

Positive Pressure Breathing as a Protective Technique in + Gz Acceleration

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Abstract

TWELVE experienced air-crew subjects were exposed to +G_z acceleration to assess the protection afforded by 30 mm of Hg Positive Pressure Breathing (PPB) and anti-g-suit. PPB in combination with anti-g-suit provided a consistent and significant protection over relaxed tolerance (Mean increase in tolerance 2.64 ± 0.34). No serious ECG abnormalities were seen.

Introduction

The advances in technology have made it possible to design and build aircraft capable of withstanding higher + G_z loads than the currently available aircraft¹. In such environment the ability of man to tolerate these loads will depend upon the protective measures used. Though the protective measures in use in present day aviation have been adequate till now, these will not be sufficient in high and sustained G environment.

The tolerance of an unprotected man in a +G_z environment is limited by a falling perfusion pressure at head level, due to the increased hydrostatic effect. All the methods of protection in current use aim at increasing the systemic arterial pressure at head level. Anti-g-suit is capable of limited protection of 1.25-1.75g, over and above the relaxed human tolerance. Thus to enable the man to cope up with the capability of future generation aircraft some additional protective method has to be used. Shubrooks² and Leveret et al³, have found positive pressure breathing (PPB) to be an effective method of increasing +G_z tolerance. We have undertaken this study to determine the increase in G tolerance given by 30 mm of PPB in a group of Combat pilots.

Materials and Methods

12 healthy aircrew in full flying medical category were subjected to +G_z exposures in Human centrifuge at IAM, Bangalore. Subjects were clinically examined to exclude any illness. Their ages ranged between 24-33 years.

A MK-20A British oxygen regulator was modified wire locking the manual operation lever, so as to deliver 30 mm of Hg PPB by operation of on-off switch only. The subject wore a P-mask and inner-G helmet during PPB and 100% O₂ was used for this. The modified regulator was fixed in front of the subject in the centrifuge gondola. The subjects were indoctrinated in the use of PPB.

Peripheral light loss (PLL) was used as end point. This end point was determined by an increase in reaction time by 2.5 to 3 times the basal value. Being aircrew subjects, acceleration exposures were started from 3g level for finding out relaxed tolerance (Type I run). The G-levels were then progressively raised to determine individual's unprotected PLL. Then tolerance with anti-g-suit was determined (Type II runs). On the next day, tolerance with anti-g-suit and 30 mm PPB was determined (Type III runs). The reaction time, g-profile and 3 lead ECG were recorded concurrently with the help of a 6-channel polygraph at 10 mm/sec paper speed.

The subjects wore a conventional 5 Bladder anti-g-suit (PPK III. 822 MG) over the inners. Anti-g valve was used in 'High' setting delivering a pressure of 1.5 to 1.75 psi per g beyond 2g level. On any particular day the number of runs did not exceed 6.

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The rate of onset was 1g/sec and deceleration was at 0.1g/sec. Peak G was maintained for 25 Sec. Gillingham and Grump⁵ have reported that in US AFSAM centrifuge the human exposures were limited to 7g for duration shorter than 60 seconds, in view of the animal pathology seen in HSG exposures. The presence or absence of similar pathology in human being could not be established despite the use of most of the available non-invasive monitoring techniques eg ECG, VCG, enzyme studies etc. Because of rather unsophisticated monitoring techniques employed in the present study, in view of the subject safety, an upper limit of 7g was imposed. An emergency switch was provided to the observer too so that he could terminate the runs whenever required.

Baseline ECG records, employing 6 limb leads and one chest lead (V₅) were obtained². Pulmonary functions were evaluated before and after the runs. After the exposures to +G_z and PPB the subjects were again clinically examined to look for any swelling around ankles, petechial haemorrhages etc. The subjects were also asked to give their subjective impressions of the runs.

Results

The relaxed tolerance of the subjects ranged between 3.2 and 4.8g with a mean and standard deviation (S.D.) of 4.26 and 0.30 g (Table I). The tolerance with anti-g-suit ranged from 4.2-6.0g (Mean and S. D. 5.96 and 0.25g). The mean increase with anti-g-suit alone being 1.21. The increase in tolerance with 30mm of Hg PPB and anti-g-suit over the relaxed tolerance had a mean and S. D. of 2.64 and 0.34g and that over type II run had a mean and S. D. of 1.43 and 0.33. In type III runs 8 out of 12 subjects did not achieve PLL at the ceiling limit of 7g. The increase could have been more than the above figure had the subjects been allowed to go to their PLL levels.

The increase brought about in type II runs over type I runs is statistically significant, and so is the increment brought about by type III runs over type I runs. The T-test for increase in tolerance by type III runs over type I runs as compared to that by type II runs over type I runs is also significant. The increase brought about by type III runs over tolerance with type II runs is also found to be statistically significant ($P < .001$). The situation in these two types of runs is not similar, as in type II runs all the subjects had achieved their PLL while in type III runs 8 out of 12 subjects did not do so. Therefore the difference in

their values is not very large but could have been so if all the subjects had been exposed to their PLL level in type III runs also.

Electrocardiogram

The changes in ECG observed are tabulated in Table II and are not significant. These changes reverted back to normal on cessation of runs and there were no subjective complaints from any of the subjects on this account. No correlation could be established between the level of G and the heart rate at peak G or between magnitude of G and the increment in heart rate from basal value⁷.

Blood Pressure

No significant correlation could be established between G values and BP changes.

Subjective Impressions and clinical examination after the runs

The results are tabulated in table III. Subjects did not complain of pain in the chest or calf nor had any swelling around ankles.

Four subjects showed 1 spot per sq.inch around one or both ankles, 2 showed more than 1 but less than 3 spots per sq.inch and one subject had 3-4 spots per sq.inch around both the ankles. Seven subjects showed petechial haemorrhages around the ankle, four of them had 1 spot per sq.inch and the other had spots ranging between 2-4 per sq.inch. The remaining five subjects did not show petechial haemorrhages.

Five subjects had mild but controllable tendency to cough either at the onset or after cessation of PPB, because of dryness of throat. Only one subject (Subject III) had a marked tendency to cough both at the onset as well as after cessation of PPB because of extreme dryness of throat.

Six subjects did not find PPB + G_z to be fatiguing. Four subjects found it to be mildly fatiguing, after the runs with PPB. Only subject III found PPB to be extremely tiring and uncomfortable both immediately after as well as later in the day. He found PPB to be tiring because of muscular effort needed to breathe against positive pressure while under +G_z. Subject VIII also found PPB to be tiring but attributed it to excessive sweating and environmental heat.

Four subjects did not complain of any tingling sensation. Seven subjects complained of mild tingling sensation on inflation of anti-g suit. One subject had tingling sensation on 2nd day only.

Discussion

Positive pressure breathing even at 1'g' is known to cause an increased mean systemic arterial pressure. This is due to an increased intrapleural pressure which is reflected on to heart and big blood vessels of thoracic cavity. This increased systemic arterial pressure is equal to the increase in interapleural pressure and is 50-100% of the positive breathing pressure applied¹ and thus compensates for any decreased cardiac output.

When PPB is coupled with +G_z acceleration, the increased intravenous pressure due to hydrostatic effect causes an increased venomotor tone, which thus will reduce the venous pooling. The latter is also reduced by anti-g suit. Anti-g suit helps further by preventing the descent of diaphragm which would otherwise have occurred with PPB. Thus PPB when used alongwith anti-g suit will increase the tolerance to +G_z acceleration by increasing mean systemic arterial pressure, improved enforced venous return and by prevention of descent of diaphragm. The results of this study have shown this to be true and such a combination has shown an increase of tolerance by $2.64 \pm 0.34g$ over the relaxed tolerance. These results are in conformity with the findings of Shubrooks Jr.⁸.

Since the aircrew at some time or the other of their flying career are exposed to PPB and are thus familiar with it, PPB can be more easily learnt and can become less distracting with practice. Also it can be easily complimented to flying environment.

Shubrooks Jr.⁸ demonstrated a greater increase in tolerance by increasing the magnitude of positive pressure breathed. However, in the present study 30 mm of Hg PPB was used irrespective of the level of G and these PPB levels are well tolerated even without counter pressure garments.

The ECG changes as observed in the present study have been reported earlier² and have not been considered serious.

Conclusions and recommendations

- (a) PPB with anti-g suit provides a consistent and significant increase in tolerance to +G_z acceleration.
- (b) No detrimental effects were observed in the present series of exposures.
- (c) Further evaluation of PPB in +G_z acceleration should be undertaken in an environment of heat stress.

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References

1. Ernsting, J. Some effects of raised intra-pulmonary pressures in man. AGARDO-graph 106 London Muckay, 1966.
2. Gillies, J. A. A text book of Aviation Physiology. Pub. Pergamon 1966.
3. Gillingham, K.K. and P.P. Grumph. Changes in clinical cardiologic measurements associated with HSG stress. Aviat. Space Environ. Med. 47: 726-733, 1976.
4. Leverett, S. D. Jr, R. R. Burton, R. J. Crossley, R. D. Michaelson and S. J. Shubrooks Jr. Human physiologic responses to high, sustained +G_z acceleration FPRC/1332, 1973.
5. Mohan Murali, N. Recording of 12 lead ECG during exercise J. of Aero Med. Society of India 13: 12-21, 1970.
6. Parkhurst M.J., S.D. Leverett Jr. and S.J. Shubrooks Jr. Human tolerance to high sustained +G_z acceleration. Aerospace Med. 43: 708-712, 1972.
7. Shubrooks, S.J. Jr. Changes in cardiac rhythm during high sustained levels of positive +G_z acceleration. Aerospace Med. 43: 1200-1206, 1972.
8. Shubrooks, S. J. Jr. Positive pressure breathing as a protective technique during +G_z acceleration. J. Appl. Physiol. 35: 294-298, 1973.

TABLE I
Results of G tolerance in type I, II and III runs

Sl. No.	Relaxed tolerance (type I run)	Tolerance with anti-g-suit inflated (type II run)	Increase in tolerance in type II run	Tolerance with 30 mm of Hg PPB and anti-g-suit (type III run)	Increase in tolerance over type II run with type III run	Total increase over relaxed tolerance	Remarks for type III run
1	4.8	6.0	1.2	7.0	1.0	2.2	NO PLL
2	3.2	4.2	1.0	6.2	2.0	3.0	PLL
3	4.3	5.5	1.2	7.0	1.5	2.7	NO PLL
4	4.3	5.3	1.0	6.7	1.4	2.4	PLL
5	4.3	5.7	1.4	7.0	1.3	2.7	NO PLL
6	4.7	6.0	1.3	7.0	1.0	2.3	NO PLL
7	4.5	5.8	1.3	7.0	1.2	2.5	NO PLL
8	4.0	5.3	1.3	7.0	1.7	3.0	NO PLL
9	4.5	5.7	1.2	7.0	1.3	2.5	NO PLL
10	3.7	5.0	1.3	7.0	2.0	3.3	NO PLL
11	4.4	5.7	1.3	7.0	1.3	2.6	PLL
12	4.0	5.0	1.0	6.5	1.5	2.5	PLL
Mean	4.22	5.43	1.12	6.87	1.43	2.64	
S.D.	+ 0.44	+ 0.51	+ 0.14	+ 0.26	+ 0.33	+ 0.34	

(1 for 5 and 7 not significant. 1 for 3 and 4, 3 and 6 and 5 and 8 highly significant)

TABLE II
ECG changes seen in all the three types of runs

Sl. No.	Electrocardiogram findings	Remarks
1.	Peaked T-wave in type-I & II runs only	Mild sinus arrhythmia in resting ECG
2.	Acceleration brady-cardia in type-I run only	Mild sinus arrhythmia in resting ECG
3.	Flattening of T-wave then inversion in lead III in type-I run and flat T-wave in lead III in type II run.	—
4.	NAD	—
5.	NAD	—
6.	Deep 'S' and peaked T in lead II, III & V ₂ .	—
7.	NAD	—
8.	NAD	—
9.	T-inversion in all leads in all the types of runs.	—
10.	T-inversion in all leads in type III runs.	—
11.	NAD	—
12.	T-wave inversion in all leads in all types of runs.	Mild sinus arrhythmia in resting ECG,

TABLE III

Results of subjective impression and examination after the runs of all the three types

Sl. No.	Pain chest	Cough	Fatigue	Sweating and subjective impressions of thermal environment
1.	Nil	Nil	Nil	Comfortable
2.	Nil	Mild tendency to cough after PPB due to dryness of throat	Nil	Comfortable
3.	Nil	Marked tendency to cough after PPB due to severe throat dryness	Felt extremely fatigued immediately after the run and later in the day	Mild sweating & felt irritation because of heat
4.	Nil	Nil	Mild	Comfortable
5.	Nil	Tendency to cough when first bout of PPB comes on. Later due to dryness of throat	Nil	Comfortable
6.	Nil	Nil	Nil	Mild sweating but comfortable
7.	Nil	Nil	Felt tired 5-6 hrs after the run. No fatigue immediately after the run with PPB	Mild sweating but within tolerable limits
8.	Nil	Nil	Felt moderately fatigued and sleepy after the run with PPB	Sweating was quite a lot and at one stage felt like giving up.
9.	Nil	Felt urge to cough only after the run as throat became dry because of PPB	4-5 hrs after the run felt fatigued and yawning set in.	Nil
10.	Nil	Felt urge to cough after the run due to dryness of throat with PPB	Nil	Nil
11.	Nil	Nil	Mildly tiring with PPB	Sweating only mild but irritating
12.	Nil	Throat becomes very dry with PPB & therefore every time PPB comes on felt like coughing. No cough after the run.	Mild fatigue 4-5 hrs after the run.	Mild sweating but tolerable.

TABLE III (Contd.)

Sl.No.	Swelling around ankles	Petechial haemorrhages	Tingling or pain	Remarks
1.	Nil	Nil	Mild tingling every time the anti-g-suit inflated.	Felt fatigued 3-4 hrs. after the PPB run, but could carry on the routine jobs.
2.	Nil	Nil	Mild tingling when anti-g-suit inflated.	Fatigue with PPB run was less than that on first day with relaxed and anti-g-suit tolerance runs.
3.	Nil	0-1 spot per sq. inch around right ankle	Moderate tingling on inflation of anti-g-suit only on 2nd day.	PPB is very uncomfortable and heat adds to it. It is very fatiguing.
4.	Nil	3-4 spots per sq. inch around both ankles	Mild tingling on and off when anti-g-suit inflated.	PPB is quite comfortable and is valuable experience as one feels great to hold such high-g-load for so long.
5.	Nil	Nil	Nil	PPB is a very good method of increasing tolerance. Felt that I could tolerate a minimum of 1 g more. Can be used in actual flying.
6.	Nil	Nil	Mild tingling whenever anti-g-suit inflated.	During PPB run because of sweating felt mildly uncomfortable but could carry on. No problem with PPB as such.
7.	Nil	0-1 spot around both ankles	Mild tingling on 2nd day every time anti-g-suit inflated.	Mildly uncomfortable with PPB because of accompanying heat. But no problems with PPB as such and could carry on.
8.	Nil	0-1 spot around lt. ankle only	Nil	PPB with G when not accompanied by sweating and heat may be O. K. but because of heat felt uncomfortable.
9.	Nil	Nil	Nil	PPB is quite comfortable. No tears in eyes, ear drums do bulge out, no pain. Clarity of vision with PPB was fantastic.
10.	Nil	0-1 spot per sq. inch around both ankles	Nil	Increase in tolerance is very high and felt that I could go for another couple of runs. I had no problems.
11.	Nil	1-2 spots around lt. ankle only	Mild tingling when g-suit inflated.	The PPB run is tiring but increase in tolerance is O.K. with further practice one can get used to it heat or no heat.
12.	Nil	1-2 spot per sq. inch around lt. ankle only	Mild tingling when anti-g-suit inflated.	Tiredness 4-5 hrs. later. But for heat I had no problems.