Quantified Muscular Contraction during AGSM and its Correlation with Straining +Gz Tolerance

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ABSTRACT

Introduction: Anti G straining manoeuvre (AGSM) is one of the most effective physiological methods, available for the aircrew, to increase his or her +G tolerance. However, there is a requirement to learn and practice the correct technique of performing AGSM to obtain optimal benefit. The present study was undertaken to assess the effectiveness of correct quantified muscular contraction practices on straining +Gz tolerance during aeromedical inductrination training for IAF fighter pilots.

Methods: 25 healthy volunteer male ab.initio fighter aircrew with age ranging from 21 to 30 years participated in the study. After explaining the protocol, relaxed and straining G tolerances of the aircrew were recorded in the High Performance Human Centrifuge (HPHC). The electromyographic (EMG) assessment of the four muscle groups involved in performance of AGSM, was carried out on the AGSM Practise and Test rig using Surface EMG (SEMG) technique. The subjects were taught the correct technique of performing the AGSM (L1 manoeuvre). EMG recordings and the G tolerances were repeated and the pre-training values were compared with the post-training values. Statistical analysis was carried out by using Students t test and Pearson correlation methods.

Results: The mean relaxed and straining +Gz tolerances were 3.95G ± 0.12 & 5.69 G ± 0.12 respectively before the formal AGSM training. The mean relaxed and straining +Gz tolerances were 3.97G ± 0.08 & 6.12G ± 0.11 respectively after the formal AGSM training. The normalized RMS EMG values of all the four groups of muscles showed significant increase in the post-training stage. Post-training EMG values of all the four muscle groups were compared and correlated with the post training straining G tolerances. Thigh muscles showed the highest positive correlation with the straining G tolerances (r = 0.343) followed by the calf muscles (r = 0.212).

Discussion: The contribution of various muscle groups in performance of AGSM was illustrated in the present study. EMG data from various muscle groups revealed that the lower limb muscles i.e thigh muscles followed by calf muscles are the most active muscles participating in the performance of AGSM.

Conclusion: The study concluded that (a) There is higher contribution of lower limb muscles (thigh followed by calf) in effective performance of AGSM. (b) The EMG activities recorded during post training phase of AGSM training had higher values than the pre training values thus emphasizing the importance of indoctrination of correct muscular contraction practices of AGSM.

Keywords: *AGSM, Electromyography, ab initio aircrew, High Performance Human Centrifuge.*

INTRODUCTION

Modern military fighter aircraft might sustain +7 to +9Gz for up to 5 to 10 seconds during Air Combat Manoeuvre (ACM) and may remain above +5Gz for over a minute in a combat engagement. In addition to the innate tolerance, the important protective measures to counter this stress are the Anti-G suit (AGS) and Anti-G Straining Manoeuvre (AGSM) [1]. The pressure created by the AGS helps in preventing the pooling of blood and thereby increases +Gz tolerance. The AGSM, on the other hand, requires the individual to perform a "near-maximal" isometric muscular contraction. AGSM can provide more than 3G improvement in G tolerance if performed correctly, for which a well-structured high G training is imparted to all ab-initio fighter aircrew.

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AGSM is a combination of continuous muscle tensing and Valsalva manoeuvre sustained in three to four second. Muscle tensing should be sustained throughout the acceleration and not relaxed during breathing. The real-time monitoring of muscular contraction by utilizing Electromyography (EMG) is an effective method of assessing strength of contraction of muscles [2]. It was considered a valuable scientific endeavour to quantify the contribution of different muscle groups towards an effective AGSM. Present study was undertaken to quantify the contribution of different muscle group after an effective AGSM training among ab-initio fighter pilots of the Indian Air Force.

MATERIAL AND METHODS

The study was carried out in the Department of Acceleration Physiology and Spatial Orientation at IAM, Bangalore. 25 healthy ab-initio fighter aircrew with the age ranging from 21 to 30 were selected for the study. It was ensured that the participants were in full flying medical category and free from any disease or disability at the time of study.

The study was carried out using the High Performance Human Centrifuge (HPHC). After brief didactic lectures on physical conditioning and AGSM, the participants were familiarized with the HPHC. After this, the participants were subjected to centrifuge runs using Gradual Onset Run (GOR) profile @ 0.1G/sec on Day 1. The relaxed and straining G tolerance of all the participants were recorded. Thereafter, the participants were taken for AGSM training in the Test Rig. At this time, instrumentation for recording of the EMG from 4 selected muscle groups viz. upper torso (Pectoralis Major), lower torso (Rectus Abdominis), thigh (Vastus Lateralis) & calf (Gastrocnemius) was completed. At the beginning of AGSM training, the participants were asked to strain the way they used to do while pulling high G in the aircraft. During this time, the maximal voluntary contraction (MVC) of each muscle group was recorded. The muscle activity of these muscles was recorded in terms of RMS values. Recording of EMG from different group of muscles were repeated for three times for duration of three seconds by keeping abdominal muscle as control. This ensured the uniformity of contraction. These values were used as quantitative data to determine the contribution of different muscle groups during performance of AGSM. All the EMG values were normalized in the form of %MVC and were considered as the "Pre-training values".

Thereafter, the participants were explained about the AGSM. They were demonstrated the correct technique of performing AGSM and made to practice on the Test rig. On the next day morning i.e Day 2, participants were exposed to centrifuge run following GOR profile. Their relaxed G tolerance and straining G tolerance while performing AGSM were noted. During this time the EMG data from the same muscle groups were also recorded and were noted as "Post-training values". The SEMG data obtained through EMG sampler was analyzed using Biograph Infinity software.

RESULTS

G Tolerance

The relaxed and straining G tolerances were measured for all 25 participants before and after the AGSM training. The descriptive statistics of relaxed (GOR) and straining G tolerances (SGOR) during pre and post training phases are given in the Table 1. Increase in the post training values in comparison to pre training values is suggestive of improvement in G tolerance with performance of AGSM.

Table 1. Relaxed and straining G tolerances in pre (GOR PRE & SGOR PRE) and post training (GOR POST & SGOR POST) stages.

	GOR PRE	GOR POST	SGOR PRE	SGOR POST
Mean	3.95	3.97	5.69	6.13
Median	3.9	4	5.64	6.09
Mode	3.7	4	#N/A	5.44
SD	0.58	0.46	0.59	0.54
n	25	25	25	25

EMG Data

EMG recordings were converted from analog to digital signals by a personal computer at a sampling rate of 1000Hz. After excluding the noise, peak of EMG signal during manual muscle strength testing was selected as a normalizing value. The activity results were expressed as percentage of maximal voluntary contraction of the muscle group studied (% MVC). An increase in Normalised Mean Amplitude of RMS EMG was observed in all four groups of muscles (chest, abdomen, thigh and calf) as depicted in Fig 1.

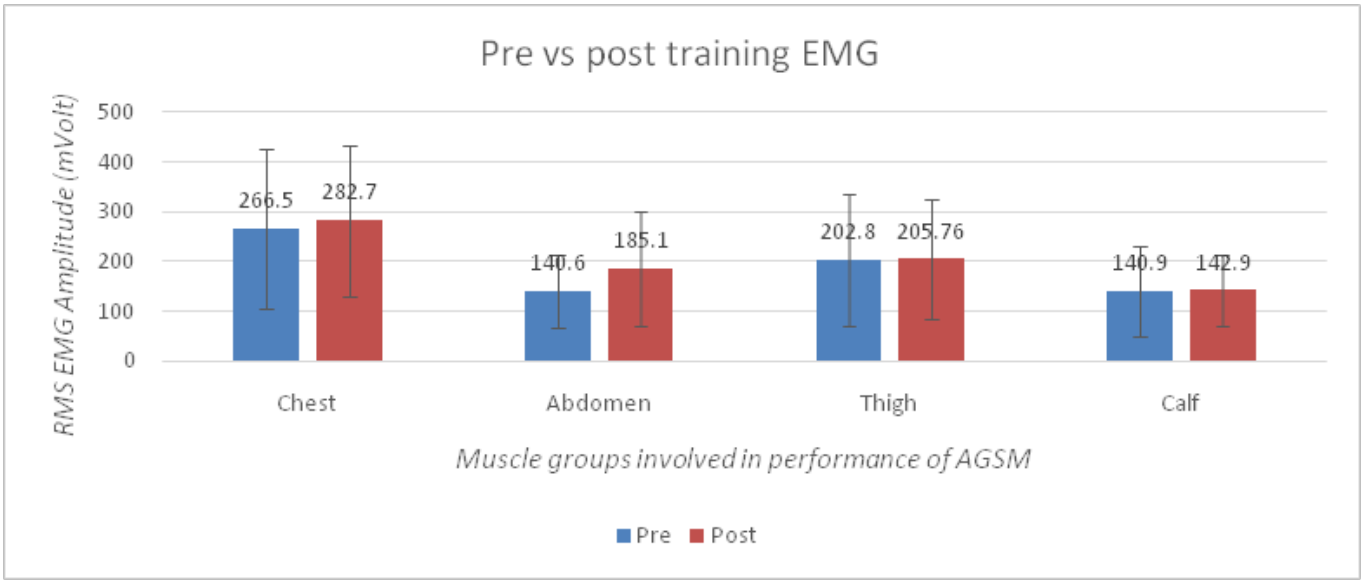

Fig 1. Comparison of Pre & Post training EMG values for Chest, Abdomen, Thigh & Calf muscles.

The pre and post-training EMG data from all four muscle groups were compared using Wilcoxon signed rank test as the data were not distributed normally (as shown in Table 2). There was a significant increase ($p<0.05$) in the post-training EMG values for all four muscle groups.

Table 2. Comparison of Pre & Post training EMG values for Chest, Abdomen, Thigh & Calf muscles participating in performance of AGSM (significant differences at $p < 0.05$)

CHEST	MEAN	SD	T	DF	P
Pre training	266.53	160.53			
Post training	282.69	152.13	0.45	2.14	0.043
ABDOMEN					
Pre training	140.60	73.32			
Post training	185.06	115.29	0.33	3.21	0.003
THIGH					
Pre training	202.08	132.61			
Post training	205.76	120.77	0.36	2.64	0.014
CALF					
Pre training	140.85	89.66			
Post training	142.88	70.24	0.36	3.60	0.001

EMG Vs Straining G Tolerance

The increase in RMS EMG values of the muscles in post-training stages were studied for correlations with post-training straining G tolerances (SGOR POST). Pearson correlations revealed a higher 'r' value for thigh muscles (0.343) and followed by calf muscles (0.212).

DISCUSSION

Acceleration stress is an additional yet inevitable burden during fighter aircraft manoeuvring specially during air combat. The need to overcome this stress has resulted

in widespread expansion of knowledge on acceleration physiology. Effective performance of AGSM is found to be beneficial in countering the adverse effects of inflight acceleration stress.

Studies have shown that if performed correctly, AGSM helps in increasing the G tolerance by approximately +3G to +4G and effective AGSM depends largely on the muscle straining using different muscle groups [3]. Epperson et al. conducted a study in 1982 to determine the most important muscles involved in performance of AGSM, following a 12 week generalised body strengthening program [4]. They found that the abdominal (sit ups) and biceps (arm curl) strengths increased by 99% and 26.2%, respectively, and were highly correlated with Simulated Air Combat Manoeuvre (SACM) tolerance time ($p<0.01$). However, their study also revealed that though effective, generalized body strengthening programs were very time consuming, leading to the reduced compliance by pilots. Balldin et al. in 1985 tried implementing Epperson's suggestions for fighter pilot to undergo abdominal muscle strengthening only. However, their study reported no significant increase in subject's G tolerance as a result of the abdominal muscle strengthening program [5]. Therefore, various physical conditioning programs are implemented for fighter aircrew to improve their generalized body strength so that they can perform AGSM more effectively. This study was undertaken to quantify the level of muscular activity by different muscle groups during the performance of AGSM, so that the specific muscle groups can be targeted during physical conditioning program.

AGSM has all the attributes of the personal protective system as it is readily available, cheap and unencumbering [6,7]. Motivation, experience and factors like physical activity, innate tolerance, body structure etc. do affect the +Gz tolerance of the aircrew. However, the most important factor that contributes to increase in G tolerance in an operational arena is the effective performance of AGSM [8].

The present study was mainly focused on determining the contribution of different muscle groups during effective performance of AGSM. The results revealed that there was significant increase in the post-training EMG values in comparison to the pre-training EMG values.

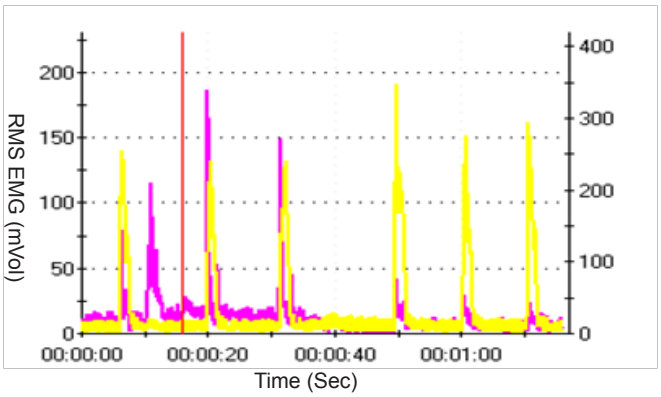

Fig 2. Raw RMS EMG data obtained from two muscles (Pink – rectus abdominis, Yellow- soleus) while performing AGSM on the AGSM training rig.

It was found that there was no statistically significant change in the relaxed +Gz tolerance after the training. This could be due to the fact that relaxed G tolerance is mostly dependent on individual's innate ability and do not change with any type of intervention and the factors affecting the G tolerance were well controlled and maintained during the study. The results of the study suggested that there is a significant improvement in straining G tolerance values, after the formal AGSM Training. Mean pre-training straining G tolerance was (5.69 ± 0.1) whereas post-training straining G tolerance (6.13 ± 0.1). The outcome of the study emphasizes the importance of indoctrination of operational training on High G for the fighter aircrew, to teach them the correct technique of AGSM. Correlation of EMG values of different muscle groups involved during the performance of the AGSM, viz. upper torso (Pectoralis major), lower torso (Rectus abdominis), thigh (Vastus lateralis), and calf (Gastrocnemius) with straining G tolerance, indicated a higher muscle activities of lower limb muscles (thigh followed by calf) during performance of AGSM. It was also found that Straining post-training G tolerance is positively correlated with post-training RMS EMG values of lower limb muscles.

The importance of contribution of lower extremity muscles in performance of AGSM as compared to those of the trunk was also illustrated in the study conducted by Cornwall and Krock where EMG data for the "best" and the "worst" riders were compared in surface

electromyography (SEMG) [9]. The findings of the present study, which are in coherence with the study by Cornwall and Krock, indicating higher contribution of the lower limb muscles than that of the trunk muscles during AGSM.

Study by Gomez had emphasized the importance of muscle strength in performance of effective AGSM and found that physical conditioning program adopted by the fighter pilots could be useful in combating the acceleration stress [7]. The findings of the present study could be used towards formulating the physical conditioning program specifically targeting the lower limb muscles. It is recommended that the exercise regimen followed by the fighter aircrew at squadron level, needs to focus on improving the strength and endurance of the lower limbs muscles through Sit Ups, Leg raises, Leg press, Leg extension and leg curl exercises. The ideal 12 week physical conditioning program is recommended as this is will not only help the aircrew to perform AGSM more effectively but with lesser effort and for longer periods under G loading.

CONCLUSION

The study concluded that (a) There is higher contribution of lower limb muscles (thigh followed by calf) in effective performance of AGSM. (b) The EMG activities recorded during post training phase of AGSM training had higher values than the pre-training values thus emphasizing the importance of indoctrination of correct muscular contraction practices of AGSM.

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