Original Article

Newer methods to enhance +Gz protection

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Acceleration stress in modern generation aircraft is a necessary evil. G-induced Loss of Consciousness (G-LOC) and high G unusual attitude conditions are a constant threat to the aircrew of high performance fighter and attack aircraft. These dangers will become even greater in the future, as greater speeds and super-manoeuverable aircraft place even greater demands on the physical capabilities of the pilot. Methods to alleviate +Gz stress have been under evaluation ever since aircraft performance exceeded the Human tolerance. While methods like tensing, crouching, Valsalva manoeuvre were connatural to the aircrew, Anti-G Straining manoeuvre (AGSM) and its variants like the Qui-Gong and Hook manoeuvre were developed as physiological methods after extensive centrifuge trails and multi-centric evaluation. They are in use in Air Forces around the world. As the +Gz envelope of the fighter aircraft increased, newer methods were required and were developed, tested and used. The Anti-G Suit - Anti-G Valve combine (Anti-G System) has seen a sea change. Advance Technology Anti-G Suit (ATAGS), High Flow Ready Pressure (HFRP) valve, COMBAT EDGE, Advance Protection System (APS), Atlantis Warrior full coverage water-filled suit (McDonnell Aircraft) and STING are some of the methods of administering enhanced protection in isolation or in combination. Brief descriptions of these methods are presented. The initial experiences with Positive Presssure Breathing for G (PBG) at IAM in the Advance Fighter Aero-medical Indoctrination Course (AFAIC) and its potential in the IAF is discussed.

Keywords: Gz stress; AGSM; ATAGS; Combat Edge; APS; STING; PBG.

An effort to enhance the +Gz tolerance of aircrew has been the endeavour of Acceleration physiologist. Fighter aircraft are inherently unstable as they are built with relaxed stability criteria to enhance manoeuverability. The Gz envelope of a fighter aircraft has been steadily increasing and the research in Aerospace technology has just managed to stay ahead of the maximum permissible +Gz loading of the aircraft. The angular excursions of current aircraft about their principle axis are limited to roll and pitch and very limited yaw [1]. However, a new generation of supermanoeuverable/super-agile aircraft with significant excursions in X and Y-axis besides high sustained Gz loads are in the

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pipeline [1]. The "man" operating the aircraft, because of his limited natural and acquired skills now limits the capability of man-machine system. With the advent of higher Gz capability, the existing modalities of +Gz stress alleviation need to be augmented, supplemented and reinforced.

In view of the hydrostatic column of blood the heart has to support to maintain cerebral perfusion, the natural human tolerance to sustain +Gz is in the order of 4.5 G [2]. This baseline relaxed human tolerance has had to be enhanced, to enable the aircrew to be able to withstand the +Gz stress. The first in this alleviation of +Gz stress was the Anti-G Suit. It has five distinct interconnected pneumatic bladders operated under equivalent pressures providing an increase in the peripheral resistance, increase in venous return & prevent peripheral pooling. Physiological measures modified from the Valsalva and the natural response to tense, grunt and graon were perfected and are in vogue. The Anti-G Straining Manoeuvre (AGSM) and its variants like QiGong & Hook manoeuvre evolved and were followed by various Air Forces. This was considered adequate protection till the mid 70's when the F-16's were developed who's G-envelope exceeded 9G. However it was configured to be used till 9G only despite its higher capability. Efforts to alleviate +Gz stress received an impetus again in the early 80's when the F-22 were developed which had a definite ability of the order of 12G. AGSM which was by now universally accepted as a $+G_z$ alleviating method due to its easy availability, cost effectiveness, and protection offered was noticed to be fraught with the problems of fatigue, interference with communication and the necessity to remain vigilant.

Review of Literature

Methods in use: The world over, the aviators are now being indoctrinated in comprehensive +Gz alleviation programmes. The methods for alleviation generally fall in one of the three groups, namely:-

a) Reduce venous pooling

b) Reduce the hydrostatic distance between the heart and brain

c) Increase Mean arterial pressure (MAP)

Among methods reducing venous pooling and thereby augmenting the venous return are the G-Suits, G-Valves & Pelvis and leg elevation (PALE seats). Newer concepts in the anti-G suits include uniform longitudinal and circumferential pressurisation to dependant areas of the body, High Flow Ready Pressure suits, Enhanced coverage of the G-suit, retrograde filling G-suit, full coverage G-suit & pneumatic uniform pressure G-suits. From servo valves to the High Flow Ready Pressure (HFRP) to microprocessor controlled Anti-G valves to valve that pulsates the G-suit, the progress continues ....! The Anti-G Suit-Anti G Valve combine can give a maximum protection in the order of 1.5-2G only, but are an important adjunct to AGSM. The methods of reducing the hydrostatic column, like the reclining seats/ seat back, prone position envisage a modification in the seat and are feasible only if incorporated in the design stage of aircraft manufacture. The F-16 has a 30-degree till back that increases G-tolerance significantly. Reclining seats beyond 45 degrees pose visual compromises and necessitate re-designing the cockipt, a feat un-accomplishable by countries not manufacturing aircraft's. Prone seats are also fraught with similar restrictions.

Hypertensive drugs can theoretically cause the increase in Mean Arterial Pressure. Carbon dioxide showed initial promise in studies [3]. But its applied importance is limited owing to its other effects. Other vasomotor tone increasing agents tested have not shown results that merit

mention[3]. Also drugs and flying being mutually exclusive in the IAF, this possibility has not been explored.

The conventional methods like the time tested AGSM have been standardised. After initial indoctrination, physical conditioning and reinforcement programmes are already in vogue. Analysis of accured benefits and its cost effectiveness cannot be overstressed.

Positive Pressure Breathing is application of pressure by a regular to the breathing gas throughout the respiratory cycle[4]. Pressure Breathing for Altitude (PBA) is being operationally used on exposure to altitude above ~ 12,000 meters (Ernsting). Positive Pressure Breathing for Gz protection (PBG) evolved from the same concept as early as 1945. It was suggested for G protection in 1952, and was experimentally tried out in the Human centrifuge in 1970s. As promising results emanated the concept was first given a 'flight trail' in 1983. Since that time, many countries have adapted it. Clearly, it is an idea that has an immense potential and application, and an idea whose time has come. The necessity of an adequate mask to face seal cannot be overstressed. PPG upto 30 mm Hg are acceptable; however, for higher levels counter-pressure to the chest with a jerkin/vest is desirable ('Balanced' PPB), and upto 60-70 mm Hg pressure can be delivered[5]. Exhaling is an active process in PBG and being an altered physiological function, is disconcerting initially till one gets used to it (Burton).

It is therefore evident that from the currently available methods for alleviation of +Gz stress, none is a panacea all-powerful; so the current trend of evolving programmes incorporating more than one method.

Newer methods in +Gz protection under evaluation/evolution

Almost all the current day +Gz stress alleviation protocols are a judicious mix of various methods of protection, the most basic combination being AGSM & Anti-G Suit.

TheUSAF system is the "COMBAT EDGE" which was fielded in 1990. It consits of an Integrated Terminal Block (ITB) which is a simple manifold designed to equally distribute pressure to mask, helmet bladder and pressure vest. It delivers 30 mm Hg pressure in the mask-test position and a maximum of 60 mm Hg at 9G. Mounting a bladder inside helmet between the foam linear and thermoplastic linear modified the helmet hitherto being used. A hose fitting for filling bladder was incorporated. The visor was cut to fit profile of new mask.

The Air-filled Advance Technology Anti-G Suit (ATAGS) covers 40-45% of Body Surface Area (BSA) as opposed to 30% in the standard suit, and provides an additional 26% SACM endurance compared to the standard suit. Combined with COMBAT EDGE, ATAGS provided a 200% increase in SACM endurance compared to the standard suit.

The Tactical Life Support System (TLSS) developed for USAF (1987), incorporates, besides the PBG, more coverage by the five bladders G-suit (the suit volume increasing by 45%). Combined with a faster G-valve, it enhances the existing Gz protection by 0.5G.

In the Indian Air Force, only the Su-30 aircraft has the provision for PBG which cuts in at 3G (a lower level set possibly to warn the second pilot), and is delivered through a combined services connector over the seat. The

aircrews are equipped with BKK-15 Partial Pressure Suit that has provision for providing counter-pressure to the chest alone. Maximum excessive pressure in Oxygen mask under G load is 600 mm of water. The relation between mask and suit pressurisation is 1:3.2.

The design document of ILSS proposed for the LCA envisages to incorporate PBG linked to the anti-G valve, cutting in at 4G and increasing linearly @ 12 mm per G to a maximum of 60 mm at 9G.

The Northop Corporation APS, is a total life support system capable of providing altitude, acceleration, chemical and biological protection in one ensemble. It incorporates bladders in the legs, torso and arms and utilizes PBG.

Material and Methods

Rai (1979) [6] conducted initial experiments at IAM. With the international advent of PBG in alleviating +Gz stress, the initial experiments were carried out at IAM on the 13 volunteers of Advance Fighter Aeromedical Indoctrination Course (AFAIC) and the officers of Stage IIa who reported for the respective courses at IAM in 1998-1999.

Protocol

The following schedule has been evolved:

a) Didactic lecture on PBG, its mechanism of action, protection & difficulties.

b) Ground exposure to 30 mm Hg pressure at the Air lock chamber in the Dept of HAP using Mk 20 regulator.

c) Low G PBG familiarisation run on human centrifuge to accustom the aircrew to the technique, selection of PBG being manual & not yet integrated to the G-valve.

d) GOR runs wearing an Anti-G suit and PBG being administered through a Mk 20A regulator 'P' mask combination and performing AGSM.

e) SACM runs with PBG.

Results

An encouraging trend has emerged with the following findings on 13 volunteers from AFAIC's:

a) Enhanced SACM endurance (Time tolerance)

   i) SACM-PBG tolerance of 214 seconds against 172 seconds SACM tolerance (Fig 1)

   ii) 6.08 peaks at SACM-PBG as against 4.92 peaks at SACM (Fig 2)

   iii) Lower Heart rate achieved in SACM-PBG runs compared to SACM runs (Fig 3)

b) Enhanced GOR Tolerance (Level tolerance)

   i) First grey-out (GOR-Relaxed) at a higher +Gz level (Fig 4)

   ii) Second grey-out (GOR-Straining) at a higher +Gz level or not at all (Fig 4)

   iii) Lower heart rate achieved in GOR-PBG runs compared to GOR runs (Fig 5)

c) Subjective assessment was done by administering a post exposure questionnaire to the aircrew. The results were as follows:

   i) Tolerance of the centrifuge run was better with PBG

   ii) AGSM was more comfortable with PBG

Fig 1: Duration of SACM/SACM-PBG (n=13)

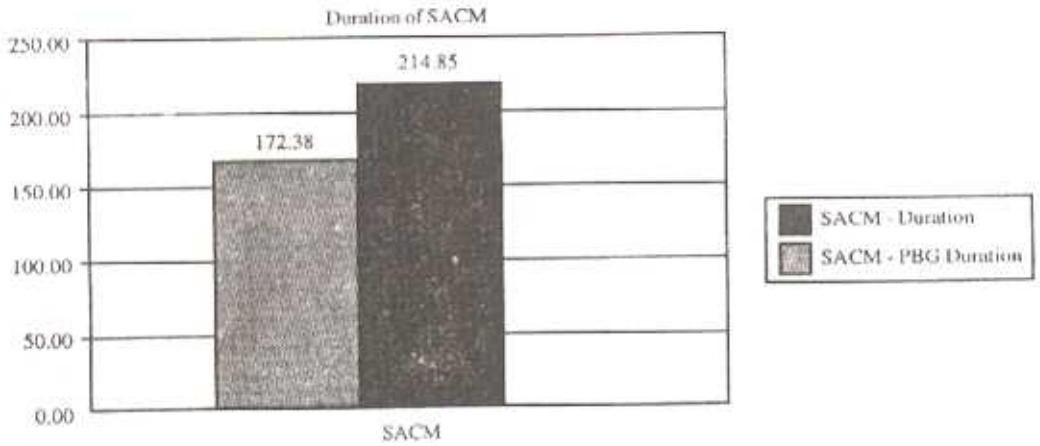
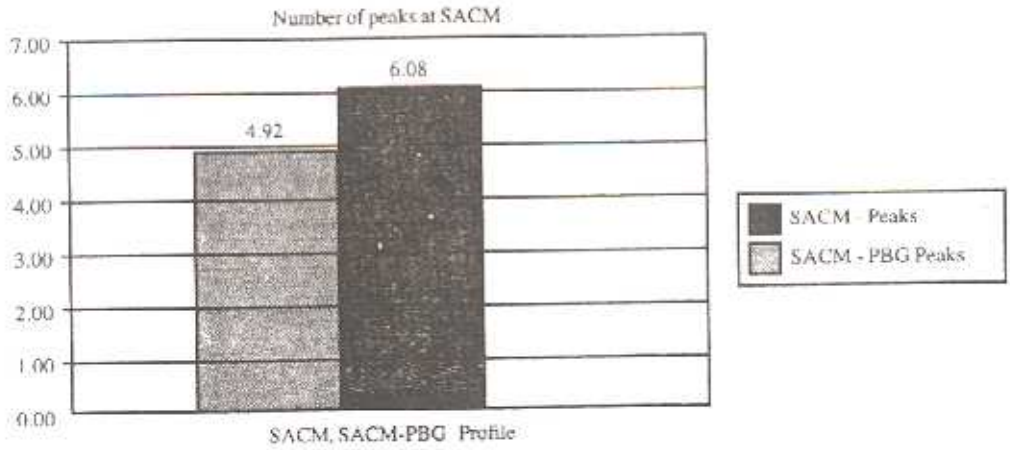


Fig 2: No of Peaks at SACM / SACM-PBG (n = 13)



iii) Duration at SACM was enhanced with PBG

iv) Fatigue was less with PBG

v) Exhaling was more difficult with PBG

vi) Aircrew would prefer to use AGSM with PBG for actual exposure to +Gz stress.

Discussion

The initial experiences of PBG at IAM have been encouraging objectively and subjectively. However, the PBG being administered through the regulator-mask combine is still independent of the Anti-G Valve. Ideally, the PBG should derive a feedback from the rising G levels and increase pari-passu with it[7]. We are about to receive an integrated Anti-G Valve with a PBG capability. Then it shall be possible to marry up the PBG with the rising G levels as perceived by the Anti-G Valve. It would be a closer simulation to the

Fig 5: HR Changes: Phases of GOR/GOR-PBG (n = 13)

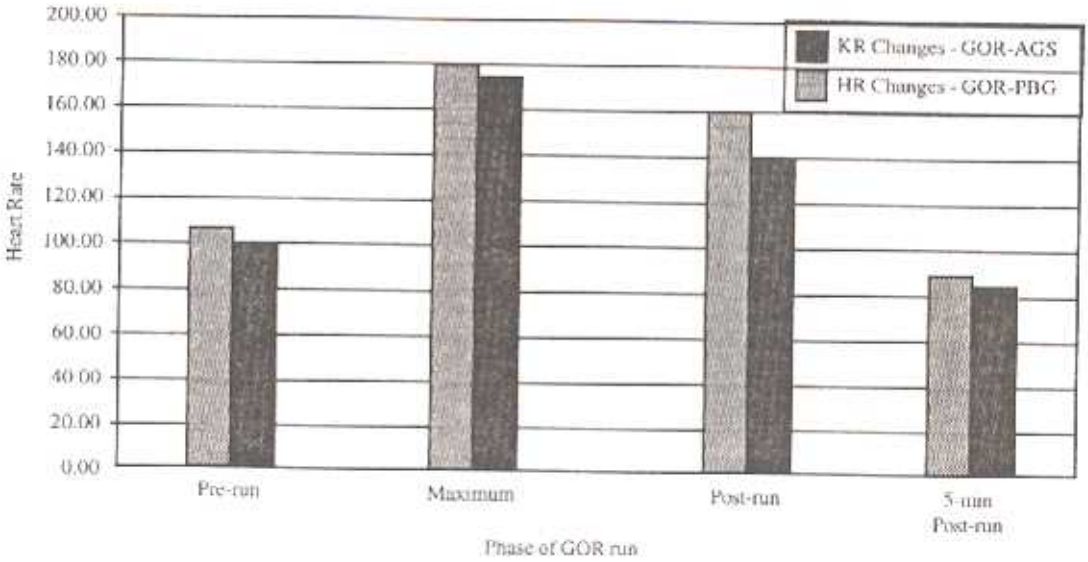
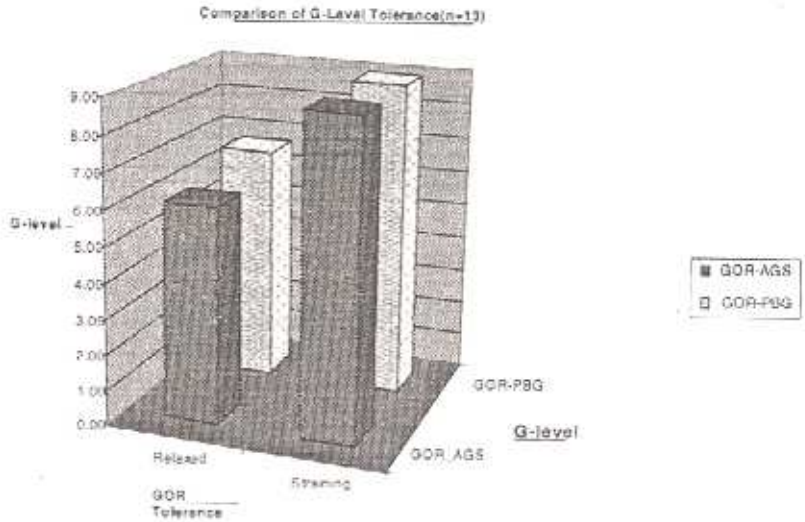
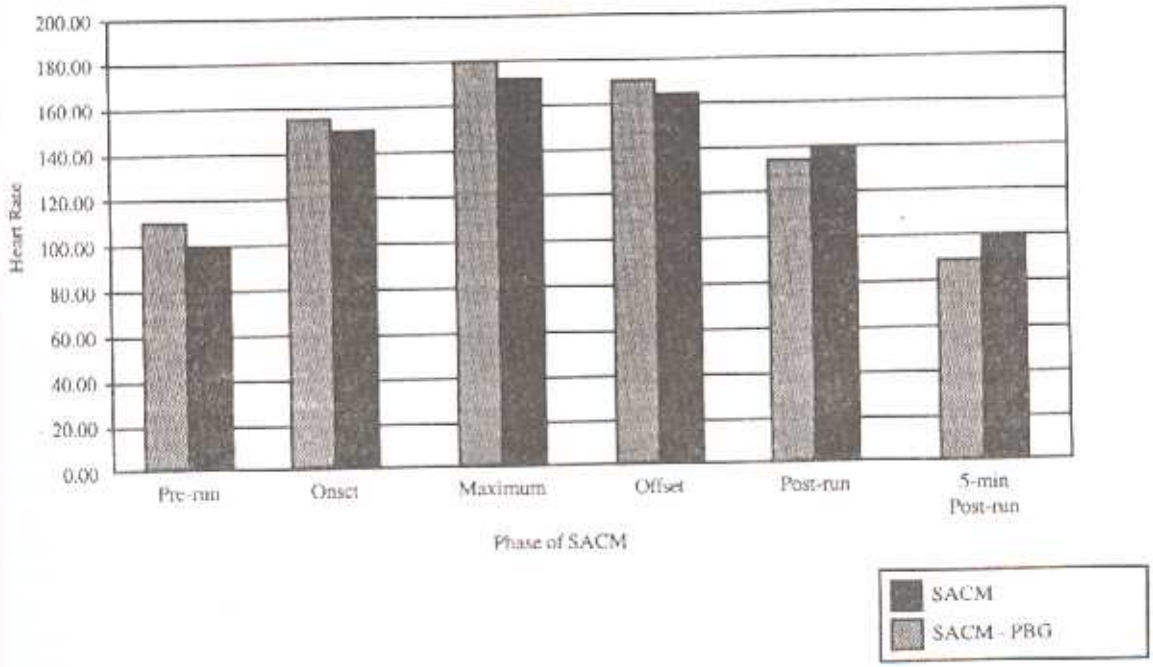


Fig 4 : GOR / GOR-PBG relaxed and straining (n = 13)



real scenario. Efforts would then be directed to work out an ideal schedule of AGSM & PBG for aircrew. Also, efforts to evaluate the feasibility of modifying the existing Anti-G Systems to provide for PBG shall have to be undertaken.

Fig 3: HR changes in SACM/SACM-PBG (n = 13)



Conclusion

PBG is an important tool in enhancing +Gz tolerance. Combined with an adequately performed AGSM with correct timing titration and technique (involving optimum speed, skill, stamina & strength), a schedule can be evolved to alleviate +Gz stress.

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