Centrifuge training for fighter aircrew: The Indian experience

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Training fighter crew in the proper performance of anti-G-straining manœuvres (AGSM) on the centrifuge is now a recognized part of the indoctrination process, particularly in Air Defence aircraft, which are more susceptible to high-G situations. The Indian Air Force commenced this kind of training in March 1991 and has so far indoctrinated 134 aircrew over 27 courses. All but 2 trainees completed the minimum standard of the course of 7 G for 15 s rapid onset rate (ROR) run with anti-G suit (AGS) inflation and AGSM. A total of 92.54% completed the 8 G 10 s ROR run and 70.15% were successful in the 9 G 5 s ROR run. The mean gain in protection by AGSM achieved was 2.80 G. Thereafter, simulated aerial combat manœuvres (SACM) profiles were introduced to enhance the practice of AGSM performance. The mean tolerance time of the 4 G 15 s/8 G 10 s SACM was 165.7 s. The critiques provided by trainees during and post-indoctrination revealed a 97.01% enthusiastic response to training. In conclusion, centrifuge training is considered a must for all fighter aircrew. It is a valuable method of increasing the awareness of G stress and allows the aircrew the opportunity to enhance individual tolerance levels by perfecting AGSM techniques in a controlled and safe environment.

Keywords: Centrifuge training; AGSM.

The most important factor that contributes to increase in G tolerance of pilots in the operational arena is a well-coordinated and timed anti-G-straining manœuvre (AGSM) [1–3]. AGSM has all the attributes of a perfect personal protective system. However, the protection afforded is directly related to the pilot's ability to perform the manœuvre correctly, be it M1 or L1. This ability is a learned effort and hence training plays an important role [2–5].

The role of the centrifuge as a training tool for improving the combat effectiveness of frontline pilots was known way back in the early seventies [2, 3]. But its full exploitation took place much later. Today, high-G training on the centrifuge has been introduced for fighter aircrew in several countries [6–9].

In India, Rai [7] was the first one to point out in 1986 the need to introduce centrifuge training for IAF frontline pilots. Subsequently, with the technical upgradation of the human centrifuge at IAM in 1988, this training was introduced in the IAF in March 1991.

Centrifuge training at IAM: high-G course

The aim of centrifuge training in the IAF is fourfold, the primary one being to improve the skill in the proper performance of AGSM, thereby increasing the individual's Gz tolerance levels. Other secondary aims include a better understanding of Gz physiology, greater appreciation of high G hazards and an increased confidence in the ability to tolerate high G stress.

With these aims in mind, a 6-day high-G centrifuge training course is conducted at IAM. The contents of the course include:

(a) Didactic lectures and video presentations on Gz physiology, G-LOC, factors affecting Gz tolerance, AGSM, other methods of protection, positive pressure breathing (PPB) and physical conditioning.

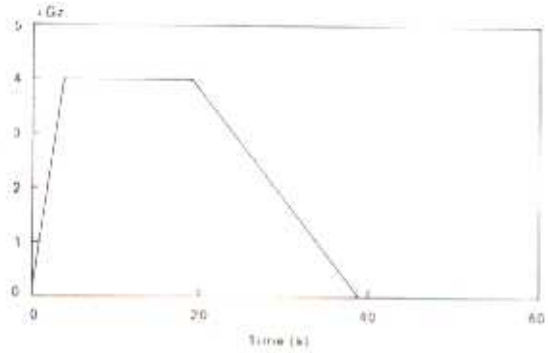

Figure 1. ROR relaxed +Gz tolerance centrifuge profile.

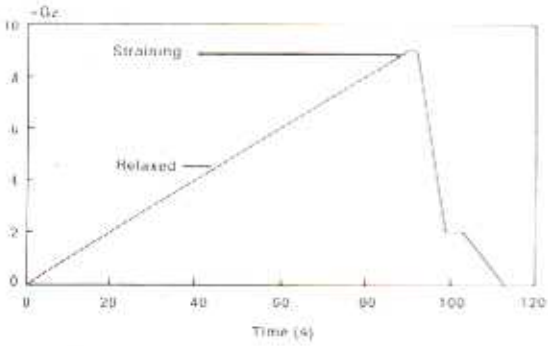

Figure 2. GOR relaxed and straining +Gz tolerance centrifuge profile.

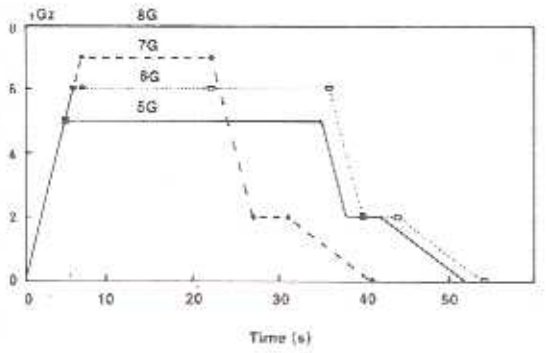

Figure 3. ROR straining +Gz tolerance centrifuge profiles.

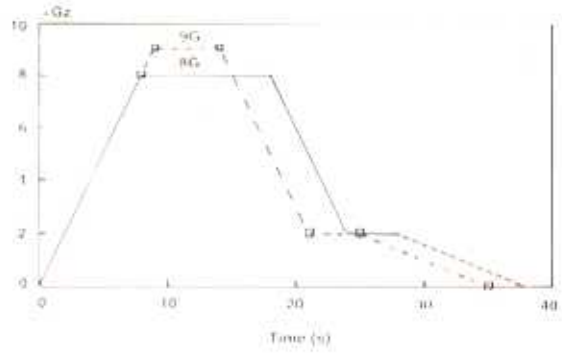

Figure 4. ROR straining +Gz tolerance centrifuge profiles.

(b) Indoctrination and demonstration of the proper technique of performance of AGSM.

(c) Centrifuge training in stages, viz.

(i) **Day 1:** Familiarization with the human centrifuge. Determination of rapid onset rate (ROR) relaxed tolerance levels (Figure 1). Determination of gradual onset rate (GOR) relaxed and straining tolerance (Figure 2).

(ii) **Day 2:** Practice of AGSM with ROR onset rate of 1 G/s and plateau phases of 5 G for 30 s, 6 G for 30 s and 7 G for 15 s (Figure 3). Protection afforded by anti-G suit (AGS) and AGSM.

(iii) **Day 3:** High-G runs with onset rate of 1 G/s plateau phases 8 G for 10 s and 9 G for 5 s (Figure 4). Protection afforded by AGS and AGSM.

(iv) **Day 4 and 5:** Simulated air combat manœuvres (SACM) profiles onset rate of 1 G/s and plateau phases of 4 G for 15 s and 8 G for 10 s to a maximum of 300 s (Figure 5). Protection afforded by AGS and AGSM.

(v) **Day 6:** Determination of GOR relaxed and straining tolerance levels with performance of the AGSM only between the two levels. SACM to enhance the practice of AGSM.

The end points in all the runs were peripheral light loss (PLL) of 52–56°, disappearance of sound on the Doppler probe fixed at the superficial temporal artery, or pilot/controller terminating run for any other reason. All centr-

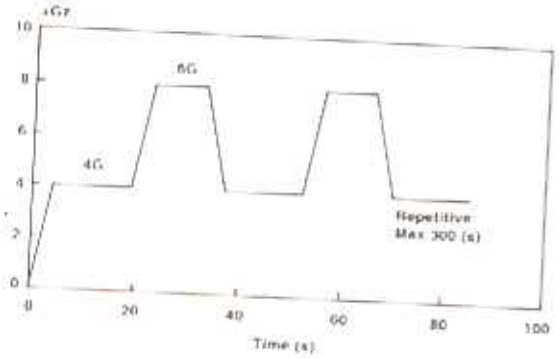

Figure 5. Simulated air combat manoeuvre centrifuge profile

fuge riders were medically examined pre- and post-run. On-line ECG recording was conducted. Exhaustive debriefing of pilots was carried out by means of video recordings of centrifuge runs.

The following minimum and maximum standards were set as goals of the training programme:

Minimum standard. At IAM we have fixed this at 7 G for 15 s ROR onset rate of 1 G/s. This training goal has been chosen based on the NATO standardization agreement (STANAG) 3827 AMD, which states that aircrew who do not complete a 7 G 15 s ROR with wearing an AGS and performing AGSM will be considered to have low G tolerance [10]. The USAFSAM also applies the same standard and uses it as the minimum-G profile for recommendation of a pilot to fly high-performance aircraft [3].

Maximum standard. The USAFSAM has set their training goal at 9 G for 15 s ROR [8]. At IAM we have fixed this at 8 G for 10 s ROR and 9 G for 5 s ROR. We believe the G stress here is sufficient to challenge most aircrew. Further, even the current generation aircraft are unlikely to operate in a sustained 9 G environment. [6].

As feedback, aircrew opinion is taken in the form of a questionnaire during the course of which their views are solicited on various aspects of the course, for example, assessment of centrifuge training, refresher course requirement, etc. Aircrew feedback is also taken post-completion of the course, once they are back in the operational squadrons. Opinions are solicited on the practical aspects and the effectivity of utilization of AGSM in combat, problems of performance, difficulty level, etc.

Results and discussion

Since March 1991, 134 aircrew of the fighter stream have been trained at IAM. Subject data are shown in Table I. Of these, 45.52% were MiG-29 and Mirage 2000 pilots; the remainder flew aircrafts such as MiG-21, MiG-23, MiG-27 and Jaguar.

Measures of the trainees' performance as a group are presented in Table II. The mean relaxed GOR tolerance of the group on day 1 was 4.79 G (SD 0.74) and straining tolerance 7.23 G (SD 1.02). This was taken as a base parameter prior to AGSM indoctrination and for comparison purposes at a later stage.

Post-AGSM indoctrination the relaxed GOR tolerance was found to be 4.97 G (SD 1.03). There is no significant difference between this and the relaxed tolerance recorded on day 1 of the course. However, in comparison to the relaxed GOR of 741 USAF fighter aircrew trained at USAFSAM in 1985–86, their's was 5.17 G (SD 0.94) [8], a significant difference ($P < 0.05$) is seen; further, our value is also significantly lower ($P < 0.01$) than the relaxed GOR tolerance of 5.51 G (SD 0.91) of 62 TAC pilots trained in USAFSAM in 1983 [11]. These differences are due to the seat configuration: in the USAFSAM studies an F-16 configured seat was used with 30° tilt-back and elevated rudder

Table I. Subject data ($n = 134$)

Parameter	Mean	Range
Age (yr)	26.91	22–36
Height (cm)	173.73	164–190
Weight (kg)	65.69	52–89
Flying experience (h)	883.40	300–3050

Table 2. Performance of 134 trainees on high-G course

Performance parameter	*n*	Mean ± SD	%	Time (s)
ROR (relaxed)	134	4.17 ± 0.79	–	–
GOR I (relaxed)	134	4.79 ± 0.74	–	–
GOR I (straining)	134	7.23 ± 1.02	–	–
ROR (straining)	132	8.61 ± 0.67	–	–
Completed 6 G run ROR	134	–	100.00	–
Completed 7 G run ROR	132	–	98.51	–
Completed 8 G run ROR	124	–	92.54	–
Completed 9 G run ROR	94	–	70.15	–
SACM 4 G 8 G	128	–	–	165.7
GOR II (relaxed)	132	4.97 ± 1.03	–	–
GOR II (straining)	132	7.77 ± 0.92	–	–

pedals as against our 13° conventional seat. The F-16 configured seat is known to enhance G tolerance by 0.5 G or more in relaxed subjects [8].

The mean GOR straining tolerance post-AGSM training for the group was found to be 7.77 G (SD 0.92). This showed a significant improvement ($P < 0.01$) compared to the GOR straining recorded on day 1, which was 7.23 G (SD 1.02). This improvement of 0.54 G is due to AGSM indoctrination; however, the gain would be much larger as the aircrew become more proficient in the performance of AGSM. Of greater significance in the context of this paper is the mean difference between relaxed and straining GOR tolerance post-indoctrination, which was determined to be 2.80 G. This difference is totally attributable to AGSM alone. This effect could have been greater had there been no G limit placed on the GOR run, as a number of trainees did achieve the 9 G limit in the run.

In comparison with the USAFSAM studies, we find that our GOR straining tolerance level is significantly lower ($P < 0.01$) than that of 741 USAF fighter pilots, which was 8.32 G (SD 0.82) [8] and 62 TAC pilots, which was 8.14 G (SD 0.94) [11]. These differences are again attributable to the seat configuration used. The F-16 configured seat is known to enhance the straining tolerance of subjects by 1 G or more [8].

The mean relaxed ROR tolerance of the group was found to be 4.17 G (SD 0.79) and straining ROR tolerance 8.61 G (SD 0.67). This is comparable to an earlier study [12], in which human tolerance of subjects wearing inflated AGS and performing AGSM was 8.8 G (SD 0.12). However, in both the studies the values do not represent the absolute maximum tolerance since the exposures, both in terms of intensity (G level) and duration, were arbitrarily fixed. In our schedule we have ROR runs of 6 G for 30 s, 7 G for 15 s, 8 G for 10 s and 9 G for 5 s.

In all ROR straining runs protection was provided by AGS and AGSM. Two trainees were unable to achieve the training goal of 7 G for 15 s and were declared unsuccessful in the course. One of these had been off flying for a period of one year prior to high-G course and developed severe motion sickness on the centrifuge. The other had episodes of G-LOC on two successive days in the 7 G ROR run. Subsequently, due to the centrifuge becoming unserviceable, he could not be given any further attempts at achieving the minimum training standard. A total of 92.54% trainees completed the ROR run of 8 G for 10 s and 70.15% achieved the ROR run of 9 G for 5 s.

A total of 128 pilots (95.52%) completed the 4 G/8 G SACM with an average sustaining duration of 165.7 s (SD 59), showing the adequacy of learning AGSM by them. These results compare well with a similar study at USAFSAM in which subjects had a mean tolerance time of 170 s (SD 70) [9].

On the last day of the course the trainees were asked to give their unbiased subjective assessment of the course. Surprisingly, it was found that 10 trainees admitted to having had episodes of G-LOC in actual flying prior to attending this course. In appreciation of the training imparted, 67 pilots (50%) found the course highly useful, 63 (47.01%) found the course useful, while only 4 did not comment on this aspect. Further, 84 trainees (62.68%) were in favour of a refresher course.

In the feedback from the squadrons, we have so far received 41 proformas from pilots who have completed the high-G course. All pilots were convinced of the benefits of AGSM but only 35 performed AGSM regularly under G loading. Fourteen pilots reported problems in speech and R/T communications, while 17 reported attentional diversion as well. Fifteen pilots were forthcoming on suggestions for modifying the course curriculum. Suggestions include more emphasis on physical conditioning, centrifuge G build-up control with the pilot, introduction of some form of visual display within the Gondola and realistic profiles with higher onset and offset rates.

Conclusion

Our limited experience in the arena of centrifuge training has shown that this form of training is indeed beneficial both subjectively and objectively and helps mainly by training the aircrew in the correct performance of AGSM. Further, it has also demonstrated that an adequately trained aircrew can easily withstand sustained high G levels likely to be encountered in today's operational G environment. Centrifuge training with AGSM indoctrination is considered a must for all fighter aircrew.

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