# Delayed Effects of Alcohol Ingestion on + Gz Tolerance

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Abstract

Consumption of alcohol lowers tolerance to + Gz in the phase while alcohol is circulating in blood. Delayed effects of alcohol ingestion have not been reported. Twenty, healthy, fully fit volunteer, male subjects were tested for their + Gz tolerance, upto PLL, in a human centrifuge on two separate days. On one occasion the subjects did not have alcohol on the previous day and on the other, they consumed a measured quantity of (180 ml) Whisky/Rum, on the previous evening and were tested 8 hrs and 12 hrs after drinking. The subjects' blood and urine samples were tested for Ethanol values by Gas Chromatography at 8 hrs and 12 hrs stages. Blood alcohol values were zero mgm % at both these times, but urine showed small quantities after 8 hrs and only two cases showed traces after 12 hrs of drinking. The + Gz tolerance showed a reduction of 0.3g at 8 hrs and 0.2g at 12hrs. A few subjects showed nausea and vomiting on the post alcohol tests. The possible physio-pathology of reduction in + Gz tolerance is discussed.

## Introduction

Acceleration as a stress is a normal concomitant of fighter flying. This is one stress which the fighter pilot has to learn to live with and operate an aircraft within his own and the aircraft's limit of tolerance to + Gz. A fully fit pilot can cope up with the normal combat requirements with the use of a proper anti G suit and personal protective measures.

Certain factors are known to lower the pilot's tolerance to + Gz. A number of such factors have been well recognised, *e.g.* hypoxia, heat, hypoglycaemia and hyperventilation[3,4,8]. A few workers[2,5,6,9,10,11,16] have also confirmed reduction in tolerance due to consumption of alcohol.

Keeping in mind the traditions of IAF and the current regulations on drinking, it was felt that most often IAF pilots do not fly soon after consumption of alcohol. All the officers' mess bars are closed in the afternoons on working days and are open in the evenings between 1900 to 2130 hours. Normally flying starts in the morning at about 0630 hours. Thus, there is invariably a gap of 9 to 10 hours between drinking and flying. The quantum of drinking has a lot of individual variation, but generally it is agreed that most pilots who know that they are likely to fly the next day do not indulge in heavy drinking, i.e. not more than 3–4 small pegs of whisky or equivalent amount of alcohol. A few who drink larger amounts occassionally, do know that "hang over" the next day is too marked to permit any useful activity, leave aside a productive fighter sortie.

This study has been designed to assess the delayed effects of alcohol on tolerance to + Gz.

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There is no reported literature in this field. The immediate ill effects of alcohol are well known and so are the generalised ill effects of severe "hang-over." Thus subjects were given medium doses, *i.e.* 180 ml of whisky/rum and their + Gz tolerance at 8 hrs and 12 hrs after drinking was compared with the basal values.

## Materials and Methods

Twenty healthy, fully fit volunteer, male subjects were chosen for the study between the age group of 21 years to 30 years. All of them were either fighter pilots, doctors or Air Force personnel who were experienced riders on the human centrifuge. They were all moderate social drinkers. The subjects were given a general physical examination to exclude any physical disability. The basal 'grey out' (PLI.) tolerance was determined early in the morning, *i.e.* at 0800 hrs and repeated at 1000 hrs. For a few subjects the basal reading was obtained a few days after the alcohol trials. The subjects were briefed not to consume alcohol one day prior to the basal test run. They were fully rested and had breakfast before the test runs.

The subjects were tested on the IAM Human Centrifuge having 5 metre radius and a standard aircraft seat with a 13° tilt from the vertical. The subjects were monitored on television and were in constant touch on the intercom. They wore normal working clothes without use of anti G suits. They were instructed to stay relaxed through out the test run and not to use any voluntary protective methods against + Gz in any of the test runs. The G exposure was started at a low level and gradually increased in steps till a repeatable PLI. was established.

The peripheral lights are mounted 28" apart and at a distance of 30" from the subject at his head level. These lights subtended an angle of 53° on the subject's eyes. He was asked to concentrate on a central red light and switch off the peripheral lights as soon as they become visible, by pressing a micro switch on the mock control column. After careful adjustment of the ambient light the brightness of the peripheral lights was adjusted so that the lights were just visible.

During exposure to + Gz the peripheral lights were presented at varying intervals. An increase in the subject's reaction time, beyond his normal, was considered as "grey out" (PLI.). The test was repeated till the subject showed "grey out" at the same G level.

Subjective confirmation of grey out was also obtained. "Black out" was ruled out by confirmation from the subject. This technique was found to be quite reliable and repeatable.[14]

### 'G' profiles used

All subjects were exposed to 'G' profiles having a 0.5 g/sec onset and 0.1 g/sec deceleration with a peak 'G' maintained for 15 secs. The peak 'G' chosen was usually 2.8 to 3 G to start with, followed by small increments till a firm PLI. was established. Subjects' reaction time was recorded on the Mingograph (multi channel Jet recorder).

All the subjects were given 180 ml of whisky/rum (alcohol content 45%) according to personal preference of the subject, between 2130 to 2230 hrs on the day prior to the test. All the subjects were tested at 0800 hrs and 1100 to 1200 hrs the next day on the centrifuge. Blood and urine samples were collected immediately after completion of the test run. Thus most subjects were tested after a lapse of 8-9 hrs and 12-13 hrs after drinking. Estimation of Ethanol in blood and urine was carried out by using an AIMIL dual column gas chromatograph Mk IIB fitted with flame ionisation and thermal conductivity detectors. The technique described by Curry et al[2] as modified by Adaval et al[1] was used for the estimation.

Subjects were asked to give their subjective reactions to the test runs. Incidence of symptoms like nausea and vomiting were enquired into.

## Results

Blood alcohol estimation, done after 8 hrs and 12 hrs of drinking showed "No alcohol" (*i.e.* below the minimum sensitivity of the Gas Chromatograph — 0.5 mg%). Urine alcohol values ranged between 1.3 mg% to 0 mg% in the subjects tested. After a lapse of 12 hrs, the urine alcohol was also found to be NIL except in 2 cases.

In the first 10 cases urine estimations of ethanol were not undertaken. Subsequently plasma

and urine estimations were undertaken only at 8 hrs and 12 hrs interval — as the tests were given only after 8 hrs and 12 hrs of ingestion of alcohol. In no subject ethanol was detected in plasma after 8 hrs duration while in 10 cases where urine was processed for the test, 5 samples yielded positive result in 8 hrs group and 2 samples in 12 hrs group. Average ethanol level in plasma in one hour group was 90.0 mg/100 ml with SD of 11.0.

TABLE I

*Blood and urine alcohol levels in mgm percent at different intervals*

| Subject No. | 1 hour | | 8 hour | | 12 hour | |
|---|---|---|---|---|---|---|
| | Blood | Urine | Blood | Urine | Blood | Urine |
| 1 | 86 | — | 0 | — | 0 | — |
| 2 | 108 | — | 0 | — | 0 | — |
| 3 | 90 | — | 0 | — | 0 | — |
| 4 | 80 | — | 0 | — | 0 | — |
| 5 | 98 | — | 0 | — | 0 | — |
| 6 | 90 | — | 0 | — | 0 | — |
| 7 | 88 | — | 0 | — | 0 | — |
| 8 | 82 | — | 0 | — | 0 | — |
| 9 | — | — | 0 | — | 0 | — |
| 10 | — | — | 0 | — | 0 | — |
| 11 | 112 | 136 | 0 | 0 | 0 | 0 |
| 12 | 75 | 88 | 0 | 0 | 0 | 0 |
| 13 | — | — | 0 | 4.2 | 0 | 3.0 |
| 14 | — | — | 0 | 2.7 | 0 | 0.9 |
| 15 | — | — | 0 | 0 | 0 | 0 |
| 16 | — | — | 0 | 4.3 | 0 | 0 |
| 17 | — | — | 0 | 0 | 0 | 0 |
| 18 | — | — | 0 | 2.6 | 0 | 0 |
| 19 | — | — | 0 | 0 | 0 | 0 |
| 20 | — | — | 0 | 0.5 | 0 | 0 |

Table II gives the Basal, 8 hrs and 12 hrs PLL values for the 20 subjects. The basal PLL value ranged between 3.5 and 5.4 G with a mean of 4.4 and SD of 0.6 G. The mean value at 8 hrs was 4.1 G with SD 0.6 G and these values at 12 hrs were 4.2 G; SD 0.7 G.

The difference between basal G tolerance and tolerance at 8 hrs and 12 hrs is also shown in Table II. These differences were checked by the "t" test and found to be significant. It is seen that the G tolerance was reduced significantly after 8 hrs and 12 hrs. even though the blood and urine alcohol values had gone down to nearly zero or unestimatable values.

TABLE II

*PLL Values of 20 Subjects — Basal, 8 hrs and 12 hrs after alcohol consumption*

| Subject No. | PLL Value | | | Difference | Difference |
|---|---|---|---|---|---|
| | Basal (a) | 8 hours (b) | 12 hours (c) | a–b | a–c |
| 1 | 3.5 | 3.5 | 3.1 | 0 | .4 |
| 2 | 3.6 | 3.5 | 3.4 | .1 | .2 |
| 3 | 4.0 | 3.6 | 3.6 | .4 | .4 |
| 4 | 4.4 | 4.7 | 4.2 | — .3 | .2 |
| 5 | 4.4 | 4.1 | 4.1 | .3 | .3 |
| 6 | 4.4 | 3.6 | 3.9 | .8 | .5 |
| 7 | 3.9 | 3.6 | 3.8 | .3 | .1 |
| 8 | 4.0 | 4.5 | 4.0 | — .5 | 0 |
| 9 | 5.1 | 5.3 | 5.1 | — .2 | 0 |
| 10 | 4.8 | 5.1 | 5.7 | — .3 | — .9 |
| 11 | 4.9 | 3.5 | 4.3 | 1.4 | .6 |
| 12 | 4.4 | 3.5 | 4.0 | .9 | .4 |
| 13 | 3.5 | 3.2 | 3.2 | .3 | .3 |
| 14 | 4.2 | 3.6 | 3.8 | .6 | .4 |
| 15 | 5.0 | 4.6 | 5.2 | .4 | — .2 |
| 16 | 4.8 | 4.4 | 4.6 | .4 | .2 |
| 17 | 5.4 | 4.8 | 5.1 | .6 | .3 |
| 18 | 5.1 | 4.4 | 4.6 | .7 | .5 |
| 19 | 4.7 | 4.6 | 4.7 | .1 | 0 |
| 20 | 4.5 | 4.0 | 4.1 | .6 | .4 |
| Means | 4.43 | 4.10 | 4.23 | .33 | .20 |
| SD | 0.6 | 0.6 | 0.7 | | |
| Range | 3.5–5.4 | 3.2–5.3 | 3.4–5.7 | ** | * |

* $t = 2.78$ ($p < 0.05$)

** $t = 3.12$ ($p < 0.01$)

Subjects No. 2, 5, 6, 11 and 14 complained of nausea after completion of the test runs especially the 8 hrs schedule. Two subjects actually vomited on completion of the test. There were no other symptoms reported.

Discussion

Reduction in tolerance to + Gz by factors like heat, hypoxia, hyperventilation and hypoglycaemia

are accepted already[8,10]. Ingestion of alcohol also produces a known reduction in the tolerance, when assessed very soon (*i.e.* upto 2 hrs of drinking) [2,4,8,9,10,11,16]. But delayed effects of drinking, i.e. 8–12 hrs after drinking moderate quantities of alcohol have not been reported so far.

Howard[10] states that "Experience has convinced most regular riders on the human centrifuge that alcohol has a deleterious effect on their performance and tolerance. Even in the absence of a "hang over" an experiment carried out on a day after a party is likely to produce severe symptoms. Even a moderate quantity of alcohol taken at lunch can prejudice a test run on the centrifuge, during the afternoon." Though the effect on 'Black out' threshold may not be marked but there is a considerable increase in the unpleasant feeling of 'toppling' as a centrifuge comes to rest. Many subjects complain of feeling sick earlier than normal. These symptoms are more often due to increased sensitivity to angular accelerations due to alcohol.[10] He has opined that nausea and disorientation produced, are themselves sufficient justification for the statement that alcohol decreases the tolerance to positive acceleration. He has suggested that objective measurement of decrement in tolerance is of interest.

Browne[4] reported his trials with subjects who were given 4 fluid ounces of whisky and their 'black out' thresholds were determined before, an hour and 2 hours after drinking. Five of the subjects tested showed a fall in their tolerance to acceleration, some at 1 hour and others more at 2 hours. The individual variation was very large. The reduction varied between 4% and 30% of the basal value. The mean reduction in tolerance in absolute values was only 0.2 g. To exclude the effect of excitement and euphoria, the experiments were repeated with certain changes in his methodology. Thus he found that the acceleration which was just sufficient to produce minimal visual symptoms produced severe grey out or 'black out' one hour after drinking. The results of his second experiment proved conclusively the immediate ill-effects of alcohol on G tolerance.

Burton and Jaggers[6] in their study exposed 8 subjects (7 males and 1 female) to 45 seconds acceleration at 3, 4, 5 and 6 G while protecting them with a standard anti G suit and permitting personal protection with the M-1 manoeuvre. The subjects were accustomed to perform a psychomotor target task during the acceleration phase. One hour after alcohol ingestion (varying quantities — 0.5 to 3 ozs of 96% alcohol) the subjects were tested again. The tracking task showed reduction in performance at 1 G of 21% associated with alcohol ingestion of 3 ozs and a mean blood alcohol of 0.12%. There was hardly any reduction in task performance below this value. The combination of 3 ozs alcohol with 3 G resulted in a potentiated 62% reduction in task performance, same way a combination of 3 ozs alcohol with 5 G produced a reduction of 79% in task performance.

They[6] concluded that low G and less alcohol together resulted in less than additive effect but high G and more alcohol cause a synergistic reduction in task performance.

There are several postulates as to the cause for the fall in tolerance. Howard[10] opines that alcohol produces vasodilatation, especially in the skin vessels. Peters and Van Slyke[13] feel that it is the toxic action on the cell metabolism which causes Histotoxic Anoxia. Machne[12] quoted by Howard[10] gave evidence of depression of the carotid sinus with moderate doses of alcohol.

Burns[5] in his trials with alcohol on dogs exposed to + Gz studied the effects on CVS. He found a reduction in tolerance to + Gz one hour and 2 hrs after ethanol administration. But the levels of blood ethanol were very high (150 to 200 mg%). There was no evidence of Myocardial depression and he surmised the reduction in tolerance to be due to increased vascular compliance (Vasodilation).

The results of this study show that there is a significant reduction in + Gz tolerance even upto 12 hrs after drinking 180 ml of whisky/rum. The decrement in G tolerance even when the blood alcohol values have returned to zero is not easy to explain. Most authors have opined that the vasodilation of skin vasculature is the cause for reduction in G tolerance, while blood alcohol values are reasonably high. This physiological effect of alcohol on peripheral circulation is well documented and accepted.

Howard[10] has postulated that the occurrence of vestibular disturbances associated with alcohol and + Gz exposure are the major factor in reducing the tolerance to + Gz. It may be argued that probably the persistent derangement of vestibular function as a delayed effect of alcohol, which seems to persist even when the blood alcohol has been burnt-up, may be the cause for reduction in G tolerance.

In this study, elucidation of the physio-pathology of such delayed effects of drinking has not been attempted. A host of factors or cumulative effects of the "hang over" type of human response to drinking may be considered the culprit in this situation. It is probable that toxic effects on cell metabolism as reported by Peters and Van Slyke[12] persist even after elimination of alcohol from the system.

The baroreceptor response of the carotid sinus is very important for maintenance of blood pressure during the orthostatic stress of + G. It is possible that the depression of carotid sinus due to alcohol as reported by Machne[12] continues to exist even after the alcohol has been metabolised, thus producing a lowered G tolerance.

Whatever be the causes for the reduction in tolerance to + Gz the results cannot be ignored. A reduction of 0.3 Gz in the tolerance of a pilot may not be such a serious problem but the synergistic effects of multiple stresses as reported by Browne[4], Burton and Jaggers[6] and Tang et al[15] has a lot of significance to a fighter pilot. Any situation precipitating either hypoxia, hyperventilation, hypoglycaemia or excessive heat alongwith the post alcohol effects may prove to be the last straw in maintaining proper control of the aircraft during high + Gz manoeuvres. Such combination of stresses cannot be predicted but is quite a common occurrence when least anticipated.

The tests carried out are upto the "grey out" tolerance only, which is known to occur at about 0.6 to 0.8G earlier than "black out." In combat, most pilots like to fly an aircraft upto its limit but keeping themselves in a zone some where between 'grey out' and 'black out.' The haemodynamic insult by + Gz increases progressively as the peak G or its duration is prolonged. It is quite possible that the ill effects of alcohol will be more pronounced at the higher levels of + Gz, *i.e.* when the subject is closer to his 'black out' tolerance. During all practice or combat fighter flying, pilots routinely fly with anti G suits and also use the well known personal protective techniques to prevent visual symptoms upto reasonably high G values. Thus pilots are known to sustain 7 to 8G for short periods, *i.e.* 5 secs or so and moderate G *i.e.* 4.5 to 5G for prolonged periods *i.e.* 30-35 secs with practically no visual symptoms. It can be assumed that the after effects of alcohol will be worse under these conditions.

## Conclusion and Recommendations

There is a significant reduction in tolerance to + Gz at 8 hrs and 12 hrs after ingestion of 180 ml of whisky/rum.

The present regulations in IAF, of a gap of 12 hrs between "bottle to throttle" is justified and must be implemented.


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