Original Article

Correlation of Simulated Air Combat Manoeuvre (SACM) Tolerance with Anaerobic and Aerobic Capacity

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Simulated Aerial Combat Manoeuvre (SACM) tolerance of 10 motivated aircrew were determined in the human centrifuge using alternating peaks of 4G for 15 seconds and 8G for 10 seconds. Critical power and anaerobic work capacity of these aircrew were also determined with the help of bicycle ergometer. SACM tolerance range was 109 seconds to 369 seconds (Mean 266.4 s). The mean values of anaerobic work capacity and critical power were 145.8 watt sec and 153.4 watt min respectively. A significant correlation was found between SACM tolerance and anaerobic work capacity ($p<0.05$) indicating that anaerobic metabolism plays a major role during SACM. Four out of five subjects showing more SACM tolerance (>200 sec) also had higher anaerobic work capacity and critical power (aerobic capacity). It was inferred that both anaerobic capacity as well as aerobic capacity in moderation helps in increasing tolerance to high sustained +Gz environment.

Key words :- Anti-G straining manoeuvre (AGSM), Anaerobic work capacity, critical power.

The latest generation combat aircraft is subjected to a spectrum of 'G' levels during aerial combat manoeuvre which vary in a continuous manner. Anti-G Straining manoeuvre (AGSM) still remains the single most important method to fight prolonged sustained 'G'. AGSM requires strenuous physical activity. Therefore, physical exercise training programme assumes importance in enhancing aircrew tolerance to fatigue.

This study has been carried out to determine the main basis of energy (aerobic or anaerobic) during sustained 'G' environment and AGSM. If both, how much is the contribution by each type of metabolism during this particular environment, what type of physical training will be helpful: aerobic training or muscular strength and endurance training to increase anaerobic capacity.

Material and Methods

Ten healthy aircrew volunteered for this study. They all reported for high "G" training in Institute of Aerospace Medicine (IAM) and were highly motivated. They had 2-8 years experience in flying high performance aircraft and were well versed with AGSM. Detailed medical history was obtained and physical examination was carried out prior to subjecting them to various tests.

The aircrew were instructed not to consume alcohol and to have proper sleep at night.

Anaerobic capacity and SACM tolerance were measured on consecutive days.

Anaerobic Work Capacity and Critical Power Measurement

Bicycle ergometer (LODE, Holland) with the provision of electrically applied brake for required power load was used for this purpose. Power load of 300 watts, 250 watts and 200 watts were given separately with a gap of at least 40 minutes between each exercise.

Subjects were required to pedal and reach 60 RPM quickly. Selected resistance (power load) was applied within 1-2 seconds. Subjects were instructed to maintain 60 RPM throughout the exercise and continue pedalling for maximum time till they could maintain this RPM.

Total time from applying the power load till the subjects were exhausted and could not maintain the required RPM, was measured with the help of stop watch. Work output (Wlim) was calculated by the time (Tlim) during which exercise was performed at the particular power

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output. The relationship between WLim and TLim has been shown to be highly linear and can be described by the equation[1].

$$Wlim = a + b\ Tlim$$

Where "a" is intercept of the line which represents anaerobic work capacity (AWC) i.e the capacity of individual to produce energy without consumption of oxygen. The Slope 'b' denoting critical power (CP) and Y intercept 'a' as anaerobic work capacity (AWC) were calculated with the help of computer.

SACM Tolerance

SACM tolerance of the subjects was determined in the human centrifuge in the Department of Acceleration Physiology at IAM.

Subjects used indigenous anti-G (MK II - Cutaway type) suits which were inflated with a Russian anti-G valve at a rate of 1PSI/G above 2G. Subject's relaxed and straining rapid onset run (ROR) (1G/sec) tolerance were determined prior to exposing them to SACM in the upright position (13^{0} seat back angle).

SACM profile included 4G for 15 sec and 8G for 10 sec alternately until the subjects felt fatigued and gave a call to terminate the run. The offset rate was 0.3G/sec. Subjects were instructed to perform AGSM while accelerating from 4G to 8G, and throughout the 8G run, till they came back to 4G. Anti-G suit was kept inflated throughout SACM. SACM tolerance was taken as the total time in seconds from start of run till its termination.

Relating Fatigue at the end of SACM and Bicycle Ergometer Exercises

To give some validity to the end point 'fatigue' after SACM and bicycle ergometer exercises, and to ensure that the subject had reached the same level of fatigue, a scale based on Borg's rating of perceived exertion was prepared[2]. Subjects were motivated and encouraged to reach almost the same scale after the different exercises and were asked to mark the level on the scale.

Correlation between SACM tolerance time and critical power and anaerobic work capacity was determined using correlation analysis with the help of computer.

Results

The physical characteristics of the subjects and their flying experience are given in Table I.

Table I: SACM, AWC, CP and Various Subjective Parameters

Subject No	Age (Yrs)	Height (cms)	Body Wt (kgs)	Flying Experience (hrs)	SACM Toler. (sec)	Anaerobic work capacity (watt sec)	Critical power (watt/min)
1	26.5	174	67	882	369	169.2	168.75
2	27	164	58	1100	184	139.2	117.21
3	23	166	61	355	179	132.0	188.28
4	28	178	70	1050	172	91.8	188.29
5	22	181	68	440	267	166.2	180.06
6	30	183	76	1140	225	169.2	142.92
7	26	183	62	650	123	145.2	117.92
8	23	166	56	300	109	143.4	168.09
9	28	171	62	874	234	147.0	152.06
10	29	166	66	1119	237	156.0	110.53
Mean	26.26	172.2	64.6	791	209.9	145.8	153.41
±SD	8.69	5.68	5.68	313.27	71.35	22.8	28.54
CV					34%	15.68%	18.6%

SACM tolerance range was 109 sec to 369 sec (Mean 209.9). The mean values for anaerobic work capacity and critical power were 145.8 watt.sec and 153.4 watt/min respectively (Table I).

Correlation Coefficient (r) between SACM tolerance and AWC was found to be 0.55 ($p<0.05$), while between SACM and critical power, it was 0.14. Besides this, multiple correlation coefficient between SACM and critical power plus AWC was 0.63. The Coefficient of variation was also calculated for SACM, AWC and critical power which was found to be 34%, 15.68% and 18.6% respectively (Table I).

Subjects were divided into two groups on the basis of SACM tolerance, an arbitrary 200 sec being taken as the separation point for high tolerance (>200 sec) and low tolerance (<200 secs). Results have been tabulated for these high tolerance and low tolerance group (Table II & III).

Discussion

The present study has tried to correlate SACM, anaerobic capacity and aerobic capacity in fighter pilots who were not trained physically prior to this study.

In this study, critical power method was chosen to evaluate the aerobic and anaerobic capacity of the subject. Various studies have reported that the values for critical power (CP) and anaerobic work capacity (AWC) are highly correlated to aerobic and anaerobic capacity respectively[1,3-5]. Critical power method is a simple, reliable, valid and repeatable method by which aerobic and anaerobic capacities can be measured simultaneously.

Table II: SACM, AWC, CP and Various Subjective Parameters in HTG Group

Subject No	Age (Yrs)	Height (cms)	Body Wt (kgs)	Flying Experience (hrs)	SACM Toler. (sec)	Anaerobic work capacity (watt. sec)	Critical power (watt/min)
1	26.5	174	67	882	369	169.2	168.75
5	22	181	68	440	267	166.2	180.06
6	30	183	76	1140	225	169.2	142.92
9	28	171	62	874	234	147.0	152.06
10	29	166	66	1119	237	156.0	110.53
Mean	27.1	175	67.8	891	266.4	161.52	150.86
±SD	2.79	6.29	4.57	252.09	53.2	8.69	23.93

Table III : SACM, AWC, CP and Various Subjective Parameters in LTG Group

Subject No	Age (Yrs)	Height (cms)	Body Wt (kgs)	Flying Experience (hrs)	SACM Toler. (sec)	Anaerobic work capacity (watt. sec)	Critical power (watt/min)
2	27	164	58	1100	184	139.2	117.21
3	23	166	61	355	179	132.0	188.28
4	28	178	70	1050	172	91.8	188.29
7	26	183	62	650	123	145.2	117.92
8	23	166	56	300	109	143.4	168.09
Mean	25.4	169.4	61.4	691	153.4	130.32	155.95
±SD	2.05	9.78	4.8	335.74	31.09	19.43	32.20

All our subjects rated fatigue at the same level during SACM and bicycle ergometer exercises based on Borg's rating of perceived exertion[2].

There was a significant correlation between SACM tolerance and anaerobic work capacity ($r=0.55$, $p<0.05$). This is in agreement with the findings of other workers[6,8]. This indicates that anaerobic metabolism plays a major role during SACM.

Tesch et al[8] found that with a 14% increase in anaerobic power, there was 34% increase in SACM tolerance time. In the present study, the coefficient of variation for AWC is about 16% while for SACM it is 34%. So it can be inferred that 16% variation in AWC caused 34% variation in SACM tolerance time. In this respect, our findings are comparable to those of Tesch's.

The peak G level of +8G for 10 sec in SACM profile during the present study required a near maximum AGSM which in turn required an intense muscular effort. Besides this, +Gz environment itself is particularly suited to the anaerobic metabolism because of increase in intramuscular venous hydrostatic pressure during G[7]. So a significant correlation between AWC and SACM tolerance was expected, and found.

Subjects were divided into two groups - high tolerance group (HTG), and low tolerance group (LTG) on the basis of SACM tolerance time as reported by Epperson et al[6], Burton et al[7] and the present study.

The mean value of critical power in both groups-HTG and LTG did not differ much (150.86 and 155.95 watt/mt respectively) but the difference in mean values of AWC in HTG and LTG was quite obvious (161.52 and 130.32 watt sec respectively). So it seems that the difference in SACM tolerance time was due to difference in AWC in two groups.

The correlation coefficient ($r=0.14$) between SACM and Critical power is not significant in a sample of ten subjects. But surprisingly the value of 'r' between SACM and critical power was found to be 0.52 in high tolerance group. The multiple correlation analysis was also done to see the effect of both critical power and AWC on SACM tolerance. The value of 'r' increased to 0.63 for a sample of ten subjects. No subject in our study developed any arrythmia or motion sickness during SACM run. This may be due to the fact that none of the subject engaged in excessive aerobic conditioning which is known to produce such effects[9,10]. Probably aerobic capacity in moderation also improves the SACM tolerance. Burton et al[7] recommended aerobic conditioning limited to 15-20 miles run per week.

With better aerobic capacity, one will have improved efficiency of lactate removal due to increase in mitochondrial content and malate aspartate shuttle activity[11,12]. There will also be faster recovery of force and metabolic content of skeletal muscle[12]. So moderately improved aerobic capacity may lead to these beneficial effects without causing any adverse effect on +Gz tolerance.

Anaerobic work capacity (AWC) and critical power (CP) both were comparatively higher in four out of five subjects in high tolerance group. So it can be inferred that both anaerobic capacity (as determined using AWC) as well as aerobic capacity (as determined using Critical power in this study) in moderation help in increasing tolerance to high sustained Gz acceleration.

Our findings show that subjects with high SACM tolerance also have better AWC and CP, but subjects with relatively low tolerance had low values for AWC. Therefore, it is recommended that aircrew should undergo physical conditioning (balanced amount of anaerobic and aerobic exercises) to increase both AWC and CP.

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