Original article

Cardiovascular Changes under Lower Body Negative Pressure in Indian Subjects

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A lower body negative pressure (LBNP) equipment was developed with the view to determine LBNP tolerance among healthy Indian subjects and assess the utility of LBNP test as a test of orthostatic tolerance. A total number of 15 healthy men were subjected to different LBNP exposure profiles varying from -25 mm Hg of 16 min exposure to -45 mm Hg of 20 min exposure. Cardiovascular variables viz. ECG and blood pressure were monitored. LBNP levels of -30, -35, -40 and -45 mm Hg exposures for 20 min produced changes in heart rate, diastolic blood pressure (DBP) and mean arterial pressure (MAP) of a magnitude a little lesser than reported in head up tilt (HUT) test for Indian subjects. The changes in pulse pressure (PP) were similar to HUT data, whereas the changes in systolic blood pressures (SBP) values were found to be much more marked on LBNP exposure as compared to HUT data reported. One subject showed presyncopal symptoms at 20th min of exposure to -35 mm Hg.

Keywords : Orthostatic tolerance, comparison with head up tilt

Application of lower body negative pressure (LBNP) is a non invasive technique used extensively for the assessment of orthostatic tolerance, for the prevention of orthostatic intolerance secondary to hypogravity situations encountered in space flights and its ground simulation eg. bed rest and water immersion and also as a therapeutic measure in some selective clinical conditions.

Application of LBNP causes an elevation in lower body vascular transmural pressure which leads to the sequestering of blood in lower body capacitance vessels and, to a lesser extent, extravasation of plasma filtrate. Pooling of blood of the order of 0.5 - 1.0 litre occurs during -30 to -50 mm Hg LBNP application[1]. The exact amount of pooling and loss of circulating volume depends upon the magnitude and duration of the reduced pressure as well as difference in individual physiological response.

Equivalance has been reported in physiological responses to certain levels of LBNP and traditional 70° head-up-tilt (HUT)[1,2]. The latter method is used routinely at this Institute for evaluating cases of orthostatic insufficiency and low 'G' tolerance cases as HUT is considered an important clinico-physiological investigation in the assessment of individuals with suspected cardiovascular reflex status abnormality[3]. The present study was carried out with a view to determine LBNP tolerance among healthy young Indian adults and assess its utility as a test for orthostatic tolerance.

Material and Methods

The LBNP equipment was developed indigenously for the purpose of this study. It consisted of a LBNP box mounted on a plywood table. The LBNP box is made from perspex sheet. It is 104 cm in length and 79 cm wide at the base. The foot end of the box is closed with a semicircular steel plate with ports for suction pump, safety valve and mercury manometer. The upper end of the box consists of a steel plate with an oval opening for the entrance of the subjects' lower body. All along this opening, a 2 mm thick rubber sheet is attached. Adjacent to the attachment of the rubber sheet to the opening of the steel plate, a pneumatic rubber tube was vulcanised all along except at the area of the table surface where the subjects' back rest. After the subjects' lower body enters into the box, the pneumatic tube is inflated. This tube and the extended flap of the rubber sheet function as the waist seal during application of suction pressure. A common house hold vacuum cleaner pump was used to create negative pressure in the box.

Lower half of the subject upto iliac crests is inserted into the box. The subject rests his crotch on a seat fitted on the table and lies supine on the table comfortably. Subject's legs and feet are free inside the LBNP box. The waist seal is placed at the level of iliac crests, with free surface of the seal flap outwards and a belt tightened over the flap around the waist.

A total number of 15 normal healthy male volunteers taken from the Institute staff were studied at seven different protocols of LBNP exposures. Age, height, weight of the subjects and their LBNP exposure profiles are shown in Table I. The subjects were made to lie supine

Table -I Physical Characteristics of the Subjects and LBNP Exposure Profiles

LBNP Profile	LBNP(mm Hg) /Duration (min)	Subject	Age (Years)	Height (cm)	Weight (kg)
I	-25/16	KCU	23	165.0	52.0
		DK	22	165.0	60.0
II	-30/16	PDN	31	178.0	68.0
		PT	35	165.0	67.0
III	-35/16	MMD	40	165.0	70.0
		CKR	30	168.0	64.0
IV	-30/20	AKC	34	175.0	60.0
		MS	26	169.0	60.0
		SS	21	165.0	58.0
V	-35/20	RK	26	178.0	66.0
		SC	22	165.0	60.0
VI	-40/20	PS	29	163.0	69.0
		SC	25	167.0	53.0
VII	-45/20	PKS	23	160.0	71.0
		PDN	31	178.0	68.0

horizontal on the table. Lower part of body was inserted into the LBNP box and waist seal fitted at the level of iliac crest. The subjects were explained the procedure, reassured and instrumented for ECG monitoring on CM5 lead and blood pressure recording using cuff and microphone, both connected to a Polygraph (Model 7D, Grass, USA). ECG and BP were recorded at 0,4,10 and 14 minutes during the pre-LBNP resting period. During the LBNP period, ECG was continuously recorded with paper speed of 5 mm/sec. Further at every 2 minutes, ECG, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded with the paper speed of 25 mm/sec. Pulse pressure (PP) was calculated from SBP-DBP difference and the mean arterial pressure (MAP) was computed from DBP + ⅓ PP.

Result and Discussion

Out of the total 15 subjects studied, only one subject in profile V, i.e. with -35 mm Hg for 20 min protocol showed clinical features suggestive of pre-syncope. He had sweating and vague discomfort during the 20th min of the test. His 20th min recording as compared to that of 18th min showed marginal drop in HR and SBP dropped from 135 mm Hg to 120 mm Hg. Syncope or presyncopal episode has been reported to be more common with LBNP levels of more than -40 mm Hg, with incidence rising as the suction pressure increases[1].

None of the subjects developed any significant ECG changes, with no ectopics or ST-T changes seen during the test. All the subjects reported a feeling of drowsiness during the test.

Mean values of cardiovascular variables before and during LBNP exposures of different profiles are presented in table II. There were consistent increases in mean LBNP heart rate in all profiles, more markedly in profiles III to VII. Largest LBNP heart rates were always higher than the pre-LBNP values. Lowest LBNP heart rates were also higher than pre-LBNP values in all cases except in profiles I and II.

Profile I produced a slight rise in mean SBP. In all other profiles, the mean SBP values were consistently lower during LBNP compared to pre-LBNP levels. In all the profiles, the lowest SBP values were markedly lower than pre-LBNP levels.

DBP changes on LBNP did not follow a consistent pattern. While the largest values of DBP on LBNP were found to be higher than their respective pre-LBNP levels in all the profiles, the mean LBNP values were found to fall below their pre-LBNP levels in profile I, II and VI.

PP decreased in its mean LBNP values in all circumstances except in profile I. The lowest LBNP values of PP were markedly and consistently lower than their pre-LBNP levels in all the profiles. MAP values during LBNP, like those of DBP, were not consistent. The largest LBNP values of MAP were always higher than the pre-LBNP state, but the mean MAP values on LBNP were found to fall below their pre-LBNP levels in profiles I, II, IV and VI.

Table - II Mean Values of Cardiovascular Variables before and during Exposures at different Profiles of LBNP

		ProfileI (n = 2)	ProfileII (n = 2)	Profile III (n = 2)	Profile IV (n = 3)	ProfileV (n = 2)	Profile VI (n = 2)	Profile VII (n = 2)
	Pre-exp	71.3	87.5	76.9	79.2	65.6	77.0	75.6
HR	Exp-Mean	71.5	91.4	88.4	90.2	73.9	86.8	88.7
(bpm)	Max	77.5	95.0	95.0	95.0	82.5	92.5	95.0
	Min	65.5	85.0	85.0	81.7	67.5	80.0	80.0
SBP	Pre-exp	117.5	114.4	128.2	129.8	127.5	123.5	119.5
(mm Hg)	Exp-Mean	121.3	110.8	124.8	121.8	120.7	115.9	114.5
	Max	127.5	117.5	135.0	128.3	130.0	120.0	122.5
	Min	112.5	107.5	120.0	117.3	110.0	112.5	107.5
DBP	Pre-exp	71.0	68.1	81.9	80.4	66.9	75.6	73.1
(mm Hg)	Exp-Mean	68.6	67.9	87.0	82.1	73.4	79.9	78.1
	Max	75.0	72.5	95.0	85.0	90.0	82.5	84.0
	Min	60.0	—	82.5	76.3	65.0	70.0	70.0
PP	Pre-exp	46.5	46.3	46.3	49.4	60.6	47.9	46.4
(mm Hg)	Exp-Mean	52.7	42.9	37.8	39.7	47.3	42.0	36.4
	Max	60.0	50.0	47.5	50.0	57.5	45.0	50.0
	Min	40.0	37.5	27.5	32.3	30.0	32.5	25.0
MAP	Pre-exp	86.5	83.5	97.4	96.9	86.8	91.5	88.6
(mm Hg)	Exp-Mean	86.2	82.2	99.5	95.3	89.1	88.0	90.2
	Max	90.0	85.0	104.0	98.7	100.0	93.5	95.0
	Min	81.0	79.0	95.0	92.7	82.5	85.0	84.0

Table III presents the changes in cardiovascular variables during different LBNP profiles as compared to pre-LBNP values. These changes are presented as mean changes and as largest increase or fall during LBNP and are compared against similar presentation of Orthostatic data of Indians on 70° head up tilt as reported by Dikshit et al[3]. It is seen that both mean and largest increase in heart rate on LBNP profile III to VII are marginally less compared to HUT data. SBP changes, on the other hand, are much more pronounced on LBNP exposure, effecting a marked fall both in mean and lowest values of SBP in all profiles except in profile I. As compared to HUT data, the mean DBP changes on LBNP are found inconsistent. However, the largest increase in DBP are comparable to HUT data in the direction of change and to some extent in the degree of change as well. The pulse pressure changes on all LBNP profiles except

Table - III Comparison of cardiovascular changes produced by LBNP and 70 degree HUT over respective pre exposure values (mean)

Variable		LBNP PROFILES I n=2	II n=2	III n=2	IV n=3	V n=2	VI n=2	VII n=2	70° HUT Dikshit et al n = 166
HR	Average	+0.4	+3.9	+11.5	+11.0	+8.3	+9.8	+13.1	+16.0
(bpm)	Largest increase	+6.2	+3.9	+18.1	+15.8	+16.9	+15.5	+19.4	+21.0
SBP	Average	+3.8	-3.6	-3.4	-8.0	-6.8	-7-6	-5.0	+1.0
(mm Hg)	Largest fall	5.0	-6.9	-8.2	-12.5	-17.5	-11.0	-12.0	-4.0
DBP	Average	– 2.4	0.2	+5.1	+1.7	+6.5	-1.7	+5.0	+9.0
(mm Hg)	Largest increase	+4.0	+4.4	+13.1	+4.6	+23.1	+6.9	+10.9	+14.0
PP	Average	+6.2	-3.4	-6.7	-9.7	-13.3	-5.9	-10.0	-10.0
(mm Hg)	Largest fall	-6.5	-8.8	-18.8	-17.1	-30.6	-15.4	-21.4	-16.0
MAP (mm Hg)	Average	– 0.3	-1.3	+2.1-	-1.6	+2.3	-3.5	+ 1.6	+6.0

profile I are in the same direction as that seen with HUT and the values at profiles III, IV and VII compare well with HUT data. Like that of DBP changes, MAP changes seen during LBNP were also equivocal and indicative of somewhat lesser degree of change as compared to a definite increase in MAP seen during HUT.

Wolthuis et al[3] and Hoffler et al[2] have compared various levels of LBNP with HUT and passive orthostasis. They have found equivalence in respect of HR and DBP changes between -40 to -50 mm Hg LBNP with HUT or passive standing. Changes in SBP were found to be opposite i.e. a rise during orthostasis and a fall during LBNP. In the absence of a definite end point, the LBNP stress imposed on our subjects in profiles IV to VII showed somewhat similar strain as seen with HUT and could be useful in evaluating individual's orthostatic tolerance.

REFERENCES

1. Wolthuis RA, Hergman SA, Nicogossian AE : Physiological effects of locally applied reduced pressure in man. Physiol Rev. 1974;54:566-595

2. Hoffler GW, Wolthuis RA, Johnson RL : Appolo space crew cardiovascular evaluation. Aerospace Med. 1974;45:807-820

3. Dikshit MB, Banerjee PK, Rao PLN : Orthostatic tolerance of normal Indians and those with suspected abnormal cardiovascular reflex status. Aviat Space Environ Med 1986;57:168-173