Study of +Gz Protection Given by an Anti 'G' Suit Worn on Top of a Liquid Cooled Suit

AK SINGH

+Gz protection given by an anti 'G' suit worn on top of a liquid cooled suit has been evaluated. The protection provided by the anti 'G' suit when worn on top of the LCS is significantly lower than that provided by the suit when worn next to the skin.

THE abnormal physical conditions of high temperature and high accelerations as encountered by a military pilot assume practical significance due to physiological limitation of human system in dealing with these stresses. Modern high performance aircraft, having favourable thrust to weight ratio and low wing loading are capable of greater amount of manoeuvreability, thereby they are capable of attaining +Gz accelerations of high magnitude and longer duration. These high sustained accelerations are beyond human tolerance without protective devices.

Though there are many advanced systems available to protect pilots from other stresses, the only protective device available at present against high acceleration stress is the anti 'G' suit. The suit provides an average protection of 1.5 g, when the suit is properly fitting to the pilot.

Acute heat stress is another abnormal physical condition which is encountered by the aircrew of most of the fighter aircraft in Indian Air Force especially during summer months. It is well known that both physical and mental functions are adversely affected under heat stress. The onset and the degree of performance deterioration depends on the severity of thermal stress. In order to derive maximum benefit out of the performance capability of the aircraft, it becomes imperative to keep the pilots at high peak of efficiency level by providing thermal comfort inside the cockpit.

Heat stress can be counteracted either by means of provision of adequate cabin air conditioning or by introduction of personal conditioning system. Personal conditioning system in the form of liquid cooled suit (LCS) is capable of providing thermal comfort in much higher range of environmental temperatures. It is also effective during stand by period, in flight under hot climatic conditions and while wearing high altitude protective clothing.

Liquid cooled suit consists of net work of small liquid carrying pipes threaded through an undergarment. Transference of heat from the body to the LCS is by means of conduction only and as such it is desirable that it should be in close contact with the skin of the wearer.

It is almost impossible to develop any single item of aircrew equipment in isolation without considering the inter-relationship with other equipment. The functional integration of aircrew equipment must be such that performance and efficiency of any one item of equipment or clothing is not interfered by other equipments. Introduction of liquid cooled suit

to achieve thermal comfort should not interfere with the anti 'G' suit protection to a significant level as both the suits require to be worn next to the skin for their ideal performance. Keeping this aim in view this study was carried out.

Material and Methods

Ten healthy male subjects, 22-30 years old, were subjected to experimental trials in a human centrifuge to find out the protection given by the anti 'G' suit worn inside and outside the liquid cooled suit. All subjects had prior experience of +Gz accelerations either in aircraft or in the human centrifuge. Before the exposure they were given a thorough clinical examination to eliminate the possibility of any cardio pulmonary dysfunction, which could reduce +Gz tolerance.

Liquid cooled suiti:—The suit selected for this study had been designed by Beaufort in conjunction with Royal Aircraft Establishment, Farnborough, U.K. The suit is a close fitting full length garment covering body parts between neck and ankle. It is made of knitted crimpled nylon which ensures that it stays in close contact with the skin. This is available in different sizes, but size medium regular was selected for this study, which was close fitting to all subjects.

Anti 'G' Suits:—Five bladder, cut away type of anti 'G' suits of Russian make were selected according to the height of the subject and adjusted to ensure that the suit was properly fitting the subject.

Leak test of the liquid cooled suit:—The tubing of the liquid cooled suit was filled with liquid (water mixed with glycol in equal proportion) and liquid was sealed by means of selfsealing connectors attached to both inlet tubes of the suit. On top of the liquid cooled suit, subjects were fitted with anti 'G' suit which was inflated with help of an anti 'G' suit test rig upto a pressure of 5 psi for a period of 10-15 sec. The tubes were checked for any leak and at the same time subjects were asked for any pressure points or discomfort due to pressure in the suit.

Recorder:—A six channel jet recorder mingograph was used for ECG, reaction time and 'G' profile recording. 'G' profile was recorded on channel number one and second channel was used for reaction time for PLL determination. Three other channels were used for recording ECG.

End point:—Peripheral light loss (PLL) was used as the end point. An increase in the reaction time by 2.5 to 3 times from basal reaction time was taken as the end point.

Test procedure:—All the subjects were exposed to three sets of 'G' profile.

Set I:—To determine the +Gz relaxed tolerance of the subject with anti 'G' suit without inflation, worn inside an overall only.

Set II:—To determine the +Gz relaxed tolerance with inflation of the anti 'G' suit, worn inside an overall.

Set III:—To determine the +Gz relaxed tolerance with inflation of anti 'G' suit, worn on top of the liquid cooled suit.

Acceleration Profile:—For all the test runs rate of onset was kept at 0.5 g/sec. The first test run was started at 2.5 g or 3 g and progressively increasing values of +Gz were given to the subject till a firm PLL was established.

Results

Tolerance values for the 10 subjects in Type I (relaxed tolerance without anti G suit inflation) and Type II runs (with anti G suit inflated) are given in Table I. It also shows the increase in tolerance in each subject with inflation of the anti G suit (Type II run). The mean relaxed tolerance was 3.99 g with a standard deviation of 0.54. The tolerance with the anti G suit inflation (Type II run) was 5.16 g with a standard deviation of 0.44 showing an average increase of 1.17 g, over the relaxed tolerance. The increase in tolerance is statistically highly significant.

Table—I

Tolerance in Type I and II runs

Sl. No.	Relaxed tolerance (Type I run)	Tolerance with inflation of anti G suit (Type II run)	Increase in tolerance in Type II run
1.	5.1	6.0	0.9
2.	3.3	4.8	1.5
3.	3.4	4.7	1.3
4.	4.0	5.4	1.4
5.	3.8	4.8	1.0
6.	3.9	5.0	1.1
7.	4.5	5.5	1.0
8.	3.6	4.7	1.1
9.	4.0	5.5	1.5
10.	4.3	5.2	0.9
Mean	3.99	5.16	1.17
SD	±0.54	0±.44	
Mean difference 1.17 ($P < 0.001$)			

Table II compares the relaxed tolerance of the subject (Type I run) with the inflation of the anti G suit when worn on the top of the liquid cooled suit (Type III run). The mean tolerance with the anti G suit worn and inflated over the liquid cooled suit was 4.69 'G' with a standard deviation of 0.47. An average increase of 0.7 g in the tolerance in Type III over Type I run is statistically highly significant.

Table—II

G Tolerance in Type I and Type III runs

Sl. No.	Relaxed tolerance (Type I run)	Tolerance with Anti 'G' suit inflated on top of LCS (Type III)	Increase in tolerance in Type III run
1.	5.1	5.6	0.5
2.	3.3	4.2	0.9
3.	3.4	4.0	0.9
4.	4.0	5.0	1.0
5.	3.8	4.5	0.7
6.	3.9	4.7	0.8
7.	4.5	5.0	0.5
8.	3.6	4.3	0.7
9.	4.0	5.0	1.0
10.	4.3	4.6	0.3
Mean	3.09	4.69	0.7
SD	±0.54	0±0.47	
Mean difference 0.7 ($P < 0.001$)			

Table III gives the tolerance values of the subjects with anti G suit worn and inflated next to skin (Type II run) and on top of the liquid cooled suit (Type III run). There is an average decrease of 0.47 g, when the suit was worn on top of the L C S (Type III run) in comparison to the type II run. This decrease is statistically highly significant.

Table—III

G tolerance in Type II and III runs

Sl. No.	Tolerance with Anti G suit inflation (type II run)	Tolerance with Anti G suit inflation on top of L C S (Type III run)	Decrease in tolerance in type III run
1.	6.0	5.6	0.4
2.	4.8	4.2	0.6
3.	4.7	4.0	0.7
4.	5.4	5.0	0.4
5.	4.8	4.5	0.3
6.	5.0	4.7	0.3
7.	5.5	5.0	0.5
8.	4.7	4.3	0.4
9.	5.5	5.0	0.5
10.	5.2	4.6	0.6
Mean	5.16	4.69	0.47
SD	±0.44	±0.47	±0.04
Mean difference	0.47 ($P > 0.001$)		

Discussion

A pilot's performance in aerial combat where high sustained +Gz acceleration forces are encountered is limited by the functional limitation of his cardiovascular system. With increasing magnitude of acceleration the heart fails to maintain adequate prefusion pressure at head level. This fall in perfusion pressure at head level results in progressive symptoms of peripheral light loss, central light loss and unconsciousness.

All the methods available at present for increasing g tolerance are aimed at increasing perfusion pressure at the head level either by preventing increase in the head to heart distance or by preventing pooling of blood in lower parts of the body.

The anti G suit gives an average protection of 1.5 'g' when it is properly fitting. In the present study the average increase in protection in type II run over type I run is 1.17 g. It is quite well known that an anti G suit without inflation gives an average protection of 0.3 g. Thus the actual difference between type I and type II run would be 1.17+0.3= 1.47 g by the inflation of the anti G suit. This protection can be reduced even if a fold of clothing is brought in between the skin and the anti G suit. Comparison of G protection provided by the cut away type of anti G suit worn inside and outside the flying overall (IAM departmental project No. 103), currently in progress at Institute of Aviation Medicine, Bangalore does show a significant reduction in protection when the anti 'g' suit is worn outside the flying overall.

Heat stress as encountered in flight under hot climatic conditions and high speed flying also puts strain on the cardiovascular system of the pilots. Increase in heart rate and cutaneous vasodilation to remove heat from the body by evaporation leads to ineffective blood volume. Heat stress is also known to reduce the tolerance of +Gz forces. This additional stress of heat can be eased by introducing the liquid cooled suit, since comfort level temperatures are normally not achieved in most fighter aircraft du to inadequate cabin air conditioning systems.

The liquid cooled suit, requires close contac with the skin for its optimal functional efficiency. Introduction of the liquid cooled suit underneath the anti 'G' suit does interfere with proper fitting of the 'G' suit, especially in the region of the abdomen, where main inlet and outlet tubes of the liquid cooled suit are situated. In addition the bulky nature of this clothing and tubing of the liquid cooled suit interferes with the functional efficiency of the anti 'G' suit.

The present study shows a significant reduction of 0.47 g in the protection by the anti 'G' suit worn on top of the liquid cooled suit in relatively comfortable environment. There is no report available at present, where functional efficiency of liquid cooled suit in increasing +Gz tolerance by providing thermal comfort has been studied. To get maximum benefit out of the functional capacity of an anti 'G' suit either the liquid cooled suit will require a modification or the integration of the liquid cooled suit and the anti 'G' suit should be such that they do not interfere with the performance and efficiency of each other.