Original Article

Low +Gz tolerance during centrifuge training

Wg Cdr Harish Malik[a] Sqn Ldr A Agarwal[a]

High +Gz centrifuge training in Indian Air Force was started in March 1991. 314 fighter pilots have undergone the training so far. Only five pilots could not complete the minimum criteria of +Gz level and +Gz duration tolerance laid down for the successful completion of the course. One of these pilots repeated the training after 3 years and could complete the training successfully. However, one pilot who came back again only after 5 months, was not able to tolerate the required +Gz runs. The present paper discusses the minimum criteria of +Gz tolerance and the cases of low +Gz tolerance during the centrifuge training and its implications.

Keywords: G-induced loss of consciousness (G-LOC), Simulated Aerial Combat Manoeuvre (SACM), Indian Air Force

The major threat that confronts fighter pilots on every combat sortie is G-induced loss of consciousness (G-LOC). G-LOC is a premier human factor challenge facing all the modern Air Forces today. Fighter Pilot's incapacitation due to G-LOC poses a great flight safety hazard resulting in loss of expensive aircraft and more importantly, highly trained manpower. With the technological advancements, acceleration capabilities of aircraft are continually increasing and so are +Gz exposures to the pilots, both in terms of its level and duration. Each pilot has a G-tolerance limit, both in terms of peak G (G-level) and G duration, which can be exceeded in spite of the existing G-protective methods, resulting in G-LOC.

During the 1982-1990 period, at least 14 pilot lives and 18 fighter aircraft in USAF have been lost due to G-LOC and similar accidents have been reported in other countries also [1]. The G-LOC surveys conducted in India [2] and other countries [3] revealed an incidence rate of 10-19% in experienced pilots. Most frequent causes of G-LOC found in these surveys were rapid G onset, being unprepared for the aerial manoeuvre in a trainer aircraft, and performing a poor anti G straining manoeuvre (AGSM).

Centrifuge training is the single most cost effective method of prevention of aircraft accidents due to G-LOC. The primary aim of centrifuge training is to improve the skill of fighter pilots in proper performance of AGSM during exposure to high-sustained +Gz resulting in increase in G-tolerance. Impressed by the success of the centrifuge trained experimental subjects in raising their G-tolerance, centrifuge training has been introduced for fighter aircrew

[a] *Classified specialist in Aviation Medicine, Institute of Aerospace Medicine IAF Bangalore 560 017*

in several countries [4, 5, 6]. Institute of Aerospace Medicine has been conducting High G training for fighter aircrew since 1991 during which aircrew are subjected to high G runs (up to g +Gz) [7]. The present paper discusses the minimum criteria of +Gz tolerance and the cases of low +Gz tolerance during the centrifuge training and its implications.

Results

314 fighter pilots have undergone the training so far. Only five pilots could not complete the minimum criteria of +Gz level and +Gz duration tolerance laid down for the successful completion of the course. All five of them went into G-LOC during the rapid onset profile (1 G/s) of 7G for 15 s. However, two of them could complete the run on their second attempt but they went into G-LOC again during the first peak of 8 G in the Simulated Aerial Combat Manoeuvre (SACM) run. One of these pilots repeated the training after 3 years and could complete the training successfully. However, one pilot who came back again only after 5 months, was not able to tolerate the required +Gz runs.

Mean relaxed gradual onset rate (0.1 G/s; GOR) tolerance of the whole group (n=314) was 4.8 G as compared to 4.6 G in the unsuccessful pilots. Mean relaxed rapid onset rate (1G/s; ROR) tolerance of these were 4.4 G and 4.1 G respectively. Mean straining GOR tolerance (without anti-G suit) were 7.8 G and 6.5 G whereas; mean straining ROR tolerance (with anti-G suit) were 8.8G and 6.2 G respectively in the whole group and unsuccessful pilots. SACM runs could be given to only two of the unsuccessful pilots and their mean SACM tolerance 50.5 s as compared to 181 s of the whole group. There was no significant difference between the ages and height of the pilots of the two groups. However, unsuccessful pilots were thinner (mean wt = 62.3 kg) as compared to the whole group (mean weight - 65.9 kg). Moreover, unsuccessful pilots were less experienced (Total flying hours = 685 h) in comparison to the whole group (Total flying hours = 759 h). All of the unsuccessful pilots were flying ground attack/ fighters with low +Gz capability before undergoing centrifuge training.

Contributory factors: One of the unsuccessful pilots had intercurrent illness (upper respiratory tract infection) on the first two days of the course and this possibly could have affected his +Gz tolerance on the subsequent days. One pilot gave history of airsickness during pre-commissioning flying training. He developed severe motion sickness and vertigo during the centrifuge runs especially during deceleration phase, probably lowering his +Gz tolerance. This pilot also had a break of about one and a half years from flying before reporting for the centrifuge training.

The pilots, who could not complete the course, were evaluated for their orthostatic tolerance by 70° Head up tilt. It was found to be normal for all of them. Psychological and vestibular evaluations were also negative. ECG evaluation during +Gz also did not reveal any significant arrythmias in these pilots.

Discussion

G-tolerance, like other human physical and physiological characteristics, varies among individuals. It has an approximately normal distribution and can be defined on the basis of either G-duration or G-level. G-level tolerance of an individual also varies based on the rate of build up of +Gz, being more during gradual onset rate as compared to rapid onset rate. Its average values for relaxed, unprotected (without anti-G suit) young pilots of Indian Air Force are 4.4 (SD 0.6)

and 4.8 (SD 0.7) G on rapid and gradual onset rates profiles respectively with endpoint as 56° to 60° peripheral light loss (PLL). G-tolerance also varies within individuals i.e., from day to day, but not nearly to the same extent as among individuals. It is obvious that one of the ways to reduce the probability of symptoms of G intolerance in flight especially G-LOC is to avoid exposure to the high +Gz environment to those individuals with low G-tolerance. This practice has been in vogue in some countries [8]. The intention of the selection and screening procedure is, to use the fact that some healthy young pilots have an advantage due to their anthropometric and physiological parameters, to withstand more G-forces than others do. Besides, anthropometric data like a short eye-heart distance, cardiovascular response to +Gz- acceleration forces and physical attributes of a pilot, play an important role in determining high G-tolerant pilots.

Centrifuge training for fighter aircrew of Indian Air Force is being conducted since 1991. Since then, a criteria of minimum G-level tolerance standard of 7 Gz for 15 s during Rapid Onset Rate (ROR) of 1G/s for the pilots seated in an upright seat (13° seatback angle), wearing a functioning anti-G suit, and performing an anti-G straining manoeuvre (AGSM), has been adopted [7]. This standard has been laid on the basis of two documents published by the international organisations, which have defined low G-tolerance in relation to a 7-G standard. NATO Standardisation Agreement (STANAG) 3827 AMD, "Minimum Requirement for Selection, Training and Employment of Aircrew in High Sustained G Environments", that aircrew who do not successfully complete a rapid onset, +7 Gz, 15 s centrifuge profile with anti-G suit and straining manoeuvre will be considered to have low G tolerance [8]. Similarly, the Air Standardisation Coordinating Committee (ASCC) has issued Advisory Publication (ADV PUB) 61/26A, "Standardised Centrifuge G-Stress Profiles for Medical Evaluation of Aircrew Members", in which it is stated that aircrew unable to pass a +7 Gz, 15 s rapid-onset run while wearing an anti-G suit and performing an anti-G straining manoeuvre should be considered to have low G tolerance [8].

It has been our experience [7] as well as the experience of other countries [4, 5, 8] that a G-tolerance standard of +7 Gz for 15s is not a very stringent requirement for trained fighter pilots that are actively flying. Thus 311 pilots out of 314 pilots (99.04%) of our pilots could tolerate the standard without significant loss of peripheral vision or consciousness. Moreover, 300 out of 314 pilots (95.54%) and 258 out of 314 pilots (82.17%) could also complete the 8 G for 10 s and 9 G for 5 s profiles respectively. The rate of successful completion of target profiles was 68% in qualified Canadian pilots (297 out of 439 pilots) [4]. Target profile selected was 7G for 15s for pilots not normally using anti-G suits and 8G for 15s for pilots using anti-G suits. Concerns about high percentage of failure rate were reinforced by a tragic CF 18 accident in July 1995 where G LOC was identified as a probable cause factor, and the pilot of the accident aircraft had been unable to complete the target profile in his centrifuge training session 29 months before. This experience led to the revision and call for a mandatory HSG training programme for the Canadian pilots with mandatory performance objectives (7G/15 s without anti-G suit) for all 'at-risk' aircrew (defined as those regularly exposed to more than 4 G). Although NATO Air Forces do adhere to the NATO STANAG (i.e., 7G for 15 s) as a minimum G-standard, their training goal is 9 G for 15 s in the F-16 configured seat. Failure to complete an 8G-15s run in the F-16 seat results in vigorous retraining, physical conditioning, and re-exposure until the 8G, 15s run is successfully completed [9].

+Gz tolerance during aerial combat manoeuvres is, to a large extent determined by fatigue

of the pilot, who is eventually unable to continue with the G-manoeuvres because the energy used to maintain an adequate anti-G straining manoeuvre (AGSM) finally exhausts the pilot. Tolerance to aerial combat manoeuvres with fatigue as an endpoint is determined on a centrifuge using a variable G profile called simulated aerial combat manoeuvre (SACM). SACM enables us to simulate aerial combat manoeuvre to as near a realistic simulation as of the actual combat manoeuvres of aircraft. A SACM profile for the IAF pilots for the centrifuge training was developed in 1991 and mean tolerance norms determined as 174.13 (SD 66.8)s [7,10]. Based on this, we have laid down a minimum criteria of G-duration tolerance also that pilots who would be able to complete at least one cycle of SACM (4 G for 15 s followed by 8 G for 10 s) without any significant fatigue/visual symptoms or G-LOC would only be recommended for air superiority fighters.

Disposal of the pilots who are not able to complete the required G-tolerance standard, both in terms of G-level and G-duration, poses a great dilemma. These pilots are re-tested on another day, to take advantage of both the recency of instruction on the straining manoeuvre and the acute adaptation to motion sickness-producing stimuli resulting from the centrifuge exposure. If the pilot is still unable to complete the +7 Gz, 15s profile or one cycle of SACM (4 G for 15s followed by 8 G for 10 s), his ECG during the +Gz exposure is thoroughly scrutinised. Besides, they are subjected to tilt table test to evaluate integrity of CVS reflexes to orthostatic stress. Psychological evaluation and vestibular examination is also done to rule out any medical cause of low +Gz tolerance. Those pilots found fit otherwise are allowed to continue with their fighter flying but are not recommended for flying air superiority fighters like Mirage 2000, MiG 29 and Su 30, which are capable of high sustained +Gz. These pilots are required to undertake a physical conditioning (strength training) programme. One case who reported back only after five months could not complete the course. It was probably due to insufficient flying practice between the courses, inadequate weight training programme to increase his muscular strength and anaerobic capacity or continued susceptibility to angular acceleration/deceleration associated with the centrifuge exposure. One pilot who reported after three years could easily tolerate the minimum G-level and duration exposure laid down. It seems reasonable that at this point, the obvious deficiency in G-tolerance, should be treated as a type of flying deficiency like consistently inadequate situational awareness or poor gunnery scores, and be taken into account for flight safety reasons.

Canadian Air Force is enlisting the unsuccessful attendees during centrifuge training in a G-tolerance improvement programme (G-TIP) [4]. This offers measures intended to improve AGSM effectiveness through practice exercises, continued flying duty (though with an operational flying restriction limiting G-exposure to less than 4 G), aeromedical evaluation where indicated, and follow on attendance on HSG course within 6 months.

Conclusion

In conclusion, an observation made by Gp Capt Ruffell Smith about British fighter pilots in World War II is particularly pertinent today: "Successful British fighter pilots were not interested in anti-G suits because they had a higher G-tolerance anyway; those who were not successful [because of low G-tolerance] were shot down!" In contrast, the performance of today's fighter aircraft makes an anti-G suit an undisputed necessity. Moreover, value of implementing a G-tolerance standard, is without any doubt. It will help in preventing loss of expensive aircraft and trained manpower, due to attrition because of superior G-tolerance of

enemy's fighter pilots during wartime and avoidable G-LOC accidents during peacetime. Maximum flight safety for aircrew can only be achieved by avoiding the mismatch between the +Gz tolerance of pilots and the performance of aircraft in terms of its G-load generating capability.

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