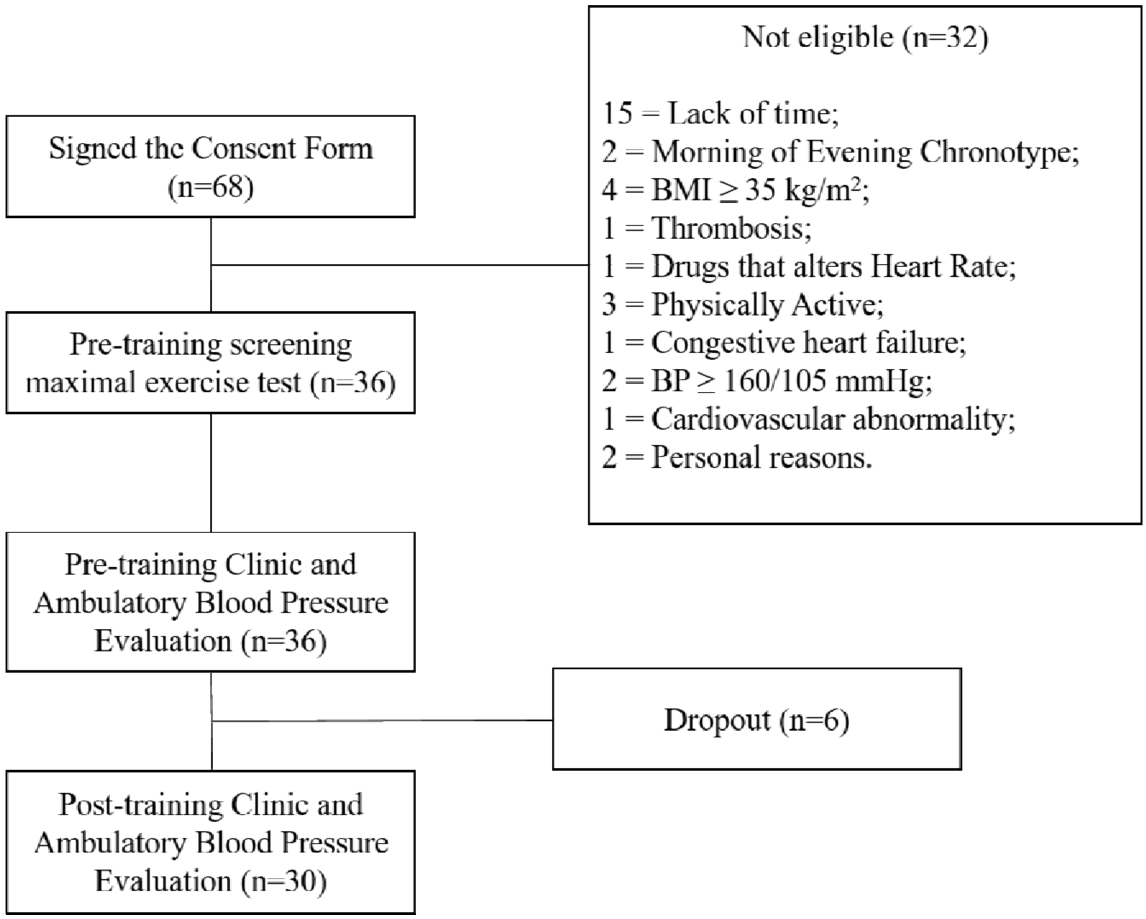

Figure 1 – Study Flowchart.

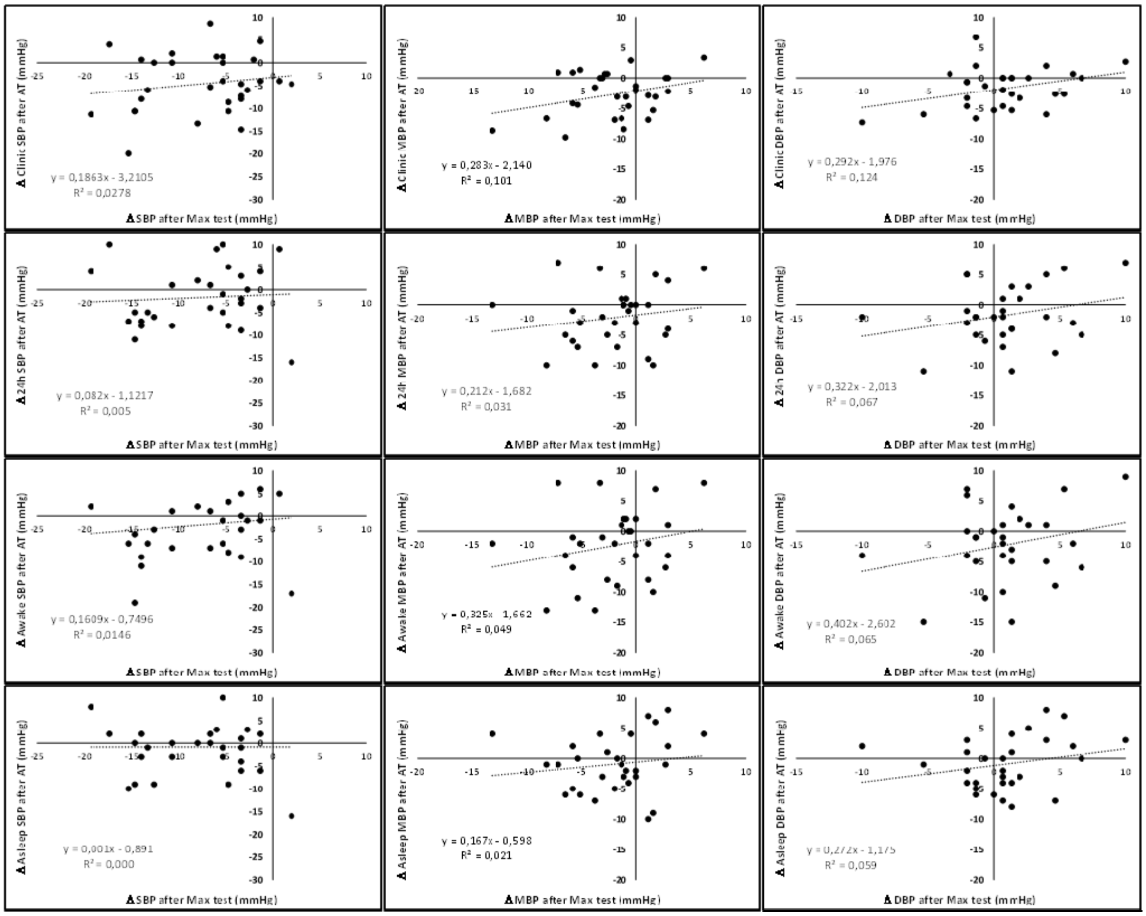

Figure 2 – Correlations between changes (Δ) in systolic (SBP), diastolic (DBP) and mean (MBP) blood pressures assessed after a maximal exercise test (Max test) and after a period of aerobic training (AT).

Table 1 – Sample characteristics (n = 30).

Characteristic	**Mean ± SD**
General	
Age (years)	50 ± 8
Body mass index (kg/m^2)	29.9 ± 4.3
Systolic blood pressure (mmHg)	133 ± 7
Diastolic blood pressure (mmHg)	90 ± 6
Antihypertensive Drugs	***n (%)***
Angiotensin II receptor blockers	15 (50)
Angiotensin converting enzyme inhibitors	11 (37)
Dihydropyridine calcium channel blockers	7 (23)
Diuretics	9 (30)
Antihypertensive Strategy	***n (%)***
Monotherapy	21 (70)
Polytherapy	9 (30)

Table 2. Post-exercise hypotension evaluated by systolic, mean, and diastolic blood pressures (BP) measured before and at 30 min after the maximal exercise test.

	Pre-test	Post-test	P
Systolic BP (mmHg)	131 ± 14	123 ± 15 *	**< 0.01**
Mean BP (mmHg)	104 ± 9	102 ± 10 *	**0.01**
Diastolic BP (mmHg)	90 ± 8	91 ± 8	0.29

* Significantly lower than pre-test

Table 3. Aerobic training blood pressure lowering effect assessed by clinic and ambulatory BPs measured before and after 10 weeks of aerobic training.

	Before training	After training	P
Clinic BP			
Clinic systolic BP (mmHg)	131 ± 12	126 ± 11 †	**< 0.01**
Clinic mean BP (mmHg)	104 ± 8	102 ± 8 †	**< 0.01**
Clinic diastolic BP(mmHg)	91 ± 6	89 ± 6 †	**0.01**
Ambulatory BP			
24h systolic BP (mmHg)	129 ± 9	127 ± 8	0.17
24h mean BP (mmHg)	100 ± 8	97 ± 6 †	**0.03**
24h diastolic BP(mmHg)	85 ± 7	83 ± 6	0.06
Awake systolic BP (mmHg)	134 ± 10	132 ± 7	0.17
Awake mean BP (mmHg)	104 ± 8	102 ± 6 †	**0.05**
Awake diastolic BP(mmHg)	90 ± 8	87 ± 6	0.06
Asleep systolic BP (mmHg)	119 ± 10	118 ± 9	0.45
Asleep mean BP (mmHg)	88 ± 7	88 ± 7	0.29
Asleep diastolic BP (mmHg)	73 ± 7	72 ± 7	0.25

† Significantly different from before training.

Table 4. Correlations between blood pressure change after the maximal exercise test (Δ BP after Max test) and clinic and ambulatory blood pressure changes observed after the aerobic training (Δ BP after AT).

	Δ BP after Max test		**Δ BP after AT**	**n**	**r**	**p**
Systolic BP (mmHg)	-7.6 ± 5.7	Clinic	-4.6 ± 6.4	30	0.17	0.38
		24 hour	-1.8 ± 6.7	29	0.07	0.72
	-7.8 ± 5.7	Awake	-2.0 ± 7.6	29	0.12	0.53
		Asleep	-0.9 ± 6.4	29	0.00	1.00
Diastolic BP (mmHg)	+0.8 ± 3.8	Clinic	-1.8 ± 3.2	30	0.35	0.06
		24 hour	-1.7 ± 4.8	29	0.26	0.18
	+0.9 ± 3.8	Awake	-2.2 ± 6.0	29	0.25	0.18
		Asleep	-0.9 ± 4.3	29	0.24	0.20
Mean BP (mmHg)	-2.0 ± 4.0	Clinic	-2.7 ± 3.6	30	0.32	0.09
		24 hour	-2.1 ± 4.9	29	0.18	0.36
	-2.0 ± 4.1	Awake	-2.3 ± 6.0	29	0.22	0.25
		Asleep	-0.9 ± 4.6	29	0.15	0.45

Data: Mean ± standard deviation.