Centrifuge training for fighter aircrew: The Indian experience - An update

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Inflight G-induced loss of consciouness (G-LOC) is perhaps the most dreaded emergency in fighter aircraft flying. With aircraft sustaining +6 Gz or more, the anti-G suit alone is inadequate, making additional protection in the form of anti-G straining manoeuvre (AGSM) unavoidable. Institute of Aerospace Medicine (IAM) has been carrying out AGSM training in the human centrifuge since 1991 and has trained over 250 pilots. The minimum standards for the course are +7 Gz for 15 s which is a world accepted norm. With training, the tolerance of pilots improved from mean figures of +4.3 Gz to +8.7 Gz for rapid onset rate (ROR) runs. Increase in tolerance for gradual onset rate (GOR) runs was from +4.8 Gz to +8 Gz. Inadvertent cases of G-LOC did occur during training. The incidence of G-LOC is 35.5% of aircrew trained, which is reportedly higher than in other air forces (10-24%). This difference may be attributed to differences in seat configuration, acceleration profiles applied, training schedules and the slower offset rates of our centrifuge. No untoward effects of G-LOC in the centrifuge have been noted. Our experience is being presented.

Keywords: High Gz training, high sustained Gz, G-LOC, AGSM.

The introduction of air superiority fighter (ASF) aircraft in the IAF has made high sustained Gz (HSG) a reality. In the HSG environment, the individual's relaxed tolerance of 4.2±0.7 Gz [1] plus the protection provided by the standard PPK-1 anti-G suit (AGS) of ~1.2 Gz is inadequate. Of the various methods suggested to bridge this gap, the most effective is centrifuge training [2-5]. The Institute of Aerospace Medicine (IAM) has been involved with centrifuge training for aircrew since 1991, and has trained 259 aircrew. Our initial experiences involving 134 pilots had been presented three years ago, at the 42nd International Congress of Aviation & Space Medicine [1]. The present paper shall bring you up to date on our results with HSG training.

Course content

The course content has been described in details earlier [1]. A few minor changes have been brought in, which are described below. The six day high Gz course has now been made a part of a two week Advanced Fighter Aircrew Indoctrination Course (AFAIC). The course content of the AFAIC is mentioned below in Table 1. The high-G training has however remained effectively unchanged.

Our experience

A total of 259 pilots have been trained at IAM till date. All aircrew trained were males as the IAF has

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Table 1. Contents of AFAIC

Sl. No.	Content
1.	High G Centrifuge training
2.	Spatial Disorientation Indoctrination
3.	High Altitude Physiology Indoctrination
4.	Psychology Indoctrination
5.	Human Factors Indoctrination
6.	Human Physiology Indoctrination

only male fighter pilots. All data mentioned below is with the upright seat configuration, as this is the seat configuration that pilots in the IAF would experience. The subject data is mentioned in Tables 2 & 3.

Table 2. Subject data

Sl. No.	Parameter	Range	Mean
1.	Age (yrs)	22-37	23
2.	Weight (kg)	50-87	56.8
3.	Height (cm)	156-190	173.7
4.	Flying Hrs	70-2680	795

Table 3. Type of aircraft

Sl. No.	Type of aircraft	No. of pilots
1.	MiG-21	150
2.	MiG-29	36
3.	Mirage-2000	16
4.	Jaguar	12
5.	Sea Harrier	3
6.	Others	42

The mean relaxed tolerance for gradual onset rate (@ 0.1 G/s) or GOR runs was 4.84±0.6 Gz. The mean straining tolerance before the course was ~ 7 Gz at the end of the course was ~ 8 Gz, thus demonstrating a highly significant ($p < 0.01$) increase in tolerance with a correctly performed AGSM. Mean increase in tolerance with the AGSM was found to be > 3 Gz at the end of the course as against 2.25 Gz before the course. The values of GOR runs are given in Table 4.

Table 4. Mean values during GOR

Sl. No.	Parameter	Before	After
1	No sustaining >8 Gz	41	140
2.	No sustaining 9 Gz	6	64
3.	Relaxed tolerance	4.84	4.89
4.	Straining tolerance	7.09	7.96
5	Protection by AGSM	2.25	3..07

During straining GOR runs, only six pilots cou
reach 9 Gz before the course. In a demonstrab
increase, 64 (25%) pilots completed 9 Gz at the er
of the course, without an AGS (Table 4). As again
only 47 (18%) pilots who could reach > 8 Gz befo
the course, 204 (79%) reached > 8 Gz after th
course.

The mean relaxed tolerance to rapid onset ra
@ 1 G/s or ROR runs was found to be 4.30±0.6 G
The mean straining tolerance (with AGS) was four
to be 8.73 Gz. All but two pilots could complete th
minimum stipulated 7 Gz for 15 s by the end of th
course [1,6]. One of these had been off flying f
one year prior to the course. He had to be asked
come back for the course. The other had G-LOC
low Gz levels and then had severe motion sickne
in the centrifuge and was disqualified. 202 (78%
aircrew successfully completed 9 Gz for 5 s and 24
pilots (93%) could sustain 8 Gz for 10 s. The va
ues are tabulated in Table 5.

One pilot had to repeat the course due to h
inability to sustain even one peak of 8 Gz durin
the simulated air combat manoeuvre (SACM).

A total of 136 incidents of G-LOC have occurre
in the human centrifuge (HC) so far, in 92 pilo
(35.5%) out of the 259 trained. Out of the total
4849 runs given, G-LOC occurred in 2.8% run
The G-LOC data is mentioned in Table 6.

At the end of the course, the pilots fill a que
tionnaire to determine whether they found the cour

Table 5. ROR performance

Sl. No.	Parameter	Completed	%age
1.	Mean Relaxed Tol	4.30	-
2.	Mean Str Tol	8.73	-
3.	7 Gz x 15 s	257	99.61
4.	8 Gz x 10 s	242	93.44
5.	9 Gz x 5 s	202	77.99
6.	SACM < 85s	11	4.25
7.	SCAM 85 - 100 s	19	7.34
8.	SACM 100 - 200 s	134	51.74
9.	SACM 200 - 300s	45	17.37
10.	SACM > 300s	26	10.04
11.	Mean SACM Tol	180.83 s	-

Table 6. G-LOC Data

Sl. No.	Parameter	Completed	%age
1.	< 7 Gz	32	23.53
2.	7-7.9 Gz	36	26.47
3.	8 - 8.9 Gz	45	33.09
4.	9 Gz	23	16.91
5.	GOR Run	33	25.38%
6.	ROR Run	84	64.62%
7.	SACM	13	10%

useful. 123 (47.49%) pilots found the course highly useful and 134 (51.74%) found it useful [7]. Only two pilots had a negative or hostile response.

The aircrew are also asked to fill a questionnaire after six months of flying following the course. A total of 56 pilots have returned the questionnaire till date. The average amount of flying put in by these pilots after the course is 85 h including a mean number of 53 combat sorties. 23 of those who responded are presently flying MiG 29s, 16 are flying Mirage 2000s and 17 are flying an assortment of other aircraft. 47 of these are pulling > 6 Gz routinely and 39 (70%) are using the AGSM regularly [7]. Despite the fact that 70% of these pilots are flying ASFs, only one pilot (1.78%) has reported an incident of G-LOC after the course which is significantly lesser ($p < 0.01$) than that reported by pilots in the IAF viz. 10.8% [8]. This pilot too, could recover consciousness in time to eject from the aircraft safely.

Discussion

At this stage it may be worthwhile to compare our results with those reported by the USAF [9]. The mean results are mentioned in Table 7.

Table 7. Comparison between IAF & USAF

Parameter	IAF	USAF	P value
Rel GOR-I tol	4.8 Gz	5.2 Gz	0.01
Str GOR-I tol	7.1 Gz	8.3 Gz	0.01
9Gz during GOR-I	2.8%	41%	0.01
8 Gz ROR	93.4%	99.8%	0.01
9 Gz ROR	78%	94%	0.01
Str GOR-II tol	8.0	-	
SACM tol	180s	170s	0.01
G LOC incidence	35.5%	9%	0.01
G-LOC/100 runs	2.8	2.1	-
Course duration	12 d	1 d	-
No. of runs	30.5	5	-

What emerges from the Table above is that tolerances of our pilot population in our centrifuge are significantly lower than those of USAF pilots both before and after the course. This is so despite having a much more rigorous course. The incidence of G-LOC is much more in our pilot population than in the USAF. Before we blame this on ethnic differences we should consider other points of difference between the two courses.

Before the USAFSAM started the high Gz centrifuge training course they upgraded their centrifuge to a 6 Gz/s capability, with a 3 Gz/s offset rate. In contrast, our centrifuge has maximum onset as well as offset rates of 1 G/s. The incidence of G-LOC is lower and recovery from G-LOC faster if the offset rates are higher [10,11]. There are many cases where the pilot complains of grey out while the centrifuge is decelerating and subsequently goes into G-LOC because the centrifuge did not stop fast enough. Such cases would definitely be prevented by faster offset rates. The chances of G-LOC are higher during GOR than in ROR runs. This is seen in the USAF statistics [9]. In our centrifuge, however the majority of G-LOC incidents (65%) have occurred in ROR runs. This is because our ROR runs are not rapid enough. For example, in a 9 Gz x 5 s run, our subject remains above 1 Gz for 23 s. In contrast, in the USAFSAM centrifuge, even during a 9 Gz x 15 s run, the total time spent above 1 Gz is 19.5 s. This contributes to fatigue and thus a higher incidence of G-LOC.

The USAF is using the F-16 seat configuration in their centrifuge, ie, a 30° seat tilt back with raised rudder pedals. This is reported to provide upto 1 Gz additional protection [9]. This has been substantiated by our studies, where the SACM performance with a tilt back is significantly better than with the upright seat configuration [12, 13]. We however do not use this configuration because all our ASF aircraft have conventional seats, despite possessing F-16 like 9 Gz capability.

This brings us to crossroads where we must ask ourselves a few questions, which are as follows:

a. Is the course useful?
b. Is the course safe?
c. Should we continue the course?
d. If so, what can we do to reduce the incidence of G-LOC?

A review of data reveals that the course is useful. The feed back from pilots is that 99% feel that the course is useful. A majority request for the course to be repeated. 70% of the respondents following the course are performing the AGSM regularly [7]. During the course, the percentage of pilots who could reach above 8 Gz in GOR runs without the help of an AGS, rose from 18% before the course to 78% after the course. An average protection of 3Gz was seen to be conferred by the properly performed AGSM.

Any discussion on safety of the course has to weigh the risks against the benefits. A review of world literature indicates that despite a high incidence of G-LOC the course is safe. Whinnery [14,15] has reported a retrospective kinetic analysis of over 500 cases of G-LOC in centrifuge and has found no long term sequelae. Whinnery and Jones [16] have reported cases of recurrent G-LOC (3-5) episodes of within 6-15 min in four subjects without long term sequelae. We have not seen any undesirable side effects in the 92 G-LOC cases in our centrifuge. An episode of G-LOC in the centrifuge is under full medical supervision. Unlike other air forces including the USAF [9], we are doing continuous ECG monitoring throughout the run and can thus monitor the subject better. A prior experience of G-LOC can shorten the incapacitation time by as much as 17 s in case of a subsequent episode of G-LOC in air. This had led leading workers in the field [17] to suggest deliberate induction of G-LOC for pilots of fighter aircraft akin to hypoxia indoctrination. We at IAM do not recommend such drastic measures. We believe that an inadvertent episode of G-LOC in the centrifuge is undesirable but safe.

Whether or not to continue the course is a purely operational decision. We will however present data which pushes us to believe that the course should continue. G-LOC in aircraft occurs regularly. IAF has a reported rate of 10.8% of pilots flying fighter aircraft [8]. As about half of the episodes are not recollected, the actual rate is estimated at 22%. Brazilian Air Force estimates a similar rate of 21% [18]. The USAF reports a higher rate of 24% or more [19], perhaps because of a higher percentage of pilots flying 9 Gz aircraft. The high-G course has demonstrably brought the rate of in-flight G-LOC down. Despite the fact that 70% of pilots after the course are flying ASFs, the total percentage of G-LOC incidents has fallen from 10.8% to 1.8%. Similarly in the USAF, after introduction of the high-G course, the accident rate due to G-LOC fell from 4 per million flying hours (pmfh) to 1.3 accidents pmfh [20].

A few measures can, however make the course safer and more productive. A better human centrifuge with better onset and offset rates would make the training more realistic and reduce the incidence of G-LOC during training. A better physiological monitoring system would allow better monitoring of the pilot and make the course safer.

Conclusion

Centrifuge training for fighter aircrew is effective in increasing Gz tolerance and reducing episodes of in-flight G-LOC to about one fifth. It is perhaps the single largest contributor to flight safety. Better equipment would make the course safer and the training more realistic.

References

1. Gomez G, Malik H, Kapur R. Centrifuge training of fighter aircrew. The Indian experience. *Ind J Aerospace Med.* 1994; 38 (2): 84-8.
2. Burton RR, Whinnery JE. Biodynamics: Sustained acceleration. In: Fundamentals of Aerospace Medicine 2nd edition. Ed. DeHart RL. Philadelphia. William & Wilkins, 1996.
3. Glaister DH. The effects of long duration acceleration. In: Aviation Medicine 2nd edition. Eds. Ernsting J, King PF. London. Cambridge University Press, 1988.
4. Wood EH. Prevention of G-LOC. *Aviat Space Environ Med.* 1992; 63:226-7.
5. Burton RR, Leverett SD Jr, Michaelson ED. Man at Hih sustained Gz acceleration - A review. Aviat Space Environ Med. 1974; 55. 1115-36.
6. Standardization agreement (STANAG) No. 3827 AMD. Minimum requirements for selection, training and employment of aircrew in high sustained Gz environment. Military agency for standardization, North Atlantic Treaty Organization. Brussels Belgium, 1981.
7. Questionnaire survey of pilots on completion of High G course. Department of Acceleration physiology, IAM, IAF, Bangalore 1991-1997.
8. Malik H, Gupta JK, Kapur R. G-induced loss of consciousness (G-LOC) in the Indian Air Force. *Ind J Aerospace Med.* 1992, 36 (1): 1-5.
9. Gillingham KK, Fosdick JP. High-G training for fighter aircrew. Aviat Space Environ Med. 1988; 59(1): 12-9.
10. Whinnery CC, Whinnery JE. The effect of Gz off-set rate on recovery from acceleration induced loss of consciousness. *Aviat Space Environ Med.* 1990; 61 (10): 929-34.
11. Lau D, Steinleitner JM. Dynamic characteristics of centrifuges. *Aviat Space Environ Med.* 1994, 65 (12): 1134-9.
12. Kapur R, Malik H, Gomez G et al. Changes in Gz tolerance with varying degrees of seat tilt-back angle. Departmental project No. 149/11/89. Department of Acceleration Physiology, IAM, IAF. 1993.
13. Malik H, Gomez G, Kapur R, et al. Evaluation of anti-g straining manoeuvre and tilt back seat as a means of increasing acceleration tolerance. AFMRC Project No. 1858/91. Dept of Acceleration Physiology, IAM, IAF, 1994.
14. Whinnery JE. Recognizing Gz induced loss of consciousness and subject recovery from unconsciousness on a human centrifuge. *Aviat Space Environ Med.* 1990; 61(5): 406-11.
15. Whinnery JE. Medical considerations for human exposure to acceleration induced loss of consciousness. *Aviat Space Environ Med.* 1991; 62 (7): 618-23.
16. Whinnery JE, Jones DR. Recurrent +Gz induced loss of consciousness. *Aviat Space Environ Med.* 1987, 58(10): 943-7.
17. Whinnery JE, Burton RR. +Gz induced loss of consciousness: a case for training exposure to unconsciousness. *Aviat Space Environ Med.* 1987; 58(5): 468-72.
18. Alvim KM. Greyout, blackout and G-loss of consciousness in the Braziliam Air Force. *Aviat Space Environ Med.* 1995; 66(7): 675-7.
19. Johnson DC, Pheeny HT. A new look at the loss of consciousness experience within the US Naval forces. Aviat Space Environ Med. 1988; 59(1): 6-8.
20. Lyons TJ, Harding, Freeman J et al. G-induced loss of consciousness accidents: USAF experience 1982-1990. *Aviat Space Environ Med.* 1992; 63(1): 60-6.