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COMPARATIVE STUDY OF HAEMODYNAMIC RESPONSES TO ACTIVE AND PASSIVE POSTURE INDUCING HEAD-WARD POOLING OF BLOOD IN MAN

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ABSTRACT

Objective: **To study the relative effects of passive head-down tilt and squatting on the cardiovascular dynamics in man.**

Design: **A pre-test/post -test study.**

Setting: **Physiology Research Laboratories in the Schools of Medicine at Addis Ababa University and the University of Dundee, UK.**

Subjects: **Ten normal healthy subjects aged nineteen to twenty two years.**

Intervention: **Cardiovascular variables measured in Passive body tilt and squatting.**

Main outcome measures: **Similar responses in forearm blood flow, arterial blood pressure, peripheral vascular resistance, and pulse rate observed in both active and passive postural changes.**

Results: **A change from the sitting to the squatting position resulted in marked changes of forearm blood flow (FBF=1.63ml/100 ml/min, $p<0.05$), mean arterial blood pressure (BP=9mmHg, $p<0.05$), mean forearm vascular resistance (PVR=-10 PRU, $p<0.05$) and mean pulse rate (PR =-5 beats/min, $p>0.05$). The corresponding changes in the head-down position were: FBF=2.37ml/100 ml/min, $p<0.05$; BP=11.0 mmHg, $p<0.05$; VR=-12.85 PRU, $p<0.05$; PR=-10 beats/min, $p>0.05$).**

Conclusion: **These results suggest that the movement of blood towards the head is only slightly more marked in the head-down tilt than in the squatting position . The changes in flow and arterial blood pressure are similarly correlated ($r=0.6291$ in squatting and $r=0.553$ in 30° head-down tilt). In both positions, blood moves to the thorax, neck and the head thus traversing the same baroreflex regions. This means that changes in cardiovascular variables in the two positions are detected by the same receptors signalling information to integrating centres via the same afferent pathways. Squatting and head-down tilt can, therefore, be used alternately to counteract orthostatic dizziness and to assess the significance of cardiovascular autonomic neuropathy in patients with disease conditions like diabetes mellitus.**

INTRODUCTION

When a person is passively tilted from the recumbent to the upright position, a number of cardiovascular changes occur. Blood pools in the lower extremities. Reflexly, the forearm blood flow and arterial blood pressure decrease and pulse rate increases(1-4), central venous pressure, cardiac output(2,5), renal blood flow(6) and hepatic blood flow(7) decrease. On assumption of passive head-down tilt, blood is shifted towards the upper thorax and head and the sympathetic tone is withdrawn. In effect, the forearm blood flow and arterial blood pressure increase and the pulse rate decreases(3,8). Venous pressure also changes with the change in posture(9). These observations reflect that orthostasis plays a major role in modifying the distribution of blood in different conditions.

An active change to the upright position produces relatively moderate decreases in forearm blood flow and arterial blood pressure and an increase in pulse rate. Squatting produces mechanical compression in the legs so greatly that blood is squeezed out of the leg veins. There is also a great deal of tension in the abdomen. In effect, the pressure in the abdomen and legs rises thus creating a pressure gradient that descends towards the upper portion of the body. These changes vary in different individuals depending on experience and habit in squatting and the myogenic condition of blood vessels in the legs. According to Sharpey-Schafer(10) and Roddie(11), squatting causes a constant increase in forearm blood flow and an immediate rise in blood pressure. In this position, both systolic and diastolic blood pressures decrease slightly in some subjects(9).

Head-ward pooling of blood occurs in both the 30° head-down tilt and squatting but it is not established if these positions produce the same pattern of correlation between arterial blood pressure and forearm blood flow and if the reflex responses have afferent pathways in common. The present study was, therefore, conducted to compare the systemic cardiovascular responses to the two positions and to see if the responses reflect some similarity of reflex mechanisms.

MATERIALS AND METHODS

Forearm blood flow (FBF), arterial blood pressure (BP), forearm vascular resistance(PVR) and heart rate(HR) were studied in ten consenting remunerated normal subjects (eight males and two females, ages 19-22 years) in a room where the temperature ranged between 22°C and 23°C throughout the study period. The measurements were made in the morning after the subjects, had taken breakfast and rested supine on a couch for about 15 minutes with their routine clothing on. None of them took any alcoholic drinks the previous night. During the recording of forearm blood flow, the arm was placed on a table with adjustable height and kept at heart level to avoid hydrostatic effect throughout the study period. A Whitney mercury-in-rubber resistance strain gauge with a balancing unit(12) coupled to a Devices set-up of preamplifier and pen recorder was used to record inflow curves of the forearm while the subjects were in the sitting, squatting, and 30° head-down positions. Arterial blood pressure and heart rate were recorded using a calibrated sphygmomanometer and an electrocardiograph, respectively. To get the maximum response to squatting, a pilot study was first made on the forearm blood flow of five subjects supporting their body weight on: (i) the toes; (ii) the heels. There was no significant difference in the mean forearm blood flow (% change = 2.9, $p>0.50$) recorded in these squatting positions. So, for convenience, the study in the squatting position was conducted while subjects were resting their body weight on the toes and the distal portion of the sole of the feet. Five to six readings of forearm blood flow, arterial blood pressure and pulse rate were recorded in the sitting, squatting and 30° head-down positions with 5 min interval between positions. Peripheral vascular resistance(PVR) was calculated using the formula, $PVR=Pa-Pv/Q$ where $Pa-Pv$ is pressure gradient and Q is mean flow. Measurements were taken at intervals of about 20 to 35 seconds for blood flow and 50 to 70 seconds for arterial blood pressure and pulse rate. These variables were measured in each subject alternately for five to seven minutes in both the squatting and head-down positions. Forearm blood flow measurement was made with the flow to the hand occluded at a pressure of about 200 mmHg; venous outflow was occluded by a pneumatic cuff placed on the upper arm at a venous occlusion pressure below the diastolic point (60 mmHg). At the end of the flow recording, the girth of the forearm under the strain gauge was measured and the strain gauge calibrated for each subject. The slope value per minute of each inflow curve recorded was multiplied by the calibration factor formulated by Whitney(12) to approximate the forearm blood flow. All readings taken in each position were averaged. Overall means, standard errors of means and P values were computed using the software Instat 2.

RESULTS

The means of variables recorded in all study subjects in three different body positions are given in Table 1. The forearm inflow curves showed steady flow in each position in all subjects. The relative changes in flow, pressure, vascular resistance and pulse rate show a consistent pattern (Figure 1). The correlation values of forearm blood flow and arterial blood pressure in both squatting ($r=0.6291$) and 300 head-down tilt ($r=0.553$) are equally significant . The changes are also similar in pattern(Figures 2 and 3). The results in general indicate that forearm blood flow, arterial blood pressure and forearm vascular resistance are significantly greater in the squatting and 30° head-down positions than in the sitting position (Table 1).

Table 1

Effect of squatting and passive 30° head-down tilt on forearm blood flow (FBF), arterial blood pressure (Bp), forearm vascular resistance (VR) and heart rate (HR)

Variables	OM±SEM in various positions			Mean difference	Comparison P value
	1 Sitting	2 Squatting	3 -30°		
FBF (ml/100 ml/min)	2.67 ± 0.22	4.30 ± 0.44	5.04 ± 0.47	(1) vs (2) = -1.63	<0.05
				(1) vs (3) = -2.37	<0.001
				(2) vs (3) = 0.74	<0.05
BP (mmHg)	83 ± 1.70	92 ± 3.31	94 ± 1.58	(1) vs (2) = -9.0	<0.05
				(1) vs (3) = -11.0	<0.01
				(2) vs (3) = -2.0	<0.05
PVR (PRU)	32.82 ± 2.47	22.72 ± 2.65	19.97 ± 2.11	(1) vs (2) = 10.10	<0.05
				(1) vs (3) = 12.85	<0.05
				(2) vs (3) = 2.75	<0.05
HR (BPM)	71 ± 3.7	66 ± 1.9	62 ± 2.45	(1) vs (2) = -5.0	>0.05
				(1) vs (3) = -10.0	<0.05
				(2) vs (3) = -5.0	<0.05

PRU = Peripheral resistance unit
BPM = Beats per minute
OM = Overall mean
SEM = Standard error of mean
PVR=Peripheral (forearm) vascular resistance

Figure 1

Effect of squatting and 30° head-down tilt on cardiovascular responses (overall mean ± sem)
FBF = forearm blood flow (ml/100ml/min); BP = arterial blood pressure (mmHg); PRU = peripheral vascular resistance unit; PR = pulse rate

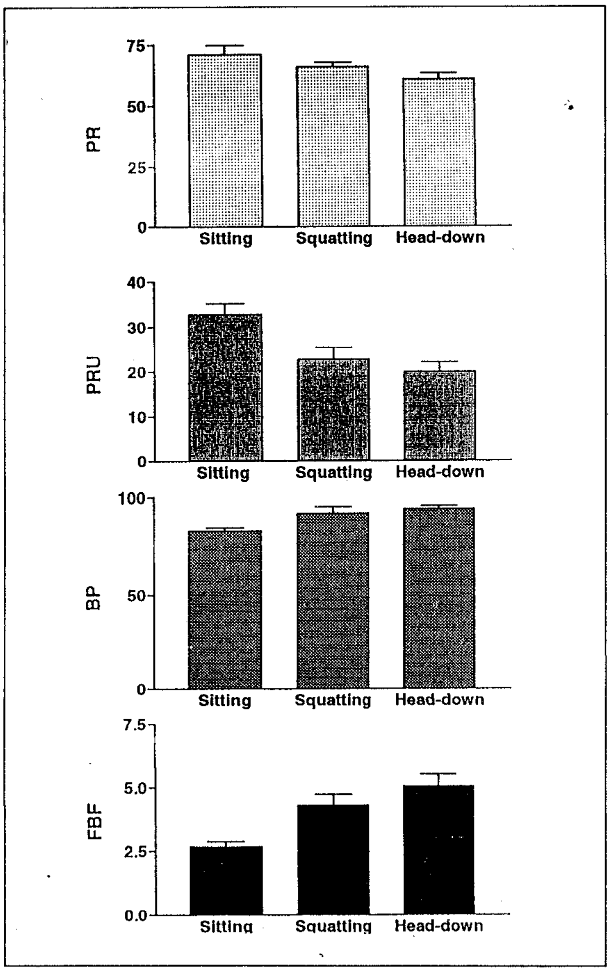


Figure 2

Correlation between the changes in mean forearm blood flow (FBF) and mean arterial blood pressure (BP) in normal squatting subjects

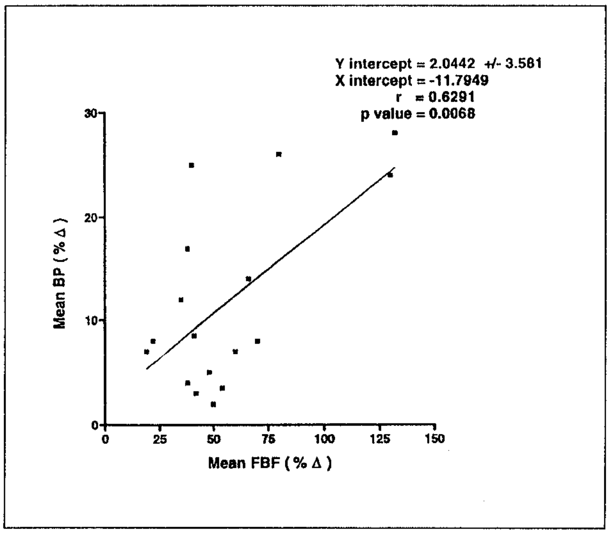
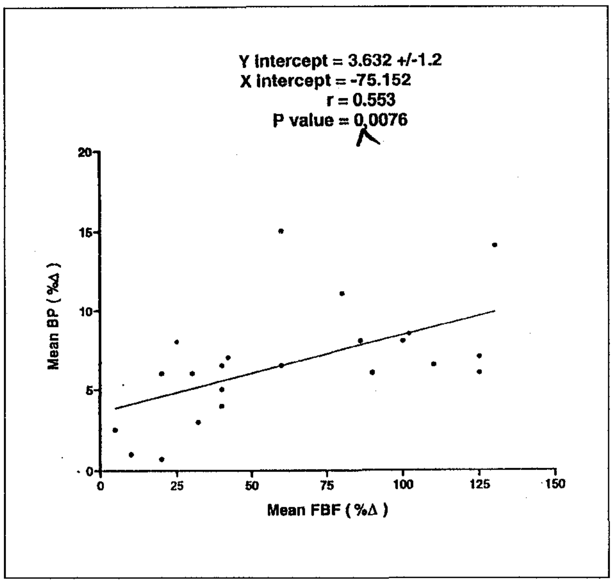


Figure 3

Correlation between the changes in mean forearm blood flow and mean arterial blood pressure in normal subjects passively tilted to a 30° head-down position



The change in pulse rate is not found to be significant ($p>0.05$). The changes in mean forearm blood flow (FBF=1.63ml/100ml/min), mean arterial blood pressure (BP=9.0mmHg), mean forearm vascular resistance (PVR =-10.1 PRU) and mean pulse rate (PR =-5 beats/min) occurring in response to squatting are similar to the corresponding changes (FBF=2.37ml/ 100ml/min, BP=11 mmHg, PVR=-12.85 PRU ,PR=-10 beats/min) observed in the 30° head-down tilt.

DISCUSSION

The flow of blood in the upper extremities is smaller in the standing and sitting positions than in the squatting(6,10,13) and head-down positions(3). The results in the present study (Figures 1-3 and Table 1) show that the relative cardiovascular responses to squatting and passive 30° head-down tilt are similar. Forearm blood flow and mean arterial blood pressure increased ($p<0.05$) while mean forearm vascular resistance ($p<0.05$) and mean pulse rate ($p>0.05$) decreased. This is a reflection of a mechanical response occurring when blood traverses the abdomen, thoracic and neck regions. Reflex responses counteracting changes occur via negative feedback mechanisms with pressure and volume receptors found in these regions.

Squatting is an active posture that causes a shift of blood from the lower extremities to the abdominal and intrathoracic vascular beds by squeezing out blood from the veins. Since there is tension even in the abdomen in this position, blood is shifted mainly to the thorax and neck and to some extent to the head. In effect, arterial blood pressure in the upper extremity is increased due to the increase in effective cardiac filling pressure and peripheral resistance in the squatting legs. Forearm blood flow is also increased in this position due to the shift of blood and the relative drop in the forearm vascular resistance. This flow pressure relationship is compatible with the observation that increase in arterial blood pressure reflects the increased flow of blood into a system(14). The passive 30° head-down tilt also causes significant pooling of blood towards thorax and head. This leads to a reflex activity that operates against the effect of gravity to maintain arterial blood pressure. The haemodynamic changes observed in this position are slightly more marked than the ones recorded in the squatting position. The responses to the two positions, though slightly different in magnitude, are essentially the same in pattern(Figure 1).

Since arterial blood pressure was estimated by auscultation, it was not possible to observe the initial changes occurring in the first one minute of head-down tilt. The changes sustained after the first minute were recorded. However, no substantial information is expected to be missed. When the position of the body is changed the initial alterations of blood pressure due to the hydrostatic effect are not secondary to reflex changes but act as intra-arterial stimuli to the mechanisms that regulate blood pressure(15). This means that the first increase or decrease in blood pressure will eventually trigger the depressor or pressor response, respectively.

To sum up, in both the squatting and 30° head-down positions, (i) the pooling of blood is to the thorax, neck and head thus traversing the same areas of both pressure and volume receptors(baroreceptors in the neck, atrial and pulmonary volume receptors in the chest); (ii) the effective cardiac filling pressure rises; (iii) the initial increase in arterial blood pressure occurring 2° to passive pooling does not return to normal quickly. It begins to return to the control value only in about five to even minutes. The changes in arterial blood pressure and forearm blood flow have not only the same pattern of change but are also similarly correlated (Figures 2 and 3); (iv) the forearm vascular resistance and mean pulse rate also show similar pattern of changes. Thus,in these positions cardiovascular changes (Table 1) may apparently be signalled to the vasomotor centre via the same afferent pathways. The results obtained in this study may also be used to suggest some practical application for postural changes. Both squatting and head-down tilt increase the effective filling pressure of the heart. They can, therefore, be used alternately, (i) to counteract orthostatic dizziness(16) emanating from pooling of blood in the lower extremities of subjects with autonomic failure or poor muscle tone due to relatively loose fascial sheaths; (ii) to differentiate systolic mummurs secondary to different diseases(17) and; (iii) to assess the presence of autonomic neuropathy in the cardiovascular system of patients like diabetics(18,19).

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