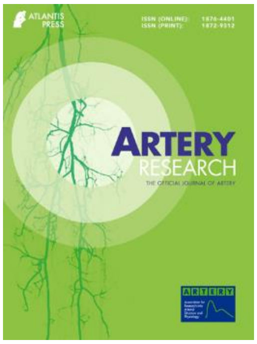


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Short communication

# Does the acute hemodynamic response to a maximum running exercise depend on the aerobic training status of the subjects?

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**KEYWORDS**
Pulse wave velocity;
High intensity exercise;
Hypertension;
Running

**Abstract** *Background:* High-intensity training has become increasingly popular in recent years but the exact effects of high intensity running on the hemodynamic system are not entirely understood and it is unknown whether the aerobic training status of the subjects might influence these hemodynamic reactions. Therefore, the study aims to evaluate whether the acute reactions of peripheral and central blood pressure (BP) and arterial stiffness (AS) to a maximal running exercise depend the training status of the subjects.
*Methods:* 41 healthy subjects were recruited. Of these were 21 aerobically trained (AE; 11 men) and 20 untrained (UN; 10 men). Aortic pulse wave velocity (PWV), peripheral and central BP was measured at rest and immediately after a maximal treadmill exercise using a ramp protocol including spirometric measurements.
*Results:* Resting hemodynamic values were not different between the groups. Systolic central and peripheral BP, and PWV increased in both groups in response to the running exercise. Δ of all measured parameters showed no difference between the groups.
*Conclusions:* The acute increases of AS and BP to a maximal running regimen seem to be independent of the subjects' training status and might therefore be an eligible training mode to maintain overall and vascular health.


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## Background

Several studies illustrate the positive effects of moderate endurance training interventions on blood pressure (BP) and arterial stiffness (AS).[1,2] High-intensity training has become increasingly popular as it is superior compared to continuous moderate aerobic training for improving cardiorespiratory fitness.[3,4] Recent studies have also shown that high intensity exercise regimens are also suitable to prevent and manage hypertension.[5] During acute physical exercise, the cardiovascular system reacts to the specific conditions by increasing heart rate, BP, and by stiffening of the central the arteries due to vasoconstriction[6,7] to enable increased blood flow which is necessary to provide sufficient oxygen supply to the working muscles.

## Aim

So far, little is known whether the aerobic training status influences these acute hemodynamic reactions. Therefore, the aim of this study was to evaluate whether the training status of the subjects influences the acute hemodynamic reactions resulting from a maximal treadmill running exercise.

## Subjects and methods

41 healthy subjects participated in this study. Of these were 21 aerobically trained (AE; 11 men, 10 women) and 20 untrained (UN; 10 men, 10 women). Inclusion criteria were that subjects were healthy, non-smokers, between 20 and 30 years of age, and had a normal brachial BP (<140/<90 mmHg). To be included in the AE group, subjects had to report a training history in aerobic endurance sport for at least two years and a regular aerobic endurance training time of at least 6 h per week. To be included in the UN group, subjects had to report a training amount of ≤4 h per week. AE reported a regular aerobic endurance training time of 11.1 ± 4.4 (triathlon, middle-distance and long-distance running) and UN of 2.5 ± 0.9 h per week. All subjects gave written informed consent to participate in this study.

Anthropometric data of the subjects were measured using *seca® medical Body Composition Analyzer* (mBCA 515, seca GmbH & Co.KG., Hamburg, Germany). Subjects conducted a maximum running test on a treadmill (Woodway, Weil am Rhein, Germany) until subjective exhaustion using a ramp protocol with spirometric measurements (Metamax 3B, CORTEX Biophysik GmbH, Leipzig, Germany).[8]

All hemodynamic measurements were performed using Mobil-O-Graph (IEM, Stollberg, Germany) a validated device for the measurement of systolic and diastolic brachial BP (pSysBP, pDiaBP),[9] systolic and diastolic central BP (cSysBP, cDiaBP),[10] and aortic pulse wave velocity (PWV).[11] Hemodynamic measurements were performed pre (after 5 min of seated rest) and post running (30 s after finishing the test). The measurement takes 2.5 min with marginal deviation. The hemodynamic values presented for the post measurement were therefore recorded 3 min after the test. Results are expressed as mean ± SD. Anthropometric and performance data were analyzed using an unpaired t-test. A two-way mixed ANOVA (time × group) with Bonferroni post-hoc testing was used to evaluate the effects of the running exercise on hemodynamic parameters in AE and UN. Differences in Δ of the measured parameters between the groups were analyzed using an unpaired t-test. Differences were considered as significant with $p \leq 0.05$. Statistics were performed using the software package GraphPadPrism 6 (La Jolla, USA).

## Results

Anthropometric and performance data of the participants are presented in Table 1. Running led to significant increases in both groups in pSysBP (AE: 118.9 ± 9.1 to 144.0 ± 19.5, $p < 0.001$; UN: 118.1 ± 10.7 to 147.1 ± 15.9, $p < 0.001$; Fig. 1a), cSysBP (AE: 105.7 ± 9.0 to 124.7 ± 14.9, $p < 0.001$; UN: 104.8 ± 8.2 to 124.4 ± 9.9, $p < 0.001$; Fig. 1c), and PWV (AE: 5.0 ± 0.4 to 5.8 ± 0.6, $p < 0.001$; UN: 4.9 ± 0.4 to 5.8 ± 0.4, $p < 0.001$; Fig. 1e). pDiaBP (AE: 74.0 ± 7.6 to 77.6 ± 10.2, $p = 0.044$; UN: 75.3 ± 9.1 to 77.5 ± 11.0, $p = 0.230$; Fig. 1b) and cDiaBP (AE: 75.9 ± 7.7 to 80.1 ± 10.3, $p = 0.006$; UN: 76.4 ± 8.3 to 79.4 ± 8.5, $p = 0.052$; Fig. 1d) increased significantly only in AE. Δ of

**Table 1** Anthropometric, performance and peripheral blood pressure characteristics of aerobically trained and untrained subjects. Data are presented as means with ± standard deviation. *BMI* body mass index, *$VO_2max$* relative maximal oxygen consumption. *$p \leq 0.05$ vs. aerobically trained subjects.

| Parameter | Aerobically trained subjects (n = 21) | Untrained subjects (n = 20) | p value |
|---|---|---|---|
| Age [years] | 23.3 ± 3.2 | 23.2 ± 2.3 | 0.881 |
| Height [cm] | 178.0 ± 8.0 | 173.5 ± 9.2 | 0.104 |
| Weight [kg] | 70.6 ± 8.8 | 73.1 ± 14.5 | 0.500 |
| BMI [$kg/m^2$] | 22.1 ± 1.5 | 23.7 ± 2.5* | 0.012 |
| Fat mass [%] | 15.6 ± 7.0 | 21.9 ± 7.1* | 0.007 |
| Muscle mass [%] | 40.1 ± 4.1 | 37.2 ± 5.1* | 0.050 |
| $VO_{2max}$ [ml/kg/min] | 52.2 ± 7.1 | 40.9 ± 6.2* | <0.001 |
| Max. running velocity [m/s] | 5.0 ± 0.6 | 4.2 ± 0.7* | <0.001 |
| Time to exertion [s] | 334.4 ± 56.4 | 249.0 ± 70.9* | <0.001 |
| Pre systolic blood pressure [mmHg] | 118.9 ± 9.1 | 118.1 ± 10.7 | 0.797 |
| Post systolic blood pressure [mmHg] | 144.0 ± 19.5 | 147.1 ± 15.9 | 0.576 |
| Pre diastolic blood pressure [mmHg] | 74.4 ± 7.6 | 75.3 ± 9.1 | 0.469 |
| Post diastolic blood pressure [mmHg] | 77.6 ± 10.2 | 77.5 ± 11.0 | 0.971 |
| Pre heart rate [1/min] | 67.1 ± 10.0 | 83.6 ± 16.3* | 0.029 |
| Post heart rate [1/min] | 89.8 ± 19.3 | 103.8 ± 15.1 | 0.108 |

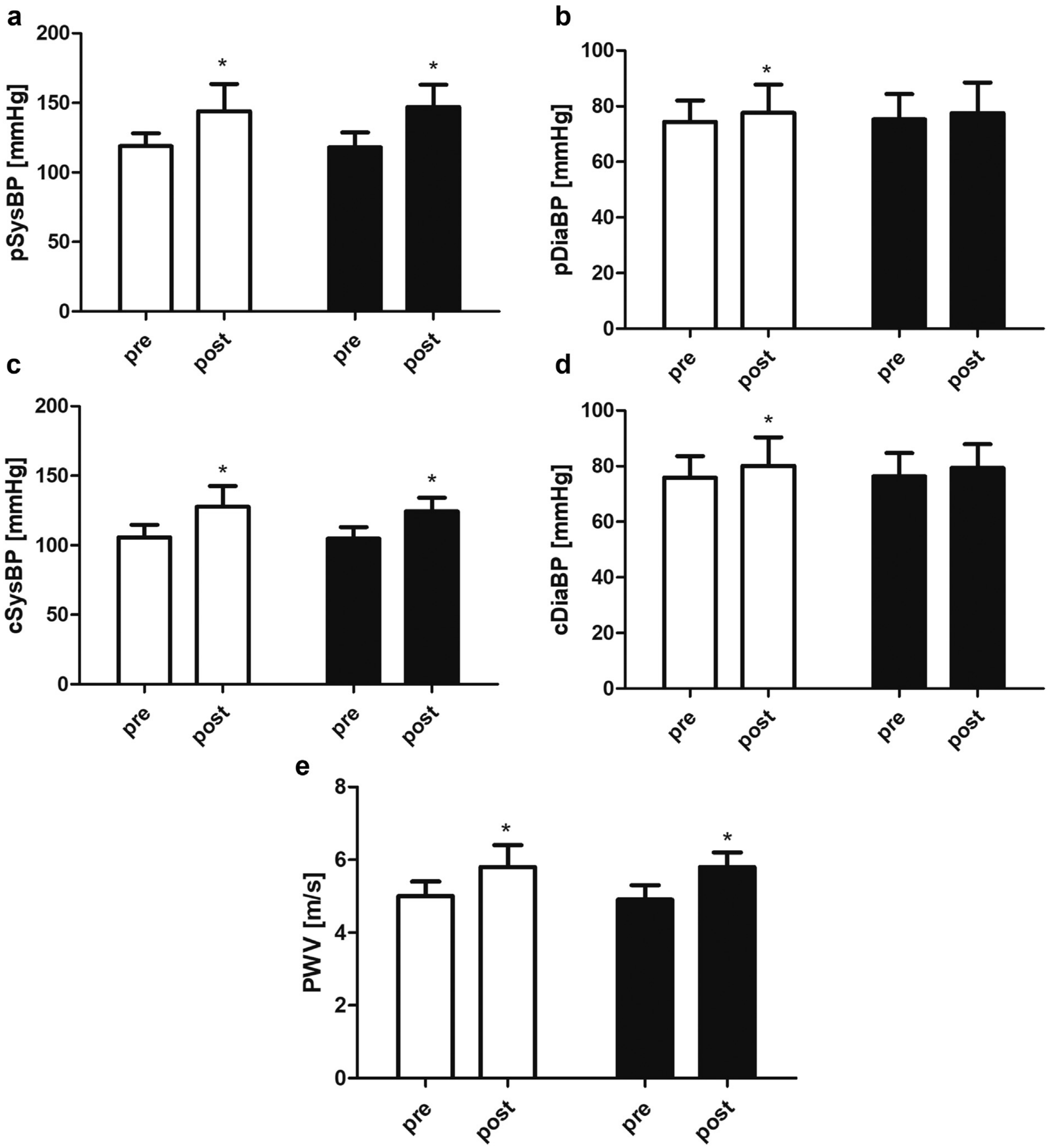


**Figure 1** Pre and post values of hemodynamic parameters of aerobically trained (white bars) and untrained subjects (black bars): (a) peripheral systolic blood pressure (pSysBP), (b) peripheral diastolic blood pressure (pDiaBP), (c) central systolic blood pressure (cSysBP), (d) central diastolic blood pressure (cDiaBP), and aortic pulse wave velocity (PWV). Data are presented as means with $\pm$ standard deviation. * indicates $p \leq 0.05$ vs. the pre value of the same group.

pSysBP, pDiaBP, cSysBP, cDiaBP, and PWV were not significantly ($p > 0.05$) different between the groups.

## Discussion and conclusion

The study aimed to provide information on the effects of a maximal running exercise on hemodynamic reactions in AE and UN as highly intensive training modes have gained increased popularity in recent years. Results show that resting values of pSysBP, cSysBP, and PWV are not different in AE and UN. Hence, regular aerobic training does not yet seem to influence resting BP and PWV in this young adult age. Though, it is well known that regular physical activity, particularly aerobic endurance training, positively affects the cardiovascular system, especially BP and AS.[12] One possible explanation for the lack of differences in resting PWV and BP might be that values of both groups are very low and in a healthy range. Due to the fact that pSysBP correlates positively with PWV even in younger subjects,[13] differences in resting values of pSysBP, cSysBP and PWV between AE and UN were unlikely to occur.

The cardiovascular system shows specific reactions to physical exercise which go along with an increase in HR, central and peripheral BP and a stiffening of the central arteries. This is observed in both groups of the present study and is in line with previous studies.[14,15] The hemodynamic response of these parameters to the exercise does not seem to depend on the aerobic endurance status of the subjects as none of the Δ of the measured parameters are different between the two groups.

The observation that AE subjects reached a higher maximum velocity during the running exercise shows that the entire running time was longer in AE than in UN. Hence, the cardiovascular strain was also longer in AE. It is known that the exercise time positively correlates with the increase of BP and AS.[16] However, in the present study none of the Δ of any measured parameters is different between the groups.

This study has some limitations that are of note. UN subjects showed a good overall and vascular health. Therefore, differences in resting hemodynamic parameters between the groups were unlikely. If more unfit subjects had served as controls, differences in the hemodynamic reaction might have been more probable. AE ran longer during the test as they reached higher velocities. However, this difference was little ( 90 s) but might have influenced increases in the hemodynamic response. Furthermore, volume changes due to sweating were not evaluated which might have influenced BP.

The obtained results indicate that the acute reactions of PWV and peripheral and central BP to an acute bout of maximal running are independent of the subjects' training status. Therefore, highly intensive running exercises are equally suitable for healthy aerobically trained and untrained subjects and can be an eligible training mode to maintain vascular health.

## Conflict of interest statement

The authors have no conflicts of interest or financial disclosures to report.

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## Ethical approval

The used protocols in this study were approved by the ethics committee of the German Sport University Cologne. These protocols align with the Declaration of Helsinki of 1964.

## Informed consent

All participants gave written informed consent to participate in this study.

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