Original Article

Blood Pressure and Heart Rate Recovery in Cold Pressor Hyper-Reactor Young Males

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Abstract

Introduction: The exaggerated cardiovascular response (hyper-reaction) to the cold pressor test (CPT) can predict whether hypertension will develop later on. The study aims to assess the profile blood pressure (BP) and heart rate (HR) changes during CPT and the recovery from the pressor stimulus. **Subjects and Methods:** Thirty-four participants were asked to immerse their left hand in chilly water for 2 min, and the pressor response in terms of BP and HR changes during the ice-cold water immersion test and for 3 min (at 1-min interval) after the cessation of the test was recorded. The result of BP changes was expressed as a mean BP (MBP). The volunteer responses to CPT were classified as hyper-reactants if the change in BP (Δsystolic BP/Δdiastolic BP) was ≥22/18 mm. **Results:** The MBP of the systolic hyper-reactor (SHR) and diastolic hyper-reactor (DHR) volunteers was sustained at significantly high levels (by 20% and 25%, respectively) for a longer time (3 min) after the end of CPT relative to normal reactors (NRs). There was no change in MBP upon CPT in NR within the DHR group. The same general behavior was observed with heart rate in both groups (i.e. SHR and DHR). **Conclusion:** The hyper-reactors are characterized by an exaggerated increase in MBP and HR and a longer time for the MBP and HR to return to their baseline levels.

Keywords: Blood pressure, cold pressor test, diastolic hyper-reactors, systolic hyper-reactors

Introduction

According to several studies, the cardiovascular response to the cold pressor test (CPT) can predict whether hypertension will develop later on.[1-3] Black participants, who are more likely to develop early hypertension, exhibit higher vascular reactivity to the CPT than white subjects.[4] It has been demonstrated that CPT causes the coronary arteries of healthy participants to dilate and the coronary arteries of hypertensive subjects to constrict.[5] One study[6] accurately predicted future unfavorable cardiovascular events (such as stroke or heart attack) in asymptomatic type 2 diabetic patients using CPT-induced coronary vasoconstriction.[6] Blood pressure (BP) hyper-reactors to the CPT are people who respond with an exaggerated rise in their systolic BP (SBP) and/or diastolic BP (DBP) and who have a higher incidence rate of hypertension than normal reactor (NR), according to two large, long-term prospective studies using survival analysis.[2,3] The CPT has been used to pinpoint hyper-reactants who may develop hypertension by measuring the BP response to the external cold stimulus. Therefore, the cold pressure test study looks at how well it can predict hypertension. As a result, it aids in the early detection of hypertension so that preventive measures can be put in place to lower morbidity and mortality brought on by hypertension and its side effects.[3]

The study aims to assess the profile BP changes during CPT and the recovery from the pressor stimulus.

Subjects and Methods

In the present study, 34 healthy young male 1st-year medical students were included. Their age was 19 years old. All were free from any medical illness or taking any medication; they were not smokers, and their parents did not have diabetes or hypertension. Before giving their written informed consent, each participant received a full explanation of the study. The

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study adhered to the standard principles in the Declaration of Helsinki, and all procedures and protocols were approved by the Department's Ethical Committee at Mustansiriyah University, College of Medicine, Department of Physiology. Gender and other anthropometric measurements were registered.

Experimental protocol

Right brachial SBP, DBP, and heart rate (HR) were measured in a semi-prone position after 10 min of complete rest using an automated sphygmomanometer (Rossmax Swiss GmbH, Tramstrasse 16, CH-9442 Berneck, Switzerland) until stable values were obtained to ensure hemodynamic stability. These stable measurements were considered baseline values or pre-CPT values. Mean BP (MBP) was calculated using the following formula:[4]

$$MAP = DBP + 1/3\ (SBP–DBP) \quad (1)$$

The Valsalva maneuver should be avoided throughout the measurement; moreover, subjects were asked to maintain spontaneous respiration throughout the protocol and to remain quiet during various stages of the procedure. After achieving hemodynamic stability, the subject was asked to immerse his left hand to the level of his wrist in ice-cold water for 2 min. BP and HR measurements were obtained at the end of these 2 min, and the results were considered the response of subjects to CPT. At the end of the 2-min immersion in ice-cold water, the left hand was removed from the ice water and was wrapped up with a warm, dry towel to stop the stressful stimulus, and the BP and HR were measured after 1, 2, and 3 min. This time, a recovery period was considered after the CPT.

Individuals with rise of SBP of more than 22 mmHg and/or rise of DBP by 18 mmHg were grouped as hyper-reactors.[7-11] Participants were divided into systolic hyper-reactor (SHR) and diastolic hyper-reactor (DHR). For the sake of comparison of BP and HR changes, a number-matched control group was chosen which included the participants with the lowest responses to CPT, who were labeled as NRs. This was done to maximize the differences between hyper-reactors and NRs if they actually existed. Only individuals with SBP and DBP rises that were not more than 22 mmHg and 18 mmHg, respectively, were considered NRs.

Statistics

All of the results were expressed using the mean and standard deviation. To compare data between variables, a paired and unpaired Student's *t*-test was used. The result was considered statistically significant if $P < 0.05$.

Results

The characteristics of the recruited volunteers in the present work are shown in Table 1. CPT is associated with an MBP increased by 20% over the basal pre-CPT level in the SHR group (88.4 ± 6.4 mmHg) [Figure 1a]. During recovery, after the end of the test, MBP reduced progressively throughout the 1st, 2nd, and 3rd min after CPT but was still significantly higher (by 15%, 9%, and 8%, respectively) relative to basal pre-CPT level. In the NR group, CPT was associated with an increase in MBP by 9% over the basal pre-CPT level (91.94 ± 6.4 mmHg) and continued to be significantly higher by 7% and 3% throughout the 1st and 2nd min, respectively, after the end of the CPT and returned to normal pre-CPT level within the 3rd min after cessation of the CPT.

The CPT is associated also with an increase in MBP of 25% over the basal pre-CPT level in the DHR group (91.8 ± 5.0 mmHg) [Figure 1b]. Again, during recovery, after the end of the test, MBP reduced continuously throughout the 1st, 2nd, and 3rd min after CPT, but it was still significantly higher by 17%, 10%, and 8%, respectively, relative to basal pre-CPT level. In the NR group, the MBP showed no changes on CPT or during recovery.

Figure 2a demonstrates that during CPT, the HR in SHR group increased (by 14% relative to the baseline value of 76.8 ± 6.9 beats/min), and it maintained a high level of 12% and 8% during the 1st and 2nd min after the end of CPT, respectively. During the 3rd min of recovery, HR returned to the pre-CPT level. Relative to SHR, in NR group, HR increased by 11% during the CPT compared to the baseline value (76.2 ± 7.4 beats/min), and it remained significantly high (by 5% over the base level) throughout the 1st min after the CPT ended. Within the 2nd and 3rd min, the HR in the NR group of the SHR returned to their baseline levels.

Moreover, the behavior of the HR of DHR is depicted in Figure 2b. The DHR's HR increased by 18% during CPT compared to the pre-CPT reading (76.1 ± 5.9 beats/min), and it remained significantly higher during the 1st, 2nd, and 3rd min (by 15%, 14%, and 9%, respectively). In contrast, the HR in the NR group changed neither before nor after CPT.

Table 1: The characteristics of the recruited volunteers

	SHR ($n=12$)	NR counterpart ($n=12$)	DHR ($n=8$)	NR counterpart ($n=8$)
BMI (kg/m^2)	23.5±4.7	25.7±6.1	25.6±7.1	23.8±6.0
SBP (mmHg)	116.3±8.5	122.2±5.6	121.1±9.8	122.8±6.9
DBP (mmHg)	74.4±6.6	76.8±8.4	77.1±6.2	77.6±7.4
MBP (mmHg)	88.4±6.4	91.9±6.4	91.8±5.0	92.7±7.0
HR (beat/min)	76.8±6.9	76.2±7.4	76.1±5.9	77.0±5.4

BMI: Body mass index, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure, HR: Heart rate, SHR: Systolic hyper-reactors, DHR: Diastolic hyper-reactors, NR: Normoreactors

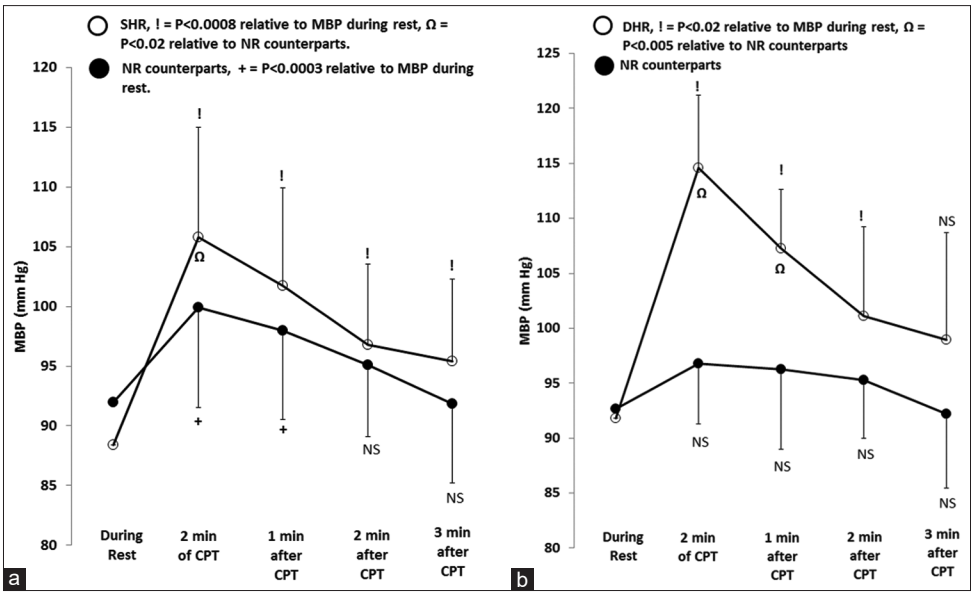

Figure 1: (a) The mean blood pressure (MBP) of systolic hyper-reactor ($n = 12$) and (b) MBP of diastolic hyper-reactor ($n = 8$) during cold pressor test phases and their normal reactors counterparts. MBP: Mean blood pressure, SHR: Systolic hyper-reactor, DHR: Diastolic hyper-reactor, NR: Normal reactor

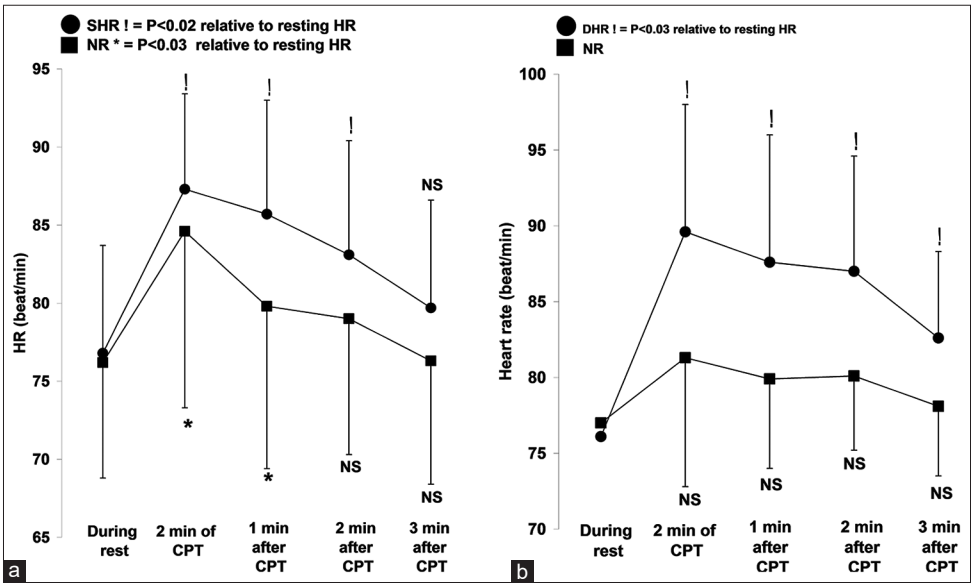

Figure 2: (a) The heart rate (HR) of systolic hyper-reactor ($n = 12$) and (b) the HR of diastolic hyper-reactor ($n = 8$) during cold pressor test phases and their normal reactors counterparts. HR: Heart rate, SHR: Systolic hyper-reactor, DHR: Diastolic hyper-reactor, NR: Normal reactor

Discussion

An established challenge test for autonomic vascular control is the CPT. The CPT is a powerful sympathoexcitatory stressor that elicits an effect on the cardiovascular system by causing an increase in SBP (due to an increase in cardiac output) and DBP (due to vasoconstriction of the arterioles of the peripheral muscular arteries, also called resistant vessels), HR, and releasing of stress hormones.[12,13] Impulses from the skin receptors induced by the cold stimulus ascend through afferent fibers through the spinal cord. These impulses end in a specific nucleus in the brain, and the integrated signals in this nucleus send impulses through efferent sympathetic neurons to the heart and peripheral blood vessels in the spinal cord to produce the pressor response during the CPT.[14] Vaseghi and Shivkumar's[15] study revealed that changes in BP and HR after CPT were caused by a massive discharge of catecholamine from the sympathetic nervous system. Normally, a temporary peripheral vasoconstriction, tachycardia, and an increase in BP occur in response to a brief cold stimulus.[16] Moreover, the heart's reactions to the CPT foretell future resting BP and the onset of hypertension.[16] Normally, BP elevation brought on by stress returns in just 5 min.[17] A greater likelihood of future BP elevation exists for people who exhibit an excessive stress-induced cardiovascular response when they are young.[18] By implementing a healthy lifestyle,

early diagnosis can help to prevent the start of cardiovascular complications.[19] The longer period that hyper-reactors need to recover may be caused by the larger magnitude of change in MBP that requires a longer time to achieve the new set point dedicated by resetting of arterial baroreceptor. This resetting of baroreceptors is a result of the painful sensation induced by ice water in this group of volunteers. This possibility was suggested by others.[20] The other possible cause of a sustained high MBP in hyper-reactors may be the baroreceptors in this group of subjects that otherwise restrain the high, prolonged elevation in MBP. This suggestion is possibly validated by the finding that patients with spinal cord injuries experience a reflex sympathetic discharge, which causes a more pronounced increase in MBP upon immersion in freezing water. There were no inhibitory signals from the supraspinal center or baroreceptor reflexes in this response, which may have prevented the BP from rising.[14] In the SHR group, the MBP and HR of NR subjects returned to the baseline level within 2 min after the end of CPT. This result parallels those reported by other researchers.[14,21,22] Similar to SHR, the MBP and HR in DHR behaved in a similar but less striking way during the CPT and recovery. In contrast, the behavior of MBP and HR in the NR group was totally blunted, with no response to CPT.

Conclusion

The MBP takes a longer time to recover in SHR and DHR than in NRs counterparts. This is possibly due to the magnitude of change in MBP on stressful stimulus or due to the baroreceptors resetting as a result of CPT.

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Conflicts of interest

There are no conflicts of interest.

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