

Various designs of LBNP devices have been reported (8–11). Most of the designs of LBNP pertains to the application of LBNP in the supine position. However, supine studies cannot be correlated to situations in military aviations, where a near upright position is assumed by the aircrew. Studies related to application of LBNP in man in seated position is limited. Hence this study was undertaken to evaluate the effect of LBNP on cardiovascular responses in man in seated position.

METHODS

Eight normal healthy male volunteers between the age group of 25–36 years participated in this study. The subjects were told not to drink alcohol and perform no exercise 12 hours before the test. The experiments were performed in thermo neutral environmental condition. The subjects were briefed about the protocol of the experiment well in advance. Before conducting the actual experiment, the subjects were given trial exposures to avoid any apprehension. They were subjected to 40 mmHg negative pressure in steps of – 10 mmHg for a duration of 5 min each. The LBNP chamber and suit were designed and developed in the laboratory. The chamber is fabricated out of fibre glass resinate. It is provided with a bucket type seat which is mounted on a tripod fitted to the floor of the chamber. The seat pan and the back are provided with replaceable foam cushions of 40 mm thickness. The height of the seat from the floor level can be adjusted by about 5 cm. The cover for the chamber has two parts consisting of semicircular front and back portions which are also fabricated from fibre glass resinate. These

concave portions which came in contact with the skin are padded with foam rubber enclosed in the rubber sheeting to prevent skin irritation. The back portion is fitted to the chamber with studs. The front portion rests on the chamber opening and can be moved up and down. After the subject sits inside the chamber, the back portion is fitted to the chamber covering the back portion of the chamber as shown in Fig.1. The seal between the subject and the

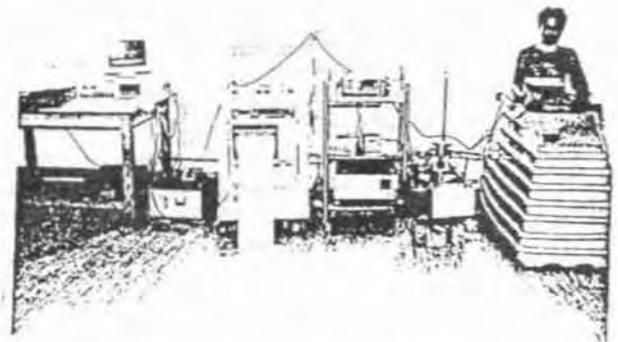


Fig. 1 : Experimental set up.

chamber is achieved by means of rubber skirt fabricated from neoprene rubber sheeting of 0.5 mm thickness. The subject wore the rubber skirt and the upper end of the skirt is fastened around the subject's xiphisternum with adhesive tape, the other end of the skirt is draped around the opening of the chamber and held in position by means of rubber ring and this allows satisfactory sealing. In case of emergency the rubber ring can be removed easily and this detaches the skirt from the chamber immediately releasing the pressure; this acts as a safety valve.

Negative pressure is produced by using a vacuum pump with 200 litres capacity. Negative pressure is sensed using a piezoelectric transducer having a range of

0 to - 760 mmHg with a resolution of 1 mmHg. The output of the transducer is connected to a digital pressure controller which has a digital display and one control set point. The set point can be adjusted to any desired value in the entire range of the transducer. During normal operation, the display indicates the input pressure and when the set button is pushed, it displays the set point.

The physiological strain imposed on man as a result of exposure to - 40 mmHg was measured in terms of changes in cardiovascular responses viz., heart rate (HR), blood pressure (BP), cardiac output (CO), and total peripheral resistance (TPR).

Blood pressure was measured at 1 min interval using Aneroid BP apparatus. The blood pressure cuff containing the crystal microphone picks up the Korotkoff sounds. The reading on the aneroid meter when the beep begins gives the systolic BP. The reading on the meter when the last beep is observed gives diastolic BP. The pulse pressure and mean arterial pressures (MAP) were calculated from measured systolic and diastolic pressures. The HR was measured during 4-5 min, 9-10 min, 14-15 min and 19-20 min. The HR was measured from lead II of ECG record using BPL ECG machine.

The CO was measured by impedance plethysmograph. The impedance waveform was recorded using Nihon Khoden, (Tokyo, Japan), Plethysmograph model AI - 601G. Disposable electrodes consisting of aluminium foil with adhesive backing are used. The electrodes were wound around the neck and the chest at the level of Xiphoid.

A constant current was passed between the outer electrodes and the variation of thoracic impedance was picked up from the inner electrodes. The stroke volume (SV) was calculated based on Kubicek's formula (12). The product of SV and HR gives the cardiac output in litres per minute. CO was measured at pre LBNP and at the end of 20th minutes of the experiment. Results were analysed using Student's 't' test.

RESULTS

Eight subjects volunteered for the study, one subject showed signs of pre syncopal symptoms like nausea, sweating and his heart rate dropped suddenly on exposure to LBNP at the closing minutes of the experiment. Other subject discontinued the LBNP run. Therefore, data of these two subjects were not included for statistical analysis.

The mean age (years) Height (M) and Body Weight (kgs) of subjects participated in the study were 30.16 ± 3.71 , 1.69 ± 0.05 and 68.33 ± 5.61 respectively.

Table I presents the responses of cardiovascular variables such as HR, BP (both systolic and diastolic) MBP, SV, CO and TPR during LBNP exposure. The data were analyzed using Student's 't' test.

The LBNP values of HR and TPR showed significant increase ($P < 0.01$) as compared to their initial values. On the other hand SV and CO showed significant decrease ($P < 0.01$) as compared to their initial response. Systolic BP and MBP, however did not show any significant changes on exposure to reduced pressure (- 40 mmHg). Diastolic BP showed a significant change on exposure to LBNP.

TABLE I : Effect of LBNP on cardiovascular variables.
(Values are mean \pm SD, n = 6)

| Parameters | Initial | 20 min of LBNP exposure |
|--|------------------|-------------------------|
| Heart Rate (beats/min) | 70.7 \pm 5.1 | 89.7 \pm 5.0** |
| Systolic BP (mmHg) | 122.7 \pm 12.5 | 108.7 \pm 17.1 |
| Diastolic BP (mmHg) | 87.0 \pm 2.1 | 92.5 \pm 4.4* |
| Stroke Volume (ml/beat) | 66.5 \pm 3.4 | 40.3 \pm 2.9** |
| Cardiac Output (lit/min) | 4.66 \pm 0.4 | 3.63 \pm 0.2** |
| Mean Blood Pressure (mmHg) | 97.2 \pm 4.7 | 98.4 \pm 9.5 |
| Total Peripheral Resistance (mmHg/L/min) | 20.9 \pm 1.3 | 27.2 \pm 2.8** |

*P < 0.05; **P < 0.01

TABLE II : Heart rate (beats/min) responses to -40mmHg LBNP in seated and supine positions.

| Subjects | Initial | 20 min of LBNP | Change observed | % Change |
|-----------------|---------|----------------|-----------------|----------|
| Seated Position | | | | |
| 1 | 68 | 98 | +30 | 44 |
| 2 | 74 | 110 | +36 | 49 |
| 3 | 65 | 88 | +23 | 36 |
| Supine Position | | | | |
| 1 | 66 | 89 | +23 | 35 |
| 2 | 71 | 88 | +17 | 24 |
| 3 | 64 | 77 | +13 | 20 |

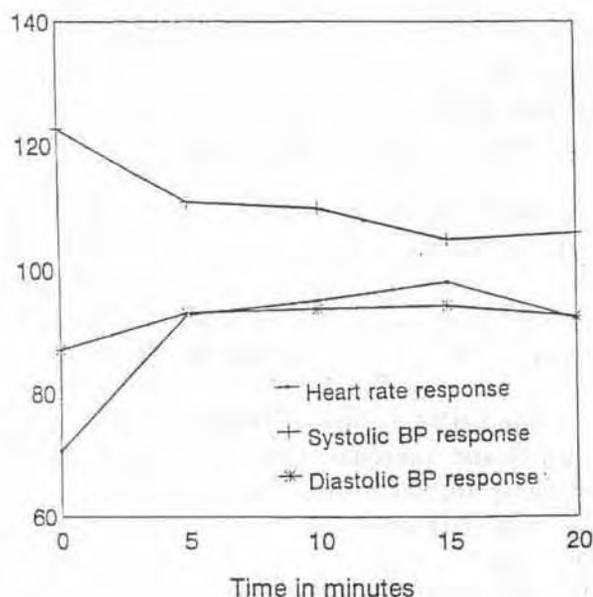


Fig. 2 : Effect of LBNP (-40 mm Hg) on cardiovascular variables (Mean values).

Table II shows results of limited number of subjects to LBNP in both supine and seated positions. Initial trend in the percentage increase in heart rate in seated position indicate higher stress on exposure to LBNP as compared to supine position. The values of HR responses in supine position in 3 subjects were 35%, 24% and 20% as against 44%, 48% and 35% respectively in seated position.

Fig. 2 shows the mean HR and BP (systolic and diastolic) responses at different time intervals. It was observed that greater fall in systolic pressure exhibit greater elevation in HR.

DISCUSSION

Lower body negative pressure is concerned with the studies in which

negative pressure is applied to lower parts of the body. Most of the investigators designed devices to apply LBNP in the supine position. In military aviation, pilots assume a near upright position and are subject to +Gz stress in this position. We have designed a special LBNP chamber and carried out the experiment. The results of our study on cardiovascular responses on application of LBNP (-4 mmHg) in seated position is given in Table I.

It is seen from results that HR increased significantly ($P < 0.01$) in all subjects at the end of 20 min of exposure to -40 mmHg. Out of 8 subjects chosen for the study, one subject showed signs of presyncope such as nausea and sweating. The HR dropped from 84 bpm to 50 bpm suddenly at the end of 19th min exposure to reduced pressure. Immediately the experiment was terminated. On cessation of LBNP application, HR and BP returned to initial level.

Systolic BP showed a decrease in the initial stages of experiment, tends to stabilize and then decrease further during termination of experiment (Fig. 2). However, the decrease in systolic BP was not statistically significant as compared to its initial value. On the other hand, diastolic BP showed an increase during course of experiment and increase was significant statistically ($P < 0.05$). The mean arterial pressure did not show any significant increase. TPR increased significantly ($P < 0.01$) at the of 20 min exposure to reduced pressure. LBNP application is known to produce pooling of blood in the lower extremities and bring about reduction

in venous return. Left ventricular output and arterial pressure are in turn reduced. This is compensated by the increase in TPR and tachycardia. It was observed that individuals with greater fall in systolic pressure exhibit greater elevation in HR and hence good correlation exists between systolic BP and HR (Fig. 2).

SV and CO decreases significantly ($P < 0.01$). Reduction in SV and subsequent reduction of CO was a result of pooling of blood in the extremities on application to LBNP. Even tachycardia which sets in on exposure to -40 mmHg pressure could not compensate fully the fall in CO.

The most important advantage of LBNP is that it can be applied in graded fashion to produce control sequestration of the central blood pool in order to differentially de-activate low pressure cardiovascular receptors (-10 to 30 mmHg) and later the arterial baroreceptors when suction pressure exceeds -30 mmHg (13, 14). In our experiment we have used graded protocol for LBNP application.

Study of HR, SV and CO responses of the subjects exposed to -40 mmHg pressure and study of similar responses in subjects exposed to +Gz stress (15, 16) suggest that physiological strain induced in seated position on exposure to LBNP is comparable to that induced by +Gz stress. It is concluded that LBNP technique in seated position can be used to study the effect of +Gz induced physiological strain in man.

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