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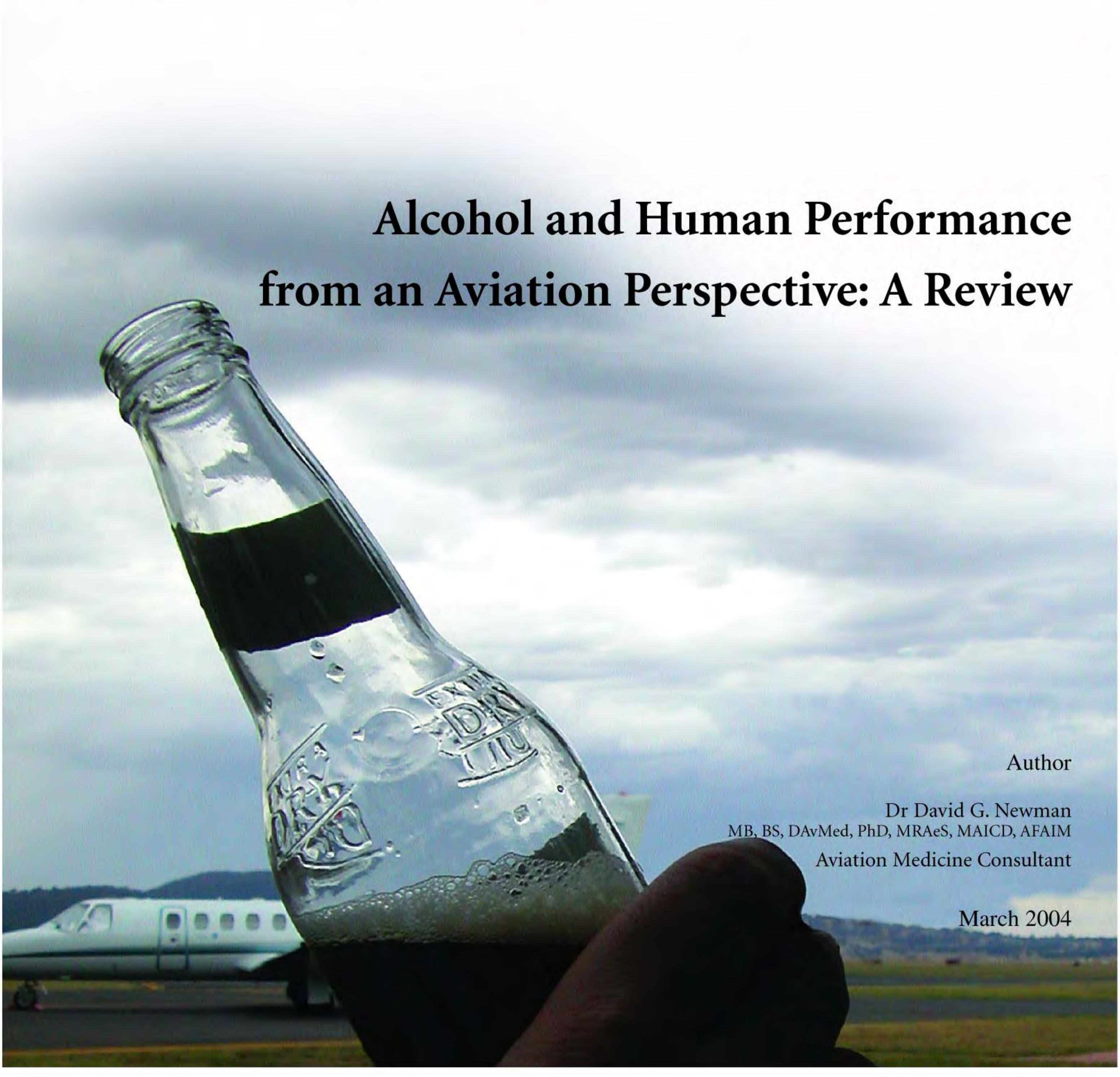
RESEARCH REPORT

Alcohol and Human Performance from an Aviation Perspective: A Review



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DISCUSSION PAPER

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CONTENTS

EXECUTIVE SUMMARY

Alcohol is a widely used drug, and its abuse is a serious public health problem. Alcohol has many widespread effects on the body, and impairs almost all forms of cognitive function, such as information processing, decision-making, attention and reasoning. Visual and vestibular functions are also adversely affected. The performance of any demanding task, such as flying an aircraft, is thus impaired by the effects of alcohol. Many studies have shown a significant proportion of aircraft accidents associated with alcohol use. Alcohol increases the risk of spatial disorientation, hypoxia and poor +Gz tolerance. Many studies have consistently shown significant detrimental effects of alcohol on pilot performance, both in the acute stages and in the post-alcohol period for up to 48 hours. Even low doses of alcohol can lead to reduced performance. While a pilot may legally fly 8 hours after drinking, the residual effects of alcohol may seriously impair their performance, especially in high workload and demanding situations. Alcohol use in pilots is therefore a major potential risk to flight safety.

INTRODUCTION

Alcohol is an intoxicating substance, and is the most widely used and misused drug in the Western world (58,68,83). The abuse of alcohol has been described as the fourth most serious public health problem after heart disease, cancer and mental illness, and is responsible for a significant proportion of hospital admissions (83).

Safe performance of the flying task requires a high level of cognitive function and psychomotor skill. Any substance that impairs these functions and skills represents a threat to flight safety. It is well known that performance of any demanding task may be impaired after alcohol (35). The use of alcohol by pilots is thus a significant flight safety hazard, and this fact is recognised by the existence of regulations governing the use of alcohol by pilots.

The purpose of this review is to examine the literature concerning the effects of alcohol on human performance from an aviation perspective. To do that, this review will first give an overview of alcohol, including its metabolism and elimination from the body. Then, the general effects of alcohol on human performance will be considered. The implications of alcohol use in the aviation environment are then examined, in terms of the prevalence of alcohol in aviation accidents and its effects on spatial disorientation and other physiological stresses of flight. Then, the literature on the acute and residual effects of alcohol on pilot performance will be discussed at length.

The ATSB seeks comment on this discussion paper which may be directed to issues of fact or interpretation. Comments may be provided by 30 April 2004 to: atsbinfo@atsb.gov.au

A brief overview of alcohol

A standard drink contains about 10 g of alcohol (68,87). In general, the more alcohol consumed the higher the blood alcohol concentration (BAC). BAC is the proportion of alcohol in grams per 100 ml of blood. The 0.05 legal driving limit equals 0.05 grams of alcohol in 100 ml of blood.

Alcoholic beverages vary in alcohol content from two to 60%. Alcohol is rapidly absorbed after ingestion. There is much variation in the time to reach peak BAC, and is anywhere from 14 to 138 minutes. A 14-fold variation in absorption times to peak BAC has been reported (34). BAC varies with several factors, such as body build and size, age, gender (females tend to be affected more than males), whether food has been taken with alcohol, and the type of drink (43,87). For these reasons, counting the number of drinks consumed is a poor estimate of the actual BAC. In fact, alcohol is still absorbed after the final drink, which means that the BAC can still rise after the last intake.

Alcohol is metabolised in the liver and eliminated from the body at the rate of about one standard drink per hour (87).

In general terms, alcohol is a central nervous system depressant (15,35,55). The effects of alcohol are dose-dependent. At a BAC of 0.025%, euphoria and some impairment of judgement are evident. At a BAC of 0.05% to 0.10%, lack of coordination and problems with gross motor control occur. A BAC in excess of 0.20% can cause stupor. If the BAC is high enough, respiratory depression and death can occur (85).

The residual effects of alcohol ingestion, known as "hangover," include headache, gastrointestinal upset and general feelings of ill-health (78,84). In addition, the alcohol hangover is characterised by decreased occupational, cognitive and visual-spatial skills performance and dexterity (106). Hangover sufferers may pose substantial risks to themselves and others, despite their BAC being zero. An individual suffering from a hangover is thus at increased risk of sustaining an injury and a performance decrement at work.

General human performance effects of alcohol

Alcohol has widespread general effects on human behaviour and performance.

In simple terms, alcohol impairs human performance (15,35,36,39,50,55,59 63,67,68,79,81,93,94,100). It has detrimental effects on cognitive functions and psychomotor abilities. Risk taking behaviour may result, and a full appreciation of the consequences of a planned action may not be possible (68). Adverse effects can also persist the day after alcohol ingestion, with reductions in alertness, concentration and vestibulo-ocular function, and increases in anxiety all being reported (63,68,94).

Almost all forms of cognitive function have been shown to be affected adversely by alcohol (36,39,50-52,55,59,72-74,79,81,100). Alcohol affects information processing, memory, verbal skills, reaction times, attention, vigilance, perception and reasoning tasks (35,50,55,63,67,72-74,79,81,100). All of these cognitive functions are required for tasks such as driving and flying.

Alcohol has a particularly serious effect on information processing and memory, particularly working or short-term memory (35,50,72-75,79,81,93). Alcohol has been shown to impair registration, recall, and organisation of information, leading to increased reaction times and/or a greater number of errors (67,79,81,100). Alcohol interferes with the integration of incoming information, and this has been suggested as the mechanism underlying alcoholic amnesia (50).

Alcohol also significantly impairs attention, especially in terms of tasks requiring sustained, selective or divided attention (35,57,63,67,72). Alcohol at a BAC of 0.015% has been shown to cause impairment of performance at tasks requiring division of attention, such as monitoring two channels of information simultaneously (72).

Psychomotor performance is also adversely affected by alcohol, in a dose-dependent way (13,35,36,39,42,43,49,55,59,62,72-75). Even low levels of alcohol have been shown to cause impaired psychomotor performance, particularly on tracking tasks (35,42,73). Skill-based psychomotor tasks such as driving are well-known to be impaired by low doses of alcohol (75).

In light of these findings, it is little surprise that alcohol has been shown to have its greatest performance-impairing effect on demanding and complex cognitive tasks (35,55,57,63,70). Furthermore, it is a consistent finding in the research literature that subjects are usually unable to accurately determine the extent of their impairment due to alcohol (36). In addition, performance has also been found to suffer most when an unexpected or unanticipated event occurs. This reflects the global cognitive impairment caused by alcohol, in that processing of new information, problem solving and abstract thought are all adversely affected (35,36,74,81).

Prevalence of alcohol in aviation accidents

Alcohol use in the general community is widespread, so it stands to reason that pilots will also use alcohol. Alcohol use and misuse has been reported in pilots in the military, commercial and general aviation environments (3,4,12-14,16-19,25,27,30,31,37,38,43,45-47,66,68,83,85,86,91,92,101,102). Alcohol and flying remains a serious and valid safety concern (31,37,45,64,68,83,93,101). Despite the existence of regulations mandating a minimum time interval between drinking and flying, some pilots believe that they are safe to fly within these times (28,89). In one study, 50% of pilots surveyed believed that they were safe to fly within 4 hours of drinking (28). Alcoholism in the ranks of professional air transport pilots remains a serious and significant issue, and many airlines run in-house rehabilitation programs for affected pilots (48,85,103).

In terms of alcohol and its association with fatal aircraft accidents, the incidence is much lower in commercial airline and military operations than in general aviation (13,31,68). However, while the rate is lower, they still occur (2,25,30,107,109). In 1977, a Japan Airlines aircraft crashed in Alaska and the pilot was subsequently found to have a BAC of 0.021% (43,107). The US and UK airline transport systems have apparently not had a fatal alcohol-associated accident since 1964 (25,31,43,68,101,107), although cases have been reported where airline pilots were found to be significantly under the influence of alcohol prior to, during or after flight (3,4,14,86). Commercial airline pilots have also been involved (as pilots) in fatal light aircraft accidents as a result of alcohol ingestion (102).

Various studies have examined the prevalence of alcohol in fatal general aviation accidents (2,12,16-18,30,31,37,38,47,60,64,91,92,101,102,109). In general terms, these studies suggest that anywhere between 10% to 30% of general aviation pilots in fatal accidents have measurable alcohol in their blood and tissue on post-mortem (13,68,84). Alcohol has also been implicated in military aircraft accidents (30,109). In one study, eight out of 102 US military toxicological analyses were positive for ingested alcohol. In two of these eight cases, ethanol was thought to be a probable cause of the accident, while in another four alcohol was thought to be at least a contributing factor to the accident (30).

The case of a fatal light aircraft accident in the UK serves as a typical example. In this accident, the aircraft crashed due to a stall at low altitude following loss of engine power. The accident investigation concluded that the pilot's ability to avoid the stall was impaired due to the effects of alcohol (102).

In the 1960s, the proportion of fatal general aviation accidents associated with alcohol was in the order of 30% to 43% (37,38,47,91). Ryan and Mohler reported that 43% of fatal accidents in 1963 were positive for alcohol (91). In a significant and often-quoted 1964 study, 35.4% of fatal general aviation accidents involving 158 pilots were associated with alcohol (47). A subsequent study in the Southwest region of the United States in 1965 found that in 30% of fatal aircraft accidents examined a BAC of over 0.015% was reported (37,38).

In 1971, the FAA introduced the 8-hour "bottle-to-throttle" rule. This led to a reduction in the alcohol-associated accident rate in US general aviation, to approximately 13% to 19% in the 1970s (60,91,92). In the UK, a study examining alcohol and general aviation accidents between 1964 and 1973 found an incidence of 11.6% of fatal light aircraft accidents in which alcohol was involved (101). In Finland, 5 pilots out of 41 involved in fatal aviation accidents between 1961 and 1970 were positive for alcohol, a rate of 12% (2). An Australian study published in 1977 found that in 9% of the fatal general aviation accidents surveyed impairment by alcohol was a probable factor (12).

Since the 1980s, a number of studies have shown that the rate of alcohol involvement in fatal general aviation accidents is approximately 7% to 10% (16-18,43,64).

A comment needs to be made at this point regarding post-mortem alcohol production. It is well established that putrefaction and microbiological fermentation after death can result in the production of alcohol, sometimes at quite high blood concentrations (2,12,25,30,31,37,68,69). Several authors have commented that early studies into the rate of alcohol involvement in fatal aviation accidents failed to adequately take into account the effect of post-mortem alcohol production (68).

As an example, Canfield et al found that in the period 1989 to 1990, 8% of post-mortem samples from fatal aviation accidents were positive for ethanol. However, subsequent analysis revealed that of these positive cases, only 28% were from alcohol ingestion, while 27% were from post-mortem alcohol production (19).

Blood samples alone do not allow a distinction to be made between alcohol ingestion and post-mortem alcohol production secondary to putrefaction. Samples from effectively sterile areas such as the vitreous humour of the eye, as well as urine, are important in determining the source of any alcohol detected (19,31). If the vitreous contains alcohol, it is generally taken to reflect alcohol ingestion, rather than putrefaction (19).

Alcohol and spatial disorientation

Spatial disorientation has been described as "a pilot's inability to correctly interpret aircraft attitude, altitude or airspeed in relation to the Earth or other points of reference" (82). If this disorientation phenomenon is not recognised immediately, it may lead to loss of control of the aircraft or controlled flight into terrain (CFIT) with disastrous consequences.

Spatial disorientation is a well-recognised cause of aviation accidents. The United States Navy has reported that during the 10-year period between 1980 and 1989, some 112 major aircraft accidents involved spatial disorientation of the crew (7). The United States Air Force for the same period reported that spatial disorientation led to 270 major aircraft mishaps (56). Between 1987 and 1995, 291 major helicopter accidents in the United States Army were attributed to spatial disorientation. These accidents accounted for the loss of 110 lives and some US$468,000,000 in materiel costs (11).

Spatial disorientation is thus a common experience for both fixed-wing and rotary-wing aircrew. Just how common an experience it can be is the finding that the career incidence of spatial disorientation in aircrew is in the range of 90 to 100% (10). In addition, flying experience has not been shown to offer any protection per se from spatial disorientation (82).

Under normal conditions, the visual system provides 80% of the sense of orientation, with the inner ear balance mechanisms (the vestibular system) and the proprioceptive or 'seat of the pants' system providing 10% each (40). Absent or inaccurate information from any or all of these systems can result in spatial disorientation.

Alcohol has been shown to have adverse effects on both the visual and vestibular systems, and as such is a contributory factor to the development of spatial disorientation in a pilot (37,40,80,94). Indeed, many spatial disorientation events and accidents may be related to vestibular malfunction secondary to alcohol (37).

Under normal conditions, the vestibular and visual systems are tightly linked. The Coriolis phenomenon (also known as cross-coupled stimulation) is a severe tumbling sensation brought on by moving the head out of the plane of rotation, simultaneously stimulating one set of semi-circular canals and deactivating another set (40,78). This disorientating phenomenon is a form of vestibular stimulation used experimentally, but also has practical implications for aviation (for example, it can be produced by a pilot in a turn looking over his shoulder or down into the cockpit).

Vestibular stimulation such as the Coriolis phenomenon generally results in visual changes, such as nystagmus. Nystagmus is the term for a series of involuntary oscillatory eye movements that are generated by stimulation of the vestibular system. The visual effects of vestibular stimulation reflect the very close connection between the two systems, which are critically important for normal orientation.

Alcohol, however, can have significant and dramatic effects on both the vestibular and visual systems. Both the Coriolis phenomenon and nystagmus have been used experimentally to reveal these adverse alcohol effects.

Impairment of vestibular function by alcohol was first reported in 1842 (80,94). Alcohol changes the specific gravity of the endolymph fluid within the vestibular system (37). This leads to it becoming more dilute, thus producing exaggerated vestibular stimulation during movement. The nystagmus that results from Coriolis stimulation can be similarly exaggerated and prolonged.

Normally, visual fixation on a target can quickly suppress the nystagmus caused by vestibular stimulation. However, alcohol has been found to significantly interfere with this ability to suppress nystagmus, especially during dynamic tracking tasks (41,42,95,96). This effect is dose-dependent, and is evident at blood alcohol concentrations of 0.03% (68). This impairment has also been found to be worse at night with reduced display illumination. The practical implications of this are clear: pilots may not be able to see their instruments properly during dynamic flight (especially at night) if they are under the influence of alcohol. This leads to blurring of vision, poor tracking performance and increased potential for spatial disorientation (41,96).

Alcohol has a number of adverse effects just on the visual system. It has been shown to reduce the speed and latency of eye movements (5,58,61). Accommodation is the term given to the eye’s ability to change the shape of its integral lens when changing from viewing a distant object to a near object (and vice versa). This phenomenon is important for accurate re-focusing. Alcohol affects this process, increasing accommodation time by up to 30%, resulting in prolonged blurred vision and difficulty with distance vision (62). Blurred vision due to eye muscle imbalance as a result of alcohol has also been reported (13). Nystagmus due directly to the effects of alcohol, in the absence of vestibular stimulation, is known as positional alcohol nystagmus (PAN). This form of nystagmus can be induced by simple head movements in the absence of a turn or other angular acceleration. The implications of this in the aviation environment can be significant.

It is not just the acute effects of alcohol that are important. The effect of alcohol on the vestibular and visual systems can persist for up to several days after blood alcohol levels have returned to zero (37,68,80,94). Nystagmus induced by Coriolis stimulation was found to be accentuated and prolonged by alcohol 11 hours after ingestion (94). Coriolis-induced nystagmus was also still evident approximately 34 hours post-ingestion, with increases in subjective tumbling also reported (94). In one study, PAN could be demonstrated with exposure to +3 Gz acceleration some 48 hours after alcohol ingestion (80).

Vestibular stimulation is extremely common during flight, since operation of the aircraft generally produces pitch, roll, yaw and accelerative forces (68). The alcohol-induced impairment of vestibular function (which may persist for many hours) can decrease perception of aircraft attitude, and impair tracking ability and visual fixation. This can lead to a reduced ability of the pilot to control the aircraft, see the instruments, maintain situational awareness and avoid collisions. There are thus potentially serious implications for a pilot of flying the morning after a night of drinking, due to residual impairment of the visual and vestibular systems that are vital for safe flight (68,78,94).

Alcohol and other physiological stresses

Alcohol has also been found to have an adverse interaction with several other physiological stresses of flight.

Altitude and hypoxia

Several studies have indicated that alcohol potentiates the effect of altitude (25,38,43,44,46,68), while other studies have failed to show such an association (20,22-24). Alcohol has been shown to reduce the oxygen saturation of haemoglobin during hypoxia (44). However, Collins et al did not demonstrate any synergistic effect of alcohol and altitude up to 12,000 ft (22). In a later study by the same researchers, alcohol was found to significantly impair performance, but there was again no additive effect of altitude (12,000 feet) with alcohol (23,24). Some researchers have suggested that the lack of an association between alcohol and hypoxia in these studies may have been due to the simplistic nature of the tasks being performed by the subjects (20).

Fatigue

Alcohol interferes with normal sleep patterns. It causes a dose-dependent reduction in proportion of rapid eye movement (REM) sleep (15,33,68,94). The change in sleep patterns or the deprivation of REM sleep causes subjective feelings of tiredness and impaired concentration the next day. Reduced alertness and concentration have been found in several studies the morning after alcohol ingestion (68,94).

Tolerance to +Gz[1] acceleration

Of importance to aerobatic pilots is the finding that alcohol reduces tolerance to +Gz acceleration (15,78). Some studies have shown that even a moderate level of alcohol will reduce a pilot's +Gz tolerance by approximately +0.5 Gz. This is due to a combination of relaxation of the muscle within veins and arteries of the lower limbs and the dehydrating effect of alcohol leading to reduced blood volume. Both of these aspects are counter-productive for the tolerance of high +Gz loads.

The acute effect of alcohol on pilot performance

Alcohol dearly has widespread effects on cognitive, psychomotor, visual and vestibular functions, which can all adversely affect the performance of a pilot during the flying task. The pilot may be impaired or even incapacitated (65). In view of this, many researchers have studied the effect of alcohol on pilot performance. The majority of these studies have used flight simulators to assess the extent and nature of any pilot performance impairment due to the ingestion of alcohol. These studies illustrate the detrimental effects of alcohol on the complex task of flying an aircraft.

In 1954, Aksnes et al found that small doses of alcohol impaired pilot performance in a Link trainer (1). A BAC of 0.05% was sufficient to significantly reduce the ability of pilots to perform a complex skill-based task. They also demonstrated impaired performance at a BAC of 0.02%.

1 +Gz is the term used to describe the resultant inertial force experienced by a pilot undergoing headwards acceleration in the vertical or long spinal axis of the body. A pilot exposed to high +Gz will feel heavier in their seat than normal.

Since then, many studies have been performed examining the effect of alcohol on pilot performance. All of these studies have shown decrements in pilot performance at various levels of blood alcohol concentration, with these decrements being for the most part dose-dependent (25,26,35,47,53,54,70,71,77,90,107,108). Blood alcohol concentrations in the range of 0.08% to 0.10% have been consistently shown to impair overall pilot performance in a simulator (1,8,29,53,54,71,98,99,104). The performance decrements observed include impaired radio communication, increased communication errors, increased procedural errors, poor cockpit monitoring and attention, failure of vigilance, poor decision-making, deterioration in basic flying skills and breakdown of instrument flying procedures.

However, even low doses of alcohol have been found to impair pilot performance. Many researchers have examined the effects of a BAC of 0.04%, since current FAA regulations require pilots in the US to have a BAC less than this value (105). What is apparent from these studies is that the effects of alcohol are dose-dependent, and the degree of pilot impairment is related to the cognitive workload of the task being performed.

Billings et al used a 727 simulator and a group of pilots exposed to four different levels of alcohol. The pilots flew 1-hour sorties as full crews on normal air carrier flight under simulated air traffic control conditions. They found linear increases in errors related to planning, performance and procedures, as well as failure of vigilance with increasing alcohol dose. Performance decrements were also observed at the lowest BAC level used, leading the authors to suggest that even low BAC levels can affect the performance of critical tasks associated with aircraft flight (8).

Smith and Harris found that low levels of alcohol (BAC less than 0.04%) significantly impaired radio communication skills of pilots. Their hypothesis was that when the limited processing capacity of the pilot is overloaded, lowest priority tasks are shed first. Navigation performance and flying skills were not significantly impaired (97).

Another study used an approach and landing sequence in a multi-engine aircraft simulator under conditions of low blood alcohol concentrations (BAC less than 0.02%). The researchers found that this low BAC caused significant impairment in pilot performance, with pilots less able to accurately fly an approach and landing. Increased deviations from both optimal glide-slope and approach speed were observed, during instrument approaches and under asymmetric flight conditions. They concluded that the increase in cognitive workload compounded the effects of alcohol, contributing to a significant overall impairment of pilot performance (29).

Similarly, Ross et al found that at BAC of 0.04% and below, alcohol impaired flight performance only under the most demanding simulation profiles where the workload was highest (90). In a later study, they reported that a pilot's ability to detect angular motion may be reduced by a BAC of 0.04% (88). They suggested that the increase in angular motion detection threshold was due to alcohol-induced changes in vestibular functioning, most probably due to the changes in specific gravity of endolymph mentioned previously (37,76,88).

While some authors have suggested that care must be taken when extrapolating from simulated to actual flight data (32), others have suggested that simulator studies might under-estimate the problems of alcohol (90). This under-estimation is attributed to the fact that simulators do not replicate all the forces involved in flight (such as acceleration) which could produce spatial disorientation (e.g., the Coriolis phenomenon). In actual flight, the probability would increase that low levels of alcohol might cause problems for accurate flight performance (90).

In the only study of its kind, Billings et al examined the effect of alcohol on pilot performance under actual flight conditions (9). Using a Cessna 172 with a safety pilot on board, subjects were required to fly a series of instrument landing system (ILS) approaches while under the influence of alcohol. Two BAC levels were used in this study – 0.04% and 0.12%. The results of the study were dramatic: at a BAC of 0.04%, twice as many procedural errors and 1 loss of aircraft control were noted. At a BAC of 0.12%, there were three times as many procedural errors and 16 incidences of loss of aircraft control.

Post-alcohol impairment and pilot performance

Post-alcohol impairment (PAI) has been defined as performance impairment after alcohol is no longer detectable (37). Put simply, it implies that performance problems may persist after the blood alcohol concentration has returned to zero.

Australian Civil Aviation Regulations require that a pilot must not fly within 8 hours of alcohol consumption or if their ability to do so is impaired by alcohol. This so-called “bottle-to-throttle” rule is designed to ensure that pilots are safe to fly their aircraft after a suitable time has elapsed since their last alcohol ingestion. However, there is a substantial body of evidence that suggests that an 8-hour time interval may not be sufficient. The extent of alcohol impairment at the 8-hour mark will depend on a multitude of factors mentioned previously, such as the amount of alcohol consumed, individual variation in the absorption, metabolism and elimination of alcohol, as well as differences in individual tolerance and body size.

Several studies have indicated that pilot performance may continue to be measurably impaired more than 8 hours after the last alcohol ingestion (6, 25,26,70,71,98,107,108). Furthermore, post-alcohol impairment may have significant effects on specific areas of human performance that are critical for the safe conduct of an aircraft operation.

Several studies have examined the residual effect on pilot performance some hours after reaching a BAC of 0.10%. In one study, pilot performance was impaired for at least 10 hours after reaching a BAC of 0.10%. The pilots in this study had particular difficulty with bank angle and rate of turn (6). Another study found that overall flight performance impairment was still present 8 hours after reaching a BAC of 0.10% (70). In this study, alcohol appeared to magnify the severity of any errors committed by the pilots. Pilots failed to fully process the radio information they were presented with, even though they appeared to give it adequate attention (70).

In a later study by the same researchers, a BAC of 0.10% resulted again in reduced overall performance in a simulator, which was still present 2 hours later. At the 8-hour mark, there was much greater variability in performance amongst the pilots, reflecting individual variation in the susceptibility to alcohol. Significantly, the pilots were all unaware of their impaired flight performance (71).

A study by Yesavage et al (107) found that 14 hours after alcohol ingestion leading to a BAC of at least 0.10%, pilots performed much worse at a flight simulator task at a time when their BAC had returned to 0. Performance was worse on almost every level measured, such as precision and accuracy. Again, pilots were not able to accurately judge their own degree of impairment. It is probable that such performance effects would still be measurable some time after 14 hours. A later study by Yesavage et al, again using a flight simulator, confirmed their earlier findings, with pilot performance of a simulated flight task still significantly impaired at the 8-hour mark post-ingestion (108). They concluded on the basis of their research that the 8-hour bottle-to-throttle rule is insufficient to ensure an adequate margin of flight safety.

Eight hours after reaching a BAC of 0.08%, Taylor et al found that while the standard of cockpit monitoring by the pilots had improved on a simulated flying task, the standard of their radio communications remained impaired. They concluded that an 8-hour waiting period was inadequate (98). A later study by the same group did not find a carry-over effect of alcohol on pilot performance in a simulator 8 hours after a BAC of 0.08% (99). However, the authors did point to methodological issues within this study that may have had an influence on this outcome.

A residual effect of low doses of alcohol has also been described. Ross et al found that a pilot's ability to detect angular motion is compromised by a low BAC of 0.04% (88). They also reported that the elevated threshold for detection of angular motion persisted in some pilots for periods of approximately 3 hours after their peak BAC was reached.

Other studies have not been able to demonstrate a significant carry-over effect of alcohol on pilot performance. Collins et al conducted a series of studies that examined the effect of alcohol on pilot performance. While their studies all showed that low BAC levels can affect pilot performance, an 8-hour effect was not observed. However, the authors pointed out that their results should be interpreted with some caution. They noted that their studies involved subjects who were all highly motivated to perform well on the simulated task, and that other factors present in actual flight conditions (such as altitude and noise) were not present in their simulator-based study (21,22).

There are significant methodological differences between all of these studies, which may account for the lack of observed PAI effects in some of them. The studies used different simulated flight profiles and tasks, with varying levels of cognitive difficulty. Some researchers have suggested that the absence of PAI effects in some studies is probably due to the tasks undertaken by the pilots not being complex enough to draw out performance decrements (73,107). Since alcohol is known to impair the speed and capacity of working memory, pilots under the influence of alcohol may experience a degree of cognitive overload when the task complexity is high. The relative complexity of the task is thus felt by many researchers to be an important factor in whether PAI effects are observed or not (25,37,73,107).

CONCLUSION

Alcohol is a widely used substance. While taken for its intoxicating properties, alcohol has well-defined adverse effects on human performance, especially in terms of cognitive function and psychomotor skill. In addition, individuals are usually unable to accurately determine the extent and degree of their own impairment due to alcohol.

Acute ingestion of alcohol is clearly incompatible with the safe conduct of flying operations, due to the impairment of cognitive function and psychomotor abilities, as well as the visual and vestibular disturbances associated with its use. These effects increase the risk of spatial disorientation occurring in pilots, which in turn increases the risk of an accident. Indeed, a significant proportion of fatal general aviation accidents are associated with alcohol use.

Post-alcohol impairment is of particular importance in aviation. While regulations require a minimum time between drinking and flying, there is considerable evidence that performance may be impaired for much longer periods. Post-alcohol impairment can increase the potential for spatial disorientation for up to 48 hours. While a pilot may be legally able to fly eight hours after drinking, the residual effects of alcohol may seriously impair their performance when they need it most. The alcohol-induced impairment of cognitive performance becomes more evident when the nature of the flying task becomes more complex and demanding, such as in an emergency situation. A pilot suffering from the effects of post-alcohol impairment may not handle such a high-workload emergency appropriately, due to reduced attention, a slower rate of information processing, increased reaction time, and poor decision-making. All of these could ultimately result in an accident.

In summary, the scientific evidence indicates that pilot performance is impaired by alcohol, both in the acute stages and in the post-alcohol period. Even relatively low doses of alcohol can lead to reduced performance. The implications of these findings from an aviation perspective are significant. Quite clearly, therefore, alcohol use in pilots is a major potential hazard to flight safety.

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