Positive G Tolerance of Indian Subjects-Effects of Age and Flying Experience

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Average tolerance values of +Gz in Indian subjects were not available. A study has been carried out on the results of over 500 male volunteer subjects who had undergone trials on the human centrifuge at the Institute of Aviation Medicine (IAM). The subjects have been subdivided into different groups according to age and flying experience. The average tolerance values for these different groups have been calculated. The study shows that fighter pilots have a higher tolerance than other groups. The tolerance among senior fighter pilots is higher than that of junior and younger fighter pilots. An opposite trend of reduced tolerance with increasing age is seen in all other groups of subjects. Norms of tolerance values for Indian subjects in all age groups have been established for comparison and assessment of cases referred to the Medical Evaluation Centre at IAM.

IT has often been stated by pilots that an elderly pilot has lesser tolerance to acceleration than his younger colleagues. This project was started to study the changes in +Gz tolerance with ageing among pilots Certain subjects were specifically studied as part of this project and some subjects for whom data were already available were also included in the results analysed.

For the last 8 years the technique of end point determination (PLL) has been standardized at the Institute of Aviation Medicine (IAM) and results obtained have been repeatable with this method. The total available data on 508 subjects in various age groups, with different professional back grounds and flying experience have been analysed to obtain values for PLL tolerance among Indian subjects.

Tolerance of fighter pilots to +Gz at times determines the utility of a fighter aircraft in combat manoeuvres. It is quite well known that there is a large variability in human tolerance to +Gz. There may be some racial variations in these tolerance figures also. Data on tolerance of Indian fighter pilots and other groups of Indian population were not available from any published source and as such this project was initiated.

Quite often assessment of pilots after diseases, incidents of air sickness and reported low G tolerance in the air has to be carried out in the Acceleration Physiology Department of IAM. There are no known basal values available for comparison and proper assessment of such cases. This project was undertaken to fill this gap in our knowledge.

Material and Methods

All the 508 subjects in this study were fully fit, male, volunteers, reporting to IAM for various training courses and high performance medical examination. Staff at IAM also took part in these trials. All subjects were in their appropriate highest medical categories (A1 G1 for aircrew and A4 G1 for ground duty personnel). All aircrew had previous experience with high +Gz manoeuvres in aircraft and the ground duty personnel were experienced riders in the human centrifuge. Subjects were instructed to remain relaxed during the centrifuge trials to avoid the variable factors of personal protection practised by different persons.

The trials have been conducted on the human centrifuge at IAM which has a test radius of 5 metres. The centrifuge rotates in a clockwise direction. The acceleration imposed on the subject is proportional to the RPM of the arm. The gondola is free to rotate and align itself with the resultant acceleration during rotation.

The subject can be exposed to any acceleration upto +10g, with an accuracy of 0.1g. The duration at peak g can be controlled from 1 sec to 30 min. The rate of rise and decay of acceleration can be varied from 0.1g/sec to 2.5g/sec.

Test profiles used

Subjects were tested with two rates of onset of +g, fighter pilots @ 1g/sec and all other subjects @+0.5g/sec. The duration at peak g was maintained for a fixed period of 15 secs in all cases. Rate of deceleration was + 0.1g/sec in all trials. The tests were started at a low value of g and gradually increased till a firm PLL was obtained.

Monitoring facilities

The subject's face is visible on a TV screen during the test and there is a two way voice communication on intercom. The reaction time of the subjects was recorded on a multichannel jet recorder, along with the g profile.

Position of subject

The subject is seated and harnessed in a conventional aircraft seat with a back angle of 13°. The head rest provides support to the head. The subject remains seated upright with his feet supported on adjustable aircraft rudder pedals.

PLL technique

For determination of PLL the subject is asked to look at a central red light positioned at eye level Two peripheral lights are mounted on a bar, at a distance of 30" from the subject and are 28" apart. The three lights are mounted on a single bar. The intensity of the central red light and peripheral lights can be varied and are adjusted for each subject at a level where they are just perceptible and a repeatable reaction time can be obtained for the subject at rest.

The peripheral lights can be switched on by the medical monitor at random intervals. The subject has to switch off the peripheral lights by pressing a micro switch on the mock control column. The time taken by the subject to respond to the lights is recorded on a paper recorder. The basal reaction time after some practice is recorded at rest and compared with the reaction time during acceleration stress. An increase of reaction time to twice his normal is considered significant and the value of +Gz stress, where such an increase is seen, is taken as his PLL at 53°.

Multiple light system

A new multi light system for end point determination has been designed, fabricated and installed in the centrifuge under this project. The system consists of light positioned at angles of 64°, 60°, 56° and 52° in relation to the subject's vision. These lights are mounted on a semicircular frame work, kept at a sequence in such a manner that only when the subject stops responding to the outermost set of lights, the next inner pair lights up. This way, progressive loss of visual fields can be identified. This system has been evaluated and standardised on about 50 subjects under this project. Results obtained with 52° position have been included in the project report.

Results

Total data of 508 subjects, in different age groups and with varying flying experience and background have been analysed. The subjects have been divided into three age groups, ie, 20 to 34 yrs, 35 to 40 yrs, and 41 to 55 yrs. Each age group has been further divided into fighter pilots, transport pilots and other aircrew and third sub group of ground duty personnel consisting of medical officers and airmen. The data for the age group 20-34 years, 35-40 and 41-55 yrs are presented in Table I, II & III respectively.

The flying experience of pilots has been utilised to sub-divide them into three categories, viz., less than 200 hours, 201 to 1000 hours and more than 1000 hours. The values for the total number of subjects (508) have been summarised along with Table III.

TABLE - I

'G' tolerance values in age group 20-34 years

Branch	Flying experience in hours	No. of Subjects	'G' Tolerance Mean	SD	Range
FP	<200	43	4.3	0.8	2.5-6
	201-1000	168	4.4	0.7	3 - 6
	>1000	43	4.5	0.6	3-5.6
	Pooled	254	4.4	0.7	2.5-6
TR	<200	—	—	—	—
	201-1000	17	4.0	0.5	3-5.5
	>1000	18	4.1	0.5	3-5
	Pooled	35	4.0	0.4	3-5.5
GR		148	4.1	0.7	3-7.5
Total for the age group		437	4.3	0.7	2.5-7.5

FP—Fighter pilots TR—Transport pilots
GR—Ground duty personnel

TABLE - II

'G' tolerance values in age group 35-40 years

Branch	Flying experience in hrs.	No. of Subjects	G tolerance values Mean	SD	Range
FP	<200	—	—	—	—
	201-1000	—	—	—	—
	>1000	15	4.7	0.9	3-6
	Pooled	15	4.7	0.9	3-6
TR	<200	—	—	—	—
	201-1000	—	—	—	—
	>1000	11	4.4	0.6	3.5-6
	Pooled	11	4.4	0.6	3.5-5
GR		9	3.6	0.5	3-4.5
Total for the age group		35	4.3	0.8	3-6'

TABLE - III

'G' tolerance values in age group 41-55 years

Branch	Flying experience in hrs.	No. of Subjects	'G' tolerence values Mean	SD	Range
FP	<200	—	—	—	—
	201-1000	2	4.5	1.4	3.5-5.5
	>1000	11	5.3	0.6	4.5-6
	Pooled	13	5.3	0.6	3.5-6
TR	<200	—	—	—	—
	201-1000	—	—	—	—
	>1000	12	4.3	0.5	4-5.5
	Pooled	12	4.3	0.5	4-5.5
GR		11	3.9	0.5	3-4.5
Total for the age group		36	4.6	0.8	3-6
Grand total (for Tabol I & II included)		508	4.3	0.7	2.5-7.5

A study of the mean difference of g tolerance between various groups shows a significant difference between the fighter pilot and transport pilot group and ground duty personnel in all age groups.

There is a change in g tolerance between the younger pilots and elder pilots (both fighter & transport) showing a significant increase in g tolerance with increase in age. Among the ground duty personnel there is a slight decrease in tolerance as age advances, but the number tested in the two older age groups is disproportionate to the total number in the first group.

Comparison of g tolerance between the total group (n=508) and fighter pilots (n=282) is presented in Table IV. This table shows that the mean g tolerance for all subjects is practically constant at 4.3g for all age groups, whereas in the case of fighter pilots, the tolerance is 4.4g for the younger age group of 20-35 yrs 4.7g for group of 35-40 yrs and 5.3g for age group of 41-55 years, thus showing an increase of g tolerance with ageing.

TABLE - IV

+Gz Tolerance changes with age (Mean +Gz tolerance)

Age group	All subjects	Fighter pilots
20-34 years	4.3 ± 0.7 (N=437)	4.4 ± 0.7 (N=254)
35-40 years	4.3 ± 0.8 (N= 35)	4.7 ± 0.9 (N= 15)
41-55 years	4.5 ± 0.8 (N= 36)	5.3 ± 0.6 (N= 13)
	508	282

Discussion

Physiological effects of +Gz on man

The physiological effects of +Gz on man have been studied extensively and reported by many workers[1-4]. It is an exaggerated orthostatic stress which produces large changes in blood pressure, perfusion and functions of head and neck area. With increase in +Gz there is a progressive fall in BP and perfusion pressure in the cerebral region and the retinal artery, thus producing deterioration in performance. Visual symptoms and signs, eg., hazy vision, contraction of field of vision and reduced visual acuity are well known[1-4]. Peripheral light loss (PLL) is a measure of change of field of vision during +Gz stress.

There is a fall in blood pressure above the heart level and increase in blood pressure below the heart level due to very large changes in hydrostatic pressures[3]. There is a large amount of pooling of blood, in lower half of the body which reduces the venous return and thus compromises cardiac output. Baroreceptor responses from the carotid sinus produce compensatory changes in heart rate and peripheral vascular tone. Prompt and adequate response of the cardiovascular system is essential for the maintenance of cerebral and visual function during +Gz stress. It is well known that there are certain changes in CVS responses with age to all types of stresses. It has been postulated that possibly the responses among the elderly subjects will be slower and inadequate for such stresses. However, factors like rise in blood pressure in ageing, hardening of arteries and a larger flying experience may to some extent compensate for the delayed CVS response[6].

Change in +Gz tolerance with ageing

Analysis of data for all the subjects (n=508) as shown in Table IV shows no change in g tolerance with ageing. However among fighter pilots there is a significant increase in g tolerance with ageing as shown in Tables VI. The trend of increase in tolerance with ageing is also evident in transport pilot group whereas among the ground duty personnel there is a decrease in tolerance with ageing. Similar findings have been reported by Hull *et al*[4] on 50 aircrew subjects.

The possible factors which can explain the trend seen in the pilots group can be :

(a) Larger flying experience

(b) Pilots not relaxing completely during centrifuge runs.

(c) Increase in BP and hardening of arteries with age.

The elderly and experienced fighter pilots produce better and quicker physiological response to the oft-repeated stress of +Gz. Possibly this mechanism overcomes the normal expected effects of ageing.

All the subjects studied under this project were in good physical health and in appropriate highest medical category applicable for branch/trade in the Air Force. Though actual blood pressure readings have not been presented in this paper, it has been ensured that no case of hypertension or overt CVS abnormality has been included in these trials. Thus it can be concluded that the slight, expected increase in BP with ageing may have been the only change between the various age groups. To what extent such changes in BP can influence a subject's +Gz tolerance cannot be clearly defined[4].

Pilots are in the habit of using certain voluntary straining manoeuvres such as tensing of muscles and control of intrathoracic pressure to increase their tolerance to +Gz. With increase in flying experience, these manoeuvres become a second nature (involuntary in the case of experienced and elderly pilots). Though an attempt was made to record the relaxed tolerance of all the subjects, it is quite likely that the fighter pilots did not relax fully, more so the elderly, experienced fighter pilots.

Fighter pilots of all age groups had a significantly higher tolerance than the other two groups. This difference could also be explained on the basis of the physiological factors mentioned above.

Conclusions

(a) Fighter pilots in all age groups have a higher tolerance than other aircrew and ground duty personnel.

(b) There is a significant increase in tolerance with ageing especially in the fighter pilot group.

(c) The average relaxed tolerance to +Gz upto PLL for Indian subjects is 4.3 $\pm$0.7g.

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