The Effects of Alcohol on Pilot Performance and Safety

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The piloting of an aircraft is a complex task. It requires the interpretation of a variety of sensory information, the cognitive evaluation of this information, and the performance of various motor tasks in response to the perceived situation. The basic faculties required to be able to successfully pilot an aircraft include adequate and unimpaired senses of vision and hearing, sufficient intelligence and judgement, suitable personality, and motor skills. The motor skills necessary include adequate power, dexterity, and coordination to manipulate aircraft controls, sufficient power and coordination of speech for radio based communication, and the strength and agility to allow entrance-to and egress-from an aircraft. Substantial training is then required to turn these basic attributes into the ability to successfully and safely pilot an aircraft.

The demands of flying an aircraft are greater than those of driving a car. The pilot is exposed to additional factors such as the hypoxia of increasing altitude, high noise levels, the requirement for radio communication with the outside world, higher accelerations during aircraft manoeuvring, and visual-vestibular illusions with the potential for loss of three dimensional orientation. Even quite low levels of

alcohol can act to impair the human faculties required to fly in a safe and effective manner.

The ingestion of alcohol influences virtually every system in the human body in some way or another (1) (2) (3) (4). The most readily apparent effects of alcohol are usually a result of its effect on our central nervous system. The metabolism of all other body systems is altered. Included is the gastro-intestinal tract, the liver and pancreas, muscles, the blood, the heart, endocrine organs, the immune system, the respiratory system, fluid and electrolyte balance, and possibly even the incidence of cancer (1). The effect of alcohol most pertinent to aviation is its impairment of a variety of central nervous system functions.

Association with fatal aircraft accidents.

During the last four decades the relationship between alcohol ingestion and fatal aircraft accidents has been reviewed intensively (5). A high incidence of the presence of alcohol in the blood of pilots involved in fatal general aviation accidents has been demonstrated.

In the United States the percentage of pilots with elevated blood alcohol levels involved in fatal general aviation accidents during the early 1960s was approximately 43% (6). This proportion had fallen somewhat, but remained between 15% and 20% during the 1970s (7). The association between elevated blood alcohol levels and fatal, general aviation, aircraft accidents has tended to remain at the 10% - 30% level in recent times (6, 8-19). This relationship does not appear to persist when military or professional commercial aviation accidents are investigated (20, 21). A variety of factors, primarily the effect of putrefaction on measured blood alcohol levels, have caused some to argue that these postmortem studies do not accurately reflect the true incidence of alcohol ingestion by aviators (20). No similar Australian data has been seen by the author.

A statistical correlation between elevated blood alcohol levels and fatal civil general aviation accidents does not necessarily infer a causal relationship. Despite technical discrepancies in some of the studies, especially concerning the issue of putrefaction, the balance of the data does suggest a strong correlation. The considerable amount of data available and the consistency and trends of the results would tend to support the postulate that alcohol has a causative role in many of these accidents.

Impairment of flight.

The statistical correlation between elevated blood alcohol levels and fatal civil general aviation accidents has prompted attempts at identifying pilot impairment during flight (22), simulated flight (23-31), and a variety of flight related tasks (32-50).

In-flight evaluation of pilots with blood alcohol levels of 0%, 0.04%, 0.08%, and 0.12% has suggested that even quite low blood concentrations of alcohol cause significant performance decrements in flight (22). This study concluded that “blood alcohol concentrations of 0.04% are associated with substantial and highly significant increases in the number and potential seriousness of procedural errors committed by both inexperienced and highly experienced pilots”. Other studies performed using aircraft flight simulators support the relationship between the blood alcohol level and the number of aviation procedural errors (23, 25, 29, 38, 39).

Performance impairments due to the ingestion of alcohol depend, in part, on the blood alcohol levels produced and on the ability requirements of the task (51). This observation has been supported by studies on the effects of alcohol on the performance of aviation related tasks. These tasks have been shown to be impaired by blood alcohol concentrations of 0.025%, 0.04%, 0.08%, 0.1%, and 0.15%.

Impairment of higher cortical functions.

The safe and successful piloting of an aircraft requires sound functioning of the higher cortical faculties responsible for planning, judgement, cognition, calculation, attention, vigilance, sequencing, and memory. All of these faculties are impaired in some manner by the acute ingestion of alcohol (1-3, 52, 53). Acute intoxication produced by increasing concentrations of alcohol in the blood produces impairment of psychological functions such as perception, discrimination, association, and voluntary response (4, 53).

Psychomotor and spatial orientation capabilities of pilots are impaired by 0.1% blood alcohol levels (38). Complex task performance (32, 33) and reaction times (42, 45) have been shown to be impaired by blood alcohol levels in excess of 0.04% and 0.08% respectively. Blood alcohol levels as low as 0.027% cause a decrease in visual tracking performance during whole body motion (36) and in non-moving individuals (34). Alcohol disrupts the laying down of memory (52) with a likely subsequent reduction in aviation safety (49).

Reaction times to different stimuli have been shown to be increased by alcohol ingestion. (41, 42, 45, 46). The monitoring and decision components of reaction time tasks are also impaired by alcohol levels of 0.09% (43).

All of these functions play an important role in the safe piloting of aircraft. Impairment of any of these functions will be detrimental to flight safety.

The effects of alcohol on visual and visual-vestibular function.

Vision is the prime sensory modality used during aviation. The sense of vision is required for spatial orientation and navigation during both ‘visual’ and ‘meteorological’ flight conditions as well as the monitoring and adjustment of aircraft performance. In the absence of adequate visual stimulus control of an aircraft is typically lost within 60 seconds (54). Any impairment of the sense of vision, therefore, has the potential of adversely influencing flight performance and flying safety.

The speed of the eyes, in pursuing a target, is reduced by alcohol (48, 55). Similarly the speed of the eye’s saccadic motion, their latency times, and reaction times are impaired by blood alcohol concentrations in excess of 0.04% (41, 46-48, 55). Double vision and dilatation of the pupils, resulting in blurred vision, can also result from alcohol intoxication (2, 47). Blood alcohol levels of 0.05% and above have been shown to slow the ability of the eyes to accommodate or adjust their focus (47).

During the angular accelerations of flight there occur reflex rapid, oscillatory eye movements called nystagmus which tend to impair the view of objects within the aircraft. This can result in blurring of vision of instruments and a subsequent impairment of performance (36, 56). Usually a pilot is able to suppress this nystagmus by deliberately fixating on an instrument. Alcohol ingestion, and low light levels, impair the ability to suppress this nystagmus (36, 57-59). Impairment occurs at blood alcohol levels as low as 0.02% (54). One study (36)

concludes “that serious problems may even be encountered by the pilot who drinks lightly and who considers flying, especially at night”.

Another condition, called Positional Alcohol Nystagmus (PAN), also results from alcohol ingestion and also threatens flight safety (8, 56, 60). Positional Alcohol Nystagmus results in rapid, oscillatory eye movements when the head is placed in specific positions in the absence of angular acceleration. This condition may result in impairment of vision as well as spatial disorientation and has been measured 34 hours after alcohol ingestion (60, 61), long after there is no measurable alcohol in the blood. Positional Alcoholic Nystagmus has also been reported 48 hours after alcohol intake during long duration radial acceleration (62). Positional Alcohol Nystagmus has been proposed as the cause of some aviation accidents where there are no detectable blood alcohol levels (8).

Alcohol has little direct effect on visual acuity and the information concerning its effects on colour vision is conflicting (2).

Spatial orientation.

The maintenance of correct spatial orientation is an important requirement during flight. Maintaining orientation depends primarily on vision but the vestibular apparatus and the somatic sensory organs also contribute. The loss of spatial orientation, called spatial disorientation, can lead to loss of control of the aircraft and an accident will result unless control is regained.

The function of the vestibular apparatus, and its interaction with the eyes in maintaining correct posture and balance is impaired by alcohol levels greater than 0.04% (2, 50). High doses of alcohol retard the suppression of post-rotatory nystagmus (2), an important consideration in turning aircraft. Positional Alcoholic Nystagmus, mentioned above, may play a role in spatial disorientation.

Impairment, by alcohol or any other agent, of the visual system and the intimately related vestibular system would cause some degree of pilot incapacitation, and could lead to spatial disorientation and an aircraft accident. Alcohol could adversely affect flight safety in this manner.

Impairment of motor skills.

Frequent, coordinated, motor actions are required during routine flying operations. Usually only slight to moderate forces need be applied but during aircraft emergency procedures significant physical force may need to be applied. Fine dextrous movements are also required in the operation of aircraft radio communication and navigation equipment.

While alcohol has little effect on muscular strength it impairs the coordination of motor functions (2). Basic motor coordination tasks such as standing still, hand steadiness, walking, especially with the eyes closed, and a variety of sensorimotor tracking/pointing tasks are all impaired by alcohol (2).

Impaired coordination during sensorimotor actions could lead to reduced pilot performance and a reduction in flight safety.

Effects in conjunction with altitude hypoxia.

The hypoxia produced by aviation altitude exposure will subtly or potently impair pilot performance. The degree of hypoxic impairment varies with the altitude exposure. The issue of whether alcohol and

altitude act to impair performance in a purely additive manner or whether there is a synergistic effect is also of concern in the practice of aviation medicine.

It has been traditionally considered that alcohol and altitude hypoxia had a synergistic effect on performance impairment (35, 63-65). A number of mechanisms for these effects were proposed. Recent work has tended to discount this hypothesis (32-34, 66, 67). It now seems likely that there is little, if any, synergistic decrease in performance due to alcohol and altitude at less than 12,500 feet and that the rate of alcohol absorption from the gastro-intestinal tract is not increased by such altitudes.

While alcohol and altitude hypoxia both impair pilot performance it has not been conclusively shown that their interaction is anything more than additive in nature.

Alcohol induced hypoglycaemia.

Hypoglycaemia is the state of a lower than normal blood sugar level. When the blood sugar level is lower than normal performance may be impaired due to insufficient sugar for the central nervous system to function. Low blood sugar is not compatible with the safe piloting of an aircraft.

Alcohol ingestion results in a lowering of the blood sugar levels (1, 8, 68, 69) which, in turn, has lead to at least one fatal aircraft accident (68).

Performance impairment due to alcohol induced hypoglycaemia is likely to contribute to a reduction in flying safety.

Tolerance to positive radial acceleration.

In performing a balanced turn in an aircraft the pilot is exposed to a centrifugal force due to the radial acceleration. This acceleration results in an increase in his weight. High levels of this acceleration can result in impairment of vision and even unconsciousness as blood is unable to reach the eyes and brain. High levels of acceleration are not routinely experienced in general aviation but may result during aerobatics, steep turns or emergency manoeuvres, or uncontrolled spiral flight.

Ingestion of alcohol reduces the tolerance of this acceleration. A ‘moderate’ dose will reduce the threshold by 0.1 - 0.4 G (‘G’ = Unit of Gravitational Acceleration) and will intensify the severity of the symptoms produced by a given level of acceleration (54).

Interference with speech based communication.

Speech based communication is an essential component of most types of flight. A pilot relies on radio communication for traffic and procedural information, weather and safety warnings, navigational assistance, and emergency procedures. Any impairment in a pilot’s ability to speak or understand the spoken word may have a direct effect on aviation safety.

Alcohol ingestion causes alterations of speech including ‘thick, slurred speech’, ‘difficulty in speech’, ‘repetitive speech’, ‘low, raspy speech’, and ‘slow, mumbled, and incoherent’ speech (40). Memory for words, fluency in their use, and quality of word associations are also impaired by alcohol (2). Pilot radio communication has been shown to be impaired by alcohol (39). This impairment was found to be greater in older pilots than younger pilots.

Alcohol, in impairing various aspects of speech, will interfere with the efficiency of aircraft radio communication and intercommunication. This has the potential for reducing operational safety.

Risk taking behaviour.

The euphoria induced by alcohol as well as the impairment of judgement may cause a pilot to undertake manoeuvres that he would not undertake while sober (53, 70). Attempting such manoeuvres while psychomotor performance is impaired may lead to an aircraft accident.

Hangover effects.

Post Alcohol Impairment has been defined as ‘performance impairment after alcohol is no longer detectable’ (8). This condition is the equivalent of the lay term of ‘hangover’.

Post Alcohol Impairment has been observed 14 hours after alcohol ingestion (to 0.08% and 0.1% blood alcohol concentration) in simulated flight tests (71-73). There are other studies that failed to demonstrate any hangover related performance deficits (34, 50, 74).

There is conflicting evidence and opinion concerning whether or not there exists any consistent hangover related performance deficit that could adversely affect aviation safety.

CONCLUSION.

Flying is a complex task requiring continuous and coordinated sensory, cognitive, and motor functioning by the pilot. Alcohol impairs most aspects of the flying task. Some flight related skills are adversely affected by blood alcohol levels as low as 0.025% while aircraft flight and simulator flight is clearly impaired by levels of 0.04%. Higher blood alcohol levels result in correspondingly more profound impairment of flying skills and reduction in flying safety.

The opinion of this author is mirrored by a concluding statement from one of the studies previously cited - “Any concentration of ethanol in the living pilot is unacceptable and can contribute to aircraft accidents” (20).

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