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THE EFFECTS OF TOBACCO ON AVIATION SAFETY

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16. Abstract

In 1976, the FAA was petitioned to issue regulations that would prohibit all smoking in the cockpit during commercial flight operations and prohibit preflight smoking by flight crewmembers within 8 hours before commercial flight operations.

A review of the literature was conducted to determine the effects on pilot performance of carbon monoxide (CO), nicotine, and smoking withdrawal. The literature is confusing because it frequently contains the results of studies using nonsmokers, CO only, estimated carboxyhemoglobin (COHb) levels, small and poorly ventilated chambers, and discrimination tasks where spare capacity is not a factor. Some frequently quoted results cannot be duplicated. Significant changes in psychomotor and cardiovascular performance with COHb levels $<$ 10 percent are doubtful.

The records of 2,660 fatal general aviation aircraft accidents that occurred in 1973 through 1976 have been examined. Toxicology reports are contained in 1,559 records, and 225 without fire had COHb levels $\geq$ 1 percent. Smoking was not identified as a causal factor but may have contributed to the cause of some of these accidents. However, the compound factors that were often found and the dire consequences are far less likely to occur in air commerce operations.

For some, withdrawal symptoms may occur and more than offset any benefits to aviation safety that are claimed for a ban on preflight and in-flight smoking.

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THE EFFECTS OF TOBACCO ON AVIATION SAFETY

INTRODUCTION

In 1976, the Federal Aviation Administration (FAA) was petitioned by the Airline Pilots Committee of 76, the Public Citizen's Health Research Group, and the Aviation Consumer Action Project for rulemaking to amend Part 91 of the Federal Aviation Regulations to (i) ban the smoking of any tobacco product in the flight deck area during the operation of any flight in air commerce and (ii) ban any person acting as a flight crewmember on any flight in air commerce within 8 hours of smoking any tobacco product (17).

One of the groups had reviewed the scientific literature on the effects of carbon monoxide (CO) and smoking on mental and physiological functions and submitted a report of their findings in support of the petition (18).

In FAA medical education and physiological training programs for flight instructors and other pilots, we regularly mention the possible adverse effects of CO and nicotine from smoking on altitude tolerance, vision, and performance. Yet, we have had no research or accident data to verify these concerns. However, a causal role is not likely to be ascribed if it is not looked for, considered, and understood. Margins obviously exist, pilots are usually healthy, and adaptation and compensation occur. We also recognize that smoking may provide useful sedative effects; furnish oral gratification; occupy the hands to reduce anxiety and tension; and maintain and even enhance performance, allay fatigue, and increase alertness from the stimulating effects of nicotine. Some classic texts on aviation medicine conclude that smoking in flight is not dangerous and, except for fire danger and possible distraction, is even probably beneficial (8,9).

The chronic effects of smoking on the health of smokers are not questioned by the authors. Health effects were not the primary issue for the petition and are not considered in this paper.

The acute effects of the CO in tobacco smoke on healthy, sedentary nonsmokers in a well-ventilated environment are not considered a safety hazard. Irritation, distraction, and possible allergic reactions of nonsmoking flight crewmembers are an issue that has not been studied and remains unresolved (except that it has never been cited as the contributory cause of an accident or incident to our knowledge).

In 1970 and 1971, the FAA and the U.S. Public Health Service did make environmental measurements and determined passengers' feelings about in-flight smoking on 14 domestic and 20 Military Airlift Command International flights (24). The average levels of carbon monoxide, particulates, ammonia, and ozone that were found were below the accepted safe limits and did not represent a known health hazard to nonsmoking passengers. (Humidity was also measured and was found to range from 10% to 16%.) However, because of odor and irritation to the eyes, nose, and throat, up to 73% of the nonsmoker passengers suggested corrective action. Separate areas for smokers and nonsmokers were established on air carrier aircraft in 1973.

Since the FAA had not conducted any research on the effects of smoking on pilot performance and since we knew of no aircraft accidents in which smoking or the resulting carboxyhemoglobin (COHb) levels have been found to be the cause or a contributing cause, the submitted references were reviewed and our only relevant data, the records of 2,660 fatal general aviation aircraft accidents that occurred in 1973 through 1976, were examined.

Several of the referenced studies were misleading. Only one of every eight airline pilots responded to a questionnaire and, predictably, most were nonsmokers. Some used nonsmokers as subjects. Reports sometimes failed to give blood COHb, reporting only ambient CO concentrations. Most used CO without including the effects of nicotine. Measurement techniques for CO in use before 1970 are now known to have had serious technical flaws and considerable error. Spaces were occasionally small and poorly ventilated, yet values were related to cockpits 5-10 times larger where the air is changed every 3-5 minutes. Performance tasks used frequently had a questionable relationship to pilot tasks. It was assumed that perfect visual acuity, depth perception, night vision, time and distance judgment, and visual brightness threshold were necessary for safe pilot performance. Decrements in time perception reported at 50 ppm CO in one study (6) were not corroborated by other research groups (12,14,15,16,22,23) nor by the original investigator (5). Our review of the literature found that the cardiovascular effects of 10% of COHb are insignificant in healthy humans (20), smoking has beneficial effects on the psychomotor performance of smokers (7,13), withdrawal effects are real (19), and the same investigator who is widely quoted as finding significant impairment of visual thresholds at 2% to 4% COHb (11) did not find driving performance seriously impaired at 17% COHb (10).

Our review of the petitioners' report and several references did not support a ban on smoking in our opinion, and we thus proceeded to examine our accident data.

METHOD

The FAA records of 2,660 fatal general aviation aircraft accidents that occurred in 1973-76 were examined. For 1,559 that contained toxicology reports, COHb levels were determined in 1,197; of the latter, 817 accidents without fire were separated into six categories (Table I).

For each accident, the location, date, time of day, weather, altitude, type aircraft, pilot age, pilot medical conditions, type of accident, available human factors details, autopsy and toxicology results, and performing laboratory were documented. Any FAA statement about each accident's possible cause was also documented, but the National Transportation Safety Board makes the official determination and their reports were not readily available for use.

TABLE I. EXPECTED EFFECTS AND RELATIONSHIP TO SMOKING OF VARIOUS CARBOXYHEMOGLOBIN LEVELS

COHb Level (%)	Expected Effect
<2	Normal level for nonsmokers.
2-4.9	Significant changes in mental functions have been reported but are controversial.
5-9.9	Performance effects have been reported.
<10	As reported. Unable to determine exact level.
10-20	Maximum levels found reported for smokers. Possible symptoms.
>20	Effects expected. Other sources of CO or laboratory error.

RESULTS

The COHb levels for the pilot fatalities in 817 general aviation accidents without fire are shown for each of the 4 years and for each of six ranges of values in TABLE II. None of the accidents involved carrying passengers for hire.

TABLE II. CARBOXYHEMOGLOBIN LEVELS, PILOT FATALITIES, GENERAL AVIATION ACCIDENTS WITHOUT FIRE

	COHb (%)						
Year	<2	2-4.9	5-9.9	<10	10-20	>20	Total
1973	169	17	13	3	6	2	210
1974	193	20	22	0	4	0	239
1975	131	20	28	1	3	4	187
1976	115	28	34	0	4	0	181

Accidents frequently involved multiple factors such as altitude, alcohol, advanced age, acrobatics, arteriosclerotic cardiovascular disease, other medical conditions, fatigue, drugs, poor judgment, disorientation, darkness, visual problems, weather, and stress (Table III).

TABLE III. OTHER FINDINGS IN SELECTED FATAL GENERAL AVIATION ACCIDENTS WITHOUT FIRE WHERE PILOT CARBOXYHEMOGLOBIN LEVELS WERE ELEVATED

COHb, %	Other Findings
1.7	Age 65, 8,020 ft, poor weather, hx of MI 3 yr before.
2.4	9,900 ft, snow, area obscured by clouds.
2.5	Rain, fog, 200-ft ceiling, pilot reportedly "exhausted."
3.0	Nighttime, 9,100 ft, age 55, blood alcohol (BA) level of 72 mg%, coronary artery bypass surgery, no medical certificate.
3.0	Aerobatics, age 60, diabetic, arteriosclerotic vascular disease.
3.4	Age 67, pilot incapacitation due to disturbance of cardiovascular system.
3.8	Pentobarbital.
3.9	Dusk, BA level at 88 mg%.
4.3	Age 59, "stroke prior to impact," exemption for hx of MI.
5.0	Canyon, 11,100 ft.
5.3	Weather, struck power lines, BA level of 188 mg%.
5.5	In-flight MI, age 51, while planting rice.
5.6	BA level of 151 mg%, dusk.
5.7	Midair, two "ag" aircraft seeding the same field.
5.9	Dusk, fuel exhaustion, BA level of 216 mg%.
6.1	Night, low altitude, fog, marijuana transportation.
6.1	Diabetes, hypertension, BA level of 111 mg%, age 52, 2,000 ft.
6.1	BA level of 252 mg%, unauthorized use of aircraft.
6.3	4,700 ft, low-level maneuvers to impress girl friend.
6.3	3,050 ft, flying under low ceiling, struck ground.
6.3	BA level of 100 mg%.
6.8	Age 61, coronary artery disease, suspected suicide.
7.0	Age 55, mild diabetic, possible pilot incapacitation.
7.0	7,500 ft, spin, flight instructor.
7.3	Struck cable.
7.8	Midair, age 62.
7.8	Age 67, disorientation, 10,500 ft.
8.0	Age 50, disorientation.
8.5	Age 63, stroke hx, laceration of descending aorta.
9.0	11,150 ft, 190 mg% BA level.
9.2	3,300 ft, 230 mg% BA level, phenobarbital.
9.5	Student pilot flying over swamp in bad weather became disoriented.
9.6	Disorientation.
<10	120 mg% BA level.
<10	Age 51, 6,000 ft, 1,600-ft overcast, obscured mountain peaks, reportedly exhausted, known to cruise on autopilot and nap when tired.
10.0	Plane began shedding parts before crash.
10.0	4,960 ft, student pilot carrying a passenger crashed on takeoff.
10.0	Stall-spin shortly after takeoff.
10.6	Age 23, obstructive atherosclerotic plaque of coronary artery found on autopsy.
11.2	Buzzing, night, 53 mg% BA level.
11.5	Attempted VFR flight in IFR weather despite advice not to.
12.0	Aerobatics, 6,000 ft, second pilot had 8% COHb. CO suggested as possible cause in FAA report.
14.0	Midair, no medical certificate.
14.0	Crashed after shallow descent, reduced power, wings level.
15.0	94 mg% BA level, other pilot 20% COHb, muffler had no detected leaks.
16.2	Dual, student training, practicing takeoffs and landings, student had 8.7% COHb.
21	Suspected incoordination and drowsiness due to CO causing crash while attempting a landing. Muffler was in good condition.
23	Cruising at 14,000 ft, icing, spin, age 53, Parkinson's Disease, Sinemet in aircraft. "Probably significant CO" in FAA report.
26	Pilot hx of renal calculus. Aircraft hx of induction fire, muffler inspection found no cracks or holes, "CO possibly contributory."
33	Night, 5,700 ft, other pilot had 25% COHb, no muffler leak found, "physiologically at 17,000 ft."
36	Night, 5,100 ft, passenger had 30% COHb, weather, poor judgment.

No accident with COHb levels clearly in the smoking range was ascribed to CO in the medical and other FAA reports.

Carbon monoxide was listed as a possible cause in five accidents with COHb levels of 12%, 21%, 23%, 26%, and 33%, but (i) a pathologist stated that a 10.6% COHb* was probably due to heavy smoking and was not significant in a pilot found on autopsy to have an "obstructive atherosclerotic plaque of the circumflex coronary artery of a magnitude known to be associated with sudden lethality," and (ii) the report of a nighttime accident at 5,100 feet due to poor judgment where the pilot had 36% COHb and the passenger had 30% COHb states, "Post-accident medical examinations of the pilot disclosed nothing significant with respect to causal factors of the accident." Thus, there is evidence of underconsideration.

The mufflers were examined in four accidents where (unless there were gross laboratory errors) the occupants had nonsmoking COHb levels of 15% and 20%, 21%, 26%, and 33% and 25% COHb. All four mufflers were found to be free of holes or cracks. Victims with the five highest reported COHb levels were all flying in the same make and model of aircraft--but 13- to 17-year-old models with normal mufflers--which raises questions about gaskets and seals in aircraft of that vintage and about exhaust/air-intake relationships.

DISCUSSION

Of necessity, the operations and accidents examined for this study are not those that were addressed in the petition. Compared to the general aviation pilots found involved in these accidents, pilots carrying passengers for hire would often be younger and healthier and would usually be more experienced, better trained, better equipped, free of drug and alcohol effects, not engaged in acrobatics, and backed up by one or two additional crewmembers. Their margin of safety should therefore be considerably greater than that noted in any of our cases.

Impaired vision, reduced altitude tolerance, and increased fatigue, which may have contributed to some of our accidents, have been reported for light smoking. Alcohol, altitude, and CO are generally thought to be additive in producing tissue hypoxia. Pilots are taught that impaired performance and errors in judgment may occur after 10-15 minutes at 12,000-15,000 feet. Skill and judgment errors were seen at all COHb levels in the accidents reported here; no dose-response relationship was observed.

Of considerable interest are accidents where the pilots had rather low COHb levels but were thought to have had a "disturbance of the cardiovascular system" at 3.4% COHb, a "stroke prior to impact" at 4.3% COHb, an in-flight myocardial infarction at 5.5% COHb, "probably pilot incapacitation" at 8.5% COHb, and "obstructive atherosclerotic plaque of the circumflex coronary artery of a magnitude known to be associated with sudden lethality" at 3.0% COHb.

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*An error was later found in the pathologist's summary. The true level for the pilot was 3.0% COHb; a passenger had the 10.6% COHb level.

Patients with coronary artery disease have been found not to have a normal increase in coronary blood flow when they were exposed to low concentrations of carbon monoxide sufficient to increase their COHb levels to 5%-9% (1,2,3,4). The oxygen extraction ratio by the myocardium was increased, the coronary sinus tension was decreased significantly, the lactate and pyruvate extraction ratios were decreased, and exercise tolerance was reduced. At least one author concludes that there may be no concentration of CO that does not exert a significant stress on those patients with advanced cardiovascular disease (21).

SUMMARY AND CONCLUSIONS

Although subject to considerable debate, it is possible that smoking has been a contributing cause to some general aviation fatal accidents in the United States during 1973-76. However, the compound factors that were often found and the dire consequences are far less likely in air commerce situations.

Carboxyhemoglobin may have been elevated in many of the 1,101 accidents for which toxicologic examinations were not performed. Increased COHb levels due entirely or in part to smoking are also possible in 380 accidents with fire, but these reports were not examined because of anticipated difficulties in determining the sources of the CO.

Despite the abundance of research on the effects of smoking, the authors feel that additional studies of (i) smokers' performance of realistic tasks in an accurate environment, (ii) the effects of withdrawal, and (iii) aircraft accidents and incidents are indicated before conclusions can be reached.

For some, withdrawal symptoms including tension, depression, irritability, difficulty in concentration, decreased heart rate, a fall in blood pressure, electroencephalographic changes, and impaired performance may occur and may more than offset any benefits to aviation safety that are expected from a ban on preflight and in-flight smoking.

Smoking cessation programs and pharmacologic approaches to nicotine replacement or substitution are endorsed for improved health, maintained levels of performance, and safety.

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