

The Annual Incapacitation Rate of Commercial Pilots

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Introduction: Scant data are available on the annual incapacitation rate of aircrew. This study analyzes all incapacitations occurring among UK commercial pilots, in flight and off duty, in 2004 to derive a baseline minimum annual incapacitation rate for the UK commercial pilot population. **Method:** The study cohort was all professional pilots holding a valid UK/JAR (Joint Aviation Requirements) Class 1 medical certificate and license in 2004. Three data sources were used to identify episodes of incapacitation: the statutory notification of prolonged illness, personal injury, or pregnancy to the UK Civil Aviation Authority; Mandatory Occurrence Reports (MORs) for in-flight medical incidents; and death certificates. The total number of incapacitations was expressed as a proportion of the number of professional pilots to give an incapacitation rate. **Results:** In 2004 there were 16,145 UK/JAR professional pilot license holders. Of the notified medical events, 36 presented as incapacitations; half were cardiac or cerebrovascular. In-flight incapacitations were predominantly of psychiatric cause. There were four sudden deaths. The type of incapacitation varied with age. A male pilot in his 60s had 5 times the risk of incapacitation of a male pilot in his 40s. The annual incapacitation rate was $40/16,145 = 0.25\%$. **Discussion:** Aeromedical emphasis on minimizing cardiovascular risk and monitoring the mental health of pilots remains appropriate. Age should influence the content and periodicity of regulatory aeromedical assessments. The demonstrated annual incapacitation rate of 0.25% may provide a basis for quantifying the acceptable risk for a pilot undertaking single pilot commercial air transport operations.

Keywords: aircrew, impairment, medical, incidents, occurrence, reports, unfit, age.

THE PERIODIC MEDICAL assessment of a commercial pilot has two main purposes. The first is to assess the functional ability of the pilot and to ascertain whether he is physically able to exercise safely the privileges of his license in all routine and emergency situations. The second is to assess his risk of incapacitation during the period of validity of the medical certificate for which he has applied.

The medical assessment consists of the evaluation of information submitted to the physician by the applicant about past medical history, inquiry about any current symptoms or medication taken, either currently or in the past, and an examination to elicit physical signs that may indicate a medical condition, physical, mental or psychological, which would otherwise be undetected. Further investigations may also be requested. This information is then used to evaluate an individual's fitness to fly within the acceptable parameters of incapacitation risk permitted by the regulatory authority.

The assessment of incapacitation risk during a finite time period is fundamental to the determination of an individual's fitness to fly. The acceptable level of incapacitation risk varies according to the type of operation and the presence of mitigating factors. The level of ac-

ceptable risk is set by the aviation safety regulator and is often quantified. A maximum incapacitation risk level of 1% per annum is used by the United Kingdom (UK) Civil Aviation Authority (CAA) as the basis for the assessment of a commercial pilot undertaking a multi-pilot operation. This risk level was derived from the anticipated contribution of medical events in pilots to the overall rate of commercial air transport fatal accidents (2,4,15). Simulator studies have demonstrated the substantial risk mitigation of having more than one qualified pilot on the flight deck (5).

The UK has had a Mandatory Occurrence Reporting System (MORS) since 1976, under which any incident that endangers or could endanger an aircraft has to be reported to the CAA and this includes in-flight pilot incapacitations. Under the UK Air Navigation Order (1) there is a statutory responsibility on a pilot not to fly if he suspects he is unfit and to notify the UK CAA of illness lasting 21 d or more or injury. The point of notification provides an opportunity to determine the method of presentation of unfitness.

The most finite form of incapacitation is sudden death. Although there is no legal requirement for the CAA to be informed of the death of a commercial pilot, a recent mortality study has confirmed that it is rare for the CAA to be unaware of the death of a pilot holding a valid Commercial License (8).

In this paper, we seek to determine the annual incapacitation rate of the UK commercial pilot population, taking into account events that occur off duty as well as during flight duty periods. Although acceptable risk levels may be cited, the actual rates of incapacitation of commercial pilots are difficult to determine. The main difficulty is in obtaining data for incapacitations that occur outside the working environment.

This study captures information about all incapacitations occurring during a defined period, irrespective of whether or not they were associated with flying. Thus a

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baseline minimum annual incapacitation rate is derived for the UK commercial pilot population.

In-flight medical incapacitation and impairment of airline pilots has been the subject of several studies. DeJohn et al. reviewed events among U.S. airline pilots from 1993 to 1998 (7). Medical causes of incapacitation included loss of consciousness, gastrointestinal (cholelithiasis, gas expansion with altitude and gastroenteritis), neurologic, cardiovascular, and renal calculi. Of 50 in-flight events identified, the 2 that led to nonfatal aircraft accidents were not from strictly medical causes: the use of a monofocal contact lens and fatigue. DeJohn described an airline pilot incapacitation rate of 0.045 and impairment rate of 0.013 per 100,000 flying hours. An increase in pilot incapacitation with age was reported and the importance of the recognition of subtle impairment of a pilot was emphasized.

Gastroenteritis was further highlighted in a review of in-flight incapacitation in UK public transport operations from 1990-1999 (9). A summary of studies of in-flight medical events concluded that the most common causes of such events were cardiovascular (myocardial infarctions and cardiac arrhythmias) and neurologic (epileptic seizures) (6). A review of the Australian Transport Safety Bureau's database of medical conditions affecting pilots in flight similarly demonstrated the flight safety risks of cardiovascular events (13). None of the papers reviewed included in-flight incapacitation rates. No more recent studies of incapacitation in aircrew have been identified from PubMed, the Aerospace Medical Association database, or Google Scholar.

Surveys of in-flight incapacitations, though limited by reliance on questionnaire responses, have provided useful qualitative data on the types of medical events experienced by pilots while on duty. Only international, collaborative surveys such as that undertaken by Buley of the International Civil Aviation Organization (ICAO) in conjunction with the International Air Transport Association and the International Federation of Airline Pilots' Associations in the 1960s and replicated by James and Green in 1991 have been of a sufficiently large scale to capture a significant number of in-flight incapacitations and deaths (3,10). Epidemiological studies of in-flight incapacitations from airline, regulatory, and loss of license insurance records have contributed information about medical causes and have repeatedly demonstrated the dominance of cardiovascular disorders (11,12,14).

Annual incapacitation rates for the general population or workers employed in safety-critical industries have not been well defined and no relevant studies were identified. As commercial pilots are a highly selected group and demonstrate a large healthy worker effect, it is unlikely that the results of such studies could reliably be extrapolated to the pilot population.

METHODS

The study cohort was all UK/JAR (Joint Aviation Requirements) Class 1 medical certificate holders with a

valid UK/JAR professional pilot's license in 2004. The total number of Class 1 periodic medical examinations undertaken during a 1-yr period from 1 January 2004 to 31 December 2004 was identified from the Medical Records database and any duplicated reference numbers (representing pilots who had undergone two examinations during 2004) were removed to determine the total number of Class 1 medical certificate holders. Non UK/JAR Professional Pilot's License holders were excluded.

The number of professional pilot license holders was obtained by averaging the number recorded in the database on 1 January, 1 July, and 31 December 2004. Although the population is dynamic the overall number remains relatively constant as new entrants and retirements balance one another out. It was also assumed that the number of pilots being assessed as temporarily unfit or fit at any fixed point in time was similar and that this would have minimal impact on the total population number to be used as the denominator for the incapacitation rate.

Three sources of data that could be used to study episodes of incapacitation of commercial pilots were identified:

- 1) Statutory notifications of prolonged illness or personal injury to the Authority—this was a source of information for incapacitations occurring both during flight and outside the flight environment;
- 2) Reports submitted through MORS on in-flight medical incidents; and
- 3) Death certificates to ascertain any sudden deaths.

All notifications of illness, injury, or pregnancy of UK/JAR Class 1 medical certificate holders received by the UK CAA during the period 1 January 2004 to 31 December 2004 were logged and analyzed. Inquiry was made about the presenting symptom either by questioning the notifier directly or by reviewing submitted medical reports to determine whether it was sudden and whether the onset had been sufficiently rapid and debilitating to have presented a threat to flight safety. If an incomplete or provisional diagnosis was given at the time of notification, or there was any uncertainty, the Medical Record was checked a minimum of 6 mo later. Once the diagnosis was confirmed the medical condition was categorized by system. If no diagnostic information was available due to persistent failure to provide reports the categorization was kept within "medical conditions," as long-term unfitness was assumed to be the most likely reason for this.

For the purpose of this study the following definitions were used appertaining to flight crew: *incapacitation*—a medical event that resulted, or would have had the propensity to result, in an inability to act as flight crew for at least 10 min; *impairment*—a partial incapacitation associated with symptoms that resulted, or would have had the propensity to result, in a reduction of function or distraction from the flight crew task, but would be unlikely to have caused loss of control of an aircraft.

The classification of episodes of incapacitation and impairment was undertaken according to the suddenness

of onset and severity of the presenting symptom rather than the diagnosis. The intention was to reflect accurately the likely effect on flight safety. In using the presenting symptom for classification the same diagnosis was sometimes classified differently. For example, chest pain due to a myocardial infarction or severe enough to warrant immediate hospital admission was classified as an incapacitation, whereas chest pain that was caused by angina but relieved by glyceryl trinitrate was classified as an impairment.

In-flight medical events were captured by inquiring at the time of notification as to whether the event had occurred while flying and by reviewing medical reports. Events that had first presented in the simulator, while flying as a passenger, or while acting as heavy crew were also noted.

MORS data were interrogated to determine the number and cause of flight crew in-flight medical events reported under the scheme. These events were compared with data obtained from notifications about in-flight presentation of medical conditions. MORS reported incidents that were clearly identified as having been also ascertained from an unfit notification were excluded to leave 'MORS only' incidents.

The CAA records information about deceased pilots when a notification of death is received. However, it is not mandatory to report the death of a commercial pilot to the CAA and some deaths may not have been reported. A parallel mortality study, being undertaken in conjunction with the London School of Hygiene and Tropical Medicine (LSHTM) at the same time as this study, was used to confirm whether any deaths had occurred to members of the cohort that had not been reported to the CAA (8). Where possible, death certificates were obtained and used to determine cause of death. Some information on cause of death of pilots not resident in the UK was obtained from AMEs. The cause of death was used to determine whether the deaths were likely to have been sudden. Aircraft Accident Investigation Branch reports were obtained where applicable.

The number of incapacitations known to have occurred in 2004 was calculated by summing the total number of incapacitations reported by way of notification, the MORS, and sudden deaths. This number was expressed as a proportion of the total number of commercial pilots who held a valid medical certificate in 2004 to give an incapacitation rate in that 1-yr period.

Similarly the number of medical events known to have occurred in 2004 was calculated by summing the number of impairments and incapacitations reported by way of notification, the MORS, and sudden deaths. Sudden deaths were included to give the overall risk of a medical event in a 1-yr period that had the potential to affect flight safety.

The cohort was divided into 10-yr age groups and the number of incapacitations, including sudden deaths, in each group was determined. Females were excluded from subsequent analysis because of the low numbers. The proportion of male pilots in each age group was compared with the proportion of male incapacitations within

that group. Pilots between 50 and 69 yr of age were further divided into 5-yr age groups and similar comparisons were made. The incapacitation rates of different age groups were compared and the age trend reviewed. A one-way analysis of variance (ANOVA) test was applied to age groups over 19 and less than 70 yr. The youngest and oldest pilots were excluded due to small numbers.

RESULTS

The following statistics were gathered during the study and form the overall numeric basis for the results:

- The total number of UK/JAR Class 1 periodic medical examinations undertaken in 2004 was 28,326. The total number of UK/JAR Class 1 medical certificate holders in 2004 was 19,934 (19,138 male, 796 female).
- The total number of UK/JAR Class 1 medical certificate holders with a valid UK/JAR professional pilot's license in 2004 was 16,145 (15,528 male, 617 female); this group formed the study cohort.
- The total number of Class 1 medical certificate holder unfit notifications in 2004 was 763, of which 43 Class 1 medical certificate holders were excluded as they did not hold a UK/JAR professional pilot's license.
- Of the 720 pilot episodes of temporary unfitness, 670 were male and 50 female (658 ATPL, 56 CPL, 6 BCPL). A total of 700 professional pilots were affected, as 20 of them had 2 episodes of unfitness.
- The proportion of UK commercial pilots who were assessed as temporarily unfit to exercise the privileges of their license at some stage during 2004 was 4.3% (700/16,145).

Episodes of unfitness were classified as being due to accidental injury, pregnancy, or a medical condition. Accidents were reported by 131 pilots (124 male, 7 female) and accounted for 18% of the unfit episodes. There were 24 pregnancy and IVF-related episodes of unfitness including a spontaneous abortion at 22 wk which was classified as an incapacitation.

The medical causes were categorized according to the affected system (Table I). Musculoskeletal disorders

TABLE I. CAUSES OF EPISODES OF TEMPORARY UNFITNESS.

System Category	Number	Percentage
Accidents	131	18
Pregnancy related	24	3
Cardiovascular	103	14
Cerebrovascular	8	1
Dermatologic	3	<1
Diabetes	8	1
Ear, Nose, and Throat	46	6
Endocrine	5	<1
Gastrointestinal	59	8
Genitourinary	30	4
Hematologic	2	<1
Infectious disease	9	1
Information not received	5	<1
Miscellaneous	12	2
Musculoskeletal	126	18
Neurologic	21	3
Neoplasms	25	3
Ophthalmologic	17	2
Psychiatric	71	10
Respiratory	15	2
Total	720	100

were the most common (18%). Of the remaining medical disorders cardiovascular illness predominated (14%), with psychiatric disorders the next most common (10%). Medical conditions (male and female) accounted for 565 [720-(131+24)] of the unfit notifications. Only 26 medical episodes of unfitness were recorded in female pilots. As the number of female pilots and episodes of female pilot unfitness were small, with almost half being related to pregnancy, further analysis of medical conditions was restricted to male pilots.

Comparing the 539 (565-26) male pilots who experienced an episode of unfitness of medical cause with the total male professional pilot population, there was a definite skew toward the older age groups (Fig. 1). The number of episodes demonstrated a plateau between the late thirties and late fifties with a marked drop after age 59 reflecting the usual retirement age of 60 for commercial pilots. The increased risk of experiencing an episode of unfitness with increasing age is clearly demonstrated.

The 36 events that presented as incapacitations of professional pilots in 2004 are summarized in Table II. Incapacitations (excluding sudden death) of all pilots by age are demonstrated in Fig. 2.

There were 13 incapacitations as a consequence of a cardiovascular event, 4 due to stroke and 1 from a subarachnoid hemorrhage. Chest pain of uncertain cause was included if it had necessitated immediate hospital admission. The three incapacitations from "arrhythmia" were due to paroxysmal ventricular tachycardia with syncope, sinoatrial node disease with syncope, and a syncopal episode that was presumed to be of cardiac origin in a pilot who went on to have an angioplasty. The pilot with sinoatrial node disease also had a coexisting cerebrovascular abnormality.

Concerning the "other" causes of incapacitation, the gastric ulcer presented with hematemesis, the syncope was from hypovolemia secondary to gastroenteritis, and the bowel obstruction was caused by a Meckel's diverticulum that had to be treated by emergency small bowel resection. The one biliary colic that was classified as an incapacitation was severe enough for the pilot to be taken to an accident and emergency department; the cause was gallstones secondary to hypothyroidism. The

one migraine classified as an incapacitation rather than an impairment was associated with motor, sensory, and visual disturbance. The prolapsed disc was cervical. The vestibular disturbance led to incapacitation in-flight. The two panic attacks also occurred in-flight and affected the same pilot, separated by a 6-mo time period. The spontaneous abortion was the only incapacitating event that affected a female pilot and was classified as an incapacitation as it occurred at 22 wk of pregnancy.

There were 76 events recorded that were considered to have caused impairment. The 20 cardiovascular events included 6 angina attacks, 4 episodes of severe chest pain of uncertain cause, 6 cases of palpitations, 1 presyncopal episode, 1 bradycardia, and 2 transient ischemic attacks. Three episodes were attributed to panic disorder/anxiety attack, all presenting in flight-associated situations—one while flying and two in the simulator.

Medical events that had presented in-flight while operating as crew or as a passenger or in the simulator are summarized in Table III. It is noteworthy that 6 out of 16 episodes were attributed to psychiatric causes and another 5 were the result of nonspecific symptoms that may have had psychiatric contributing factors. Importantly, these events were all sufficiently serious to warrant a subsequent period of suspension of license privileges.

There were 25 flight crew in-flight medical events reported via the MORS. Two warranted a PAN call to be made, one for a B-747 when the pilot developed acute vestibular neuritis and the other for a B-777 when the P2 became nauseated with a gastrointestinal complaint. The only medical event categorized as sudden and overt occurred to the single pilot of a BN2 Islander who developed acute vertigo shortly after takeoff, but he managed to

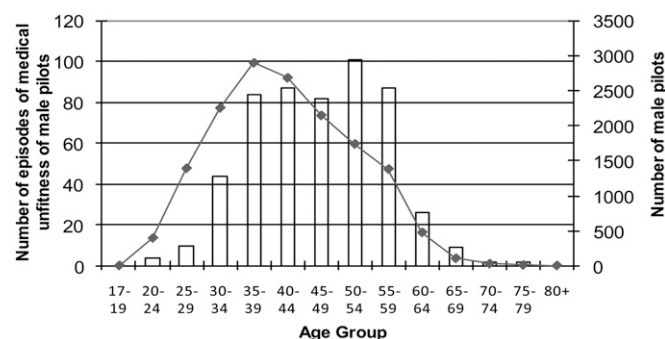


Fig. 1. Comparison of medical causes of unfitness of male pilots by age with the male pilot age distribution. Bars show number of unfit episodes; black diamonds show number of male pilots.

TABLE II. PROFESSIONAL PILOT INCAPACITATIONS IN 2004.

Cause of Incapacitation	Number of events	Ages of pilots
Cardiovascular		
Acute myocardial infarction	6	39, 52, 54, 58, 59, 64
Chest pain	2	48, 60
Arrhythmia	3	42, 50, 66
Pulmonary embolus	2	45*, 49
Cerebrovascular		
Stroke	4	33, 42, 50, 59
Subarachnoid hemorrhage	1	48
Other		
Panic attack	3	34*, 35*, 64*
Spontaneous pneumothorax	4	30, 40, 44, 62
Gastric ulcer	1	47
Perforated appendix	1	24
Syncope	1	54
Bowel obstruction	1	48
Biliary colic	1	51*
Migraine	1	47
Prolapsed intervertebral disc	1	52
Epilepsy	2	24, 55
Vestibular disturbance	1	39*
Spontaneous abortion	1	40
Total	36	

* Occurred in flight or in the simulator.

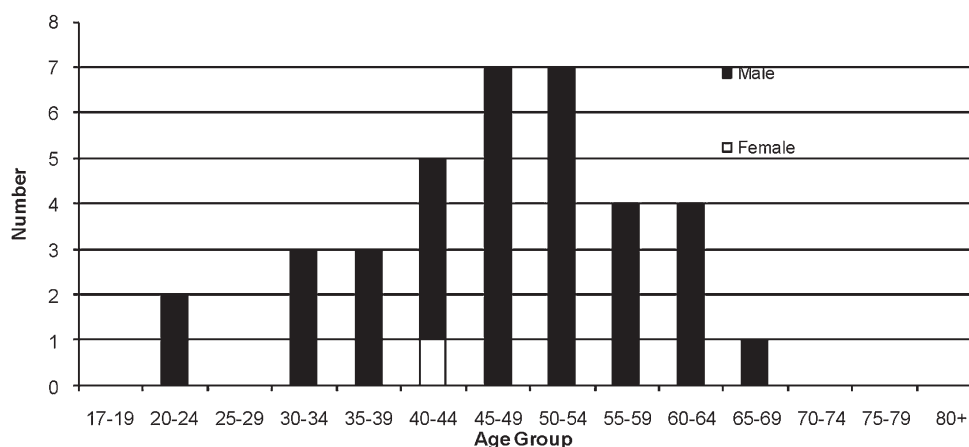


Fig. 2. Age distribution of professional pilot incapacitations in 2004. Black bars indicate males; white bar indicates females.

join the circuit and landed successfully. This was therefore classified as an impairment.

The 25 MORS reports were compared with the data obtained from unfit notifications where there had been an in-flight presentation of a medical condition. There were four fume reports (two were reports of oil smells, one was nonspecific, and one was related to perfume from a freight load) and three reports related to environmental factors. These seven reports were excluded as the precipitant of these 'medical' events was an external physical factor. Of the remaining 18 reports, 10 were related to gastrointestinal upset, 9 of which were assumed to have been of short duration and would have been unlikely to have featured in the unfit notification data though they probably led to varying degrees of impairment. The tenth led to the incapacitation of the pilot immediately postflight when he experienced 2 episodes of vaso-vagal syncope and this led to him notifying the CAA that he was temporarily unfit.

Only two other incapacitations and one impairment were positively identified as being reported through both an unfit notification and MORS report. It is likely that 14 episodes of impairment (9 gastrointestinal, 2 vertiginous/vestibular, and 3 "unwell/nonspecific/viral") were captured only through the MORS route. Because of the confidential nature of the MORS the pilots who were the subject of a MORS report could not be cross-checked against the main study data. However, the temporary nature of the symptoms described in the reports makes it unlikely that they were attributable to long-term illness and so were unlikely to have resulted in a temporary unfit notification.

Of the 14 deaths of commercial pilots with valid Class 1 medical certificates that were confirmed to have occurred in 2004, none were female. The four deaths likely to have been sudden were two myocardial infarctions, a subarachnoid hemorrhage, and a gastro-intestinal hemorrhage. One cause of death could not be determined and it is possible that one pilot may have had an arrhythmia prior to drowning but neither of these could be included as sudden deaths.

Adding the data obtained from all sources—36 unfit notifications, 0 MORS (as all were captured through unfit notifications), and 4 notifications of sudden death—the number of incapacitations known to have occurred in 2004 was 40. The annual incapacitation rate was therefore $40/16,145 = 0.25\%$.

The number of impairments known to have occurred in 2004, calculated by summing the number of conditions presenting as impairments reported by way of 76 unfit notifications and 14 not reported by routes other than the MORS, was 90. The 36 conditions presenting as incapacitations plus the 4 sudden deaths were added to give a total of 130 as the overall number of medical events that had the potential to affect flight safety in a 1-yr period. The annual rate of a medical event with the potential to affect flight safety was $130/16,145 = 0.8\%$.

The annual incapacitation rates (including sudden deaths) for male pilots by age group are shown in Table IV. Since females represented only 4% (617/16,145) of all pilots and experienced only one pregnancy-related incapacitation, the age relationship of female incapacitations was not explored further.

TABLE III. IN-FLIGHT MEDICAL EVENTS RESULTING IN NOTIFICATION OF UNFITNESS.

Cause of Unfit Episode (N = 16)	Age of Pilot (yr)	Situation
Panic attacks (same pilot) (N = 2)	34/35	In flight
Anxiety attack (N = 1)	50	Simulator
Panic attack (N = 1)	64	Passenger
Panic disorder (N = 1)	36	In flight
Stress (N = 1)	44	Simulator
Lightheaded/visual disturbance (N = 1)	54	In flight
Paresthesia in arm (N = 1)	42	In flight
Vestibular disturbance (N = 1)	39	In flight
'Unwell'/visual symptoms (N = 1)	43	In flight
Dizziness/blurred vision (N = 1)	35	In flight
Acute sinusitis/vertigo (N = 1)	47	In flight
Perforated tympanic membrane (N = 1)	48	In flight
Transient ischemic attack (N = 1)	50	In flight
Pulmonary embolus (N = 1)	45	Heavy crew
Biliary colic (N = 1)	51	Simulator

TABLE IV. ANNUAL MALE INCAPACITATION RATES BY AGE GROUP.

Age group	17-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
Male incapacitations (%)	0 (0%)	2 (5%)	6 (15%)	11 (28%)	13 (33%)	7 (18%)	0 (0%)	0 (0%)
Male pilots (%)	3 (0.02%)	1788 (11.50%)	5158 (33.20%)	4835 (31.1%)	3123 (20.10%)	581 (3.70%)	38 (0.24%)	2 (0.01%)
Percent Incapacitation rate per annum	0.00%	0.11%	0.12%	0.23%	0.42%	1.20%	0.00%	0.00%

Of the incapacitations, 15% were experienced by the 33% of male pilots who were in their 30s; 28% of incapacitations were experienced by the 31% of male pilots who were in their 40s; and 33% by the 20% of pilots in their 50s. Of all incapacitations, 18% affected the 4% of pilots in their 60s. The number of pilots over the age of 70 was too small for meaningful analysis.

Male pilots in their 20s and 30s have fewer incapacitations than would be expected if the episodes were distributed evenly through all age groups. It is evident that pilots in their 40s have approximately the same number of incapacitations that would be expected with an even distribution of age. Pilots in their 50s have a 1.5–2.0 fold increase compared with the number of expected incapacitations. Pilots in their 60s account for 15% of all incapacitations but only 3% of all male pilots. A pilot in his 60s has 5 times the risk of incapacitation of a pilot in his 40s. A linear trend in incapacitation rates between the five decade age groups between pilots in their 20s and 60s was suggested by a *P*-value of 0.06 on an analysis of variance.

DISCUSSION

The most certain hard data end point for the analysis of failure of aeromedical regulation is medical-cause accidents, but thankfully these are rare. In his 2004 study of incapacitating events affecting flight crew, DeJohn demonstrated that only two led to accidents, both non-fatal, and neither was due to a medical event (7). In-flight medical incapacitation of a pilot is substantially mitigated by the presence of another pilot on the flight deck who can take over control in the event of a medical emergency. This mitigation does not exist in single pilot operations where the incapacitation of the pilot is likely to result in a fatal accident. Even in multi-pilot operations, the incapacitation of an operating pilot poses an increased risk to the flight because of the increased workload, distraction, and stress for the pilot who has to assume control of the aircraft.

As the number of medical-cause accidents is so low, it is the ascertainment of the number of medical-cause incidents affecting flight crew that becomes important. This type of precursor measure is commonly analyzed in other areas of aviation accident and incident review. It is important to consider all medical events that affect flight crew, whether they occur in flight or when off duty. Incapacitations and impairments of flight crew are the relevant risk indicators for aviation medicine specialists.

This study emphasizes the relevance of determining the medical events that affect flight crew and which oc-

cur despite a periodic surveillance regime of regulatory assessments. It highlights the medical risks that require most attention and will inform future changes to medical requirements. It also confirms that the risk of a medical event varies with age.

This study revealed that 4.3% of the UK commercial pilot population had at least one episode of unfitness severe enough to warrant notification to the Authority during the 1-yr period of the study. This figure emphasizes the impact of pilot unfitness for the civil aviation industry and the socio-economic cost to both industry and individual pilots.

There is no single aeromedical definition of incapacitation or impairment accepted worldwide. The definitions used in this study attempt to differentiate between events that would lead to loss of control of an aircraft in a single pilot operation and ones where this would not be the outcome. The classification of a medical event as an incapacitation or impairment was subjective and based on the clinical medical experience of one of the authors. The risk determining factors of an incapacitation or impairment are the rate of onset and severity of the presenting symptoms. As these vary for almost all medical diagnoses, some degree of judgment had to be exercised based on the clinical history available.

The aim of the study was to determine an annual incapacitation rate, and therefore an event was only classified as an incapacitation if there was little doubt as to the clinical presentation. In this regard the true number of incapacitations may have been under reported. For example all episodes of renal colic were classified as impairments for consistency although some episodes of pain may have been totally incapacitating. Some diagnoses that may have presented as an incapacitation or impairment were excluded if the presenting symptom was unknown.

The high proportion of in-flight events attributed to panic disorder deserves comment and serves to emphasize the truly incapacitating nature and threat to flight safety presented by this condition. Noteworthy is the fact that two of the episodes occurred to the same pilot indicating the need for careful assessment and monitoring of individuals with a history of this condition.

The quality of the MORS reports is dependent on the reporter. As the individual submitting the report is usually a pilot who is not medically trained, there is often very little detailed medical information that can be gleaned from these reports. These data, while often useful in highlighting a medical contribution toward an occurrence, tend to be incomplete. Reasons for this include the delay in submitting the report and the fact that the

medical diagnosis will often not be determined by the time of submission. Medical comments can rarely be substantiated as the reporter's identity is protected and information on individuals cannot be linked to the medical data held by the Medical Department.

As it is not mandatory to report the death of a commercial pilot to the Authority, the true number of deaths during 2004 may have been under represented. However, the cross check with a mortality study that was being undertaken at the same time did not reveal any deaths that were not already known. It is reasonable to assume that the majority were captured. In any case the deaths provided additional information about potential incapacitations and further information would have increased rather than reduced the incapacitation rate derived.

The incapacitation rate determined by this study is based on known sudden incapacitating medical events, occurring both in-flight and outside flight duty time. The study will not have captured all sudden incapacitations outside the flight environment that were short-lived, nor all episodes that were related to a serious underlying medical disorder that resulted in a failure to revalidate a medical certificate. Although UK commercial pilots are informed that they should seek medical advice for any decrease in medical fitness, some serious conditions could be diagnosed and treated rapidly, permitting a return to flying within the 20 d statutory notification period.

Some in-flight events may not have been reported through the MORS, though this scheme is widely used in the UK and it is likely that the medical incapacitation of a pilot would be a high priority for the submission of a report. It is possible that not all deaths were known about. However, all these points relate to lack of information and any additional data would only serve to increase the incapacitation rate. It is reasonable to conclude that the incapacitation rate derived in this study is the **minimum** annual incapacitation rate for UK commercial pilots. This can be described as the 'background' risk for incapacitating events. Any risk consequent to a newly diagnosed medical condition has to be considered against this background risk.

In seeking to ascertain a minimum incapacitation rate, only definite incapacitations were included. The classification of incapacitations and impairments was deliberately strict to ensure that the medical event rates derived were 'minimum' ones and did not overlay the incidence of events.

The reliance on the self-declaration of illness, injury, and pregnancy system gives a potential bias to under ascertainment as inevitably some events will have been missed. The type of incapacitating events potentially missed by the study includes any self-limiting episode that did not occur in flight and was of a duration too short to require statutory notification to the CAA. Some incapacitations may have been the presenting symptom of a serious illness which was not reported as the pilot's medical certificate expired before the statutory notification period elapsed. The pilot could have subsequently

retired and the episode would not have been reported. However, these potential reasons for under reporting would not have undermined the 'minimum' incapacitation rate derived. The true incapacitation rate is likely to be higher than recorded by this study.

The UK uses the "1% rule" to assess the fitness of a commercial pilot undertaking multi-pilot operations. The minimum annual incapacitation risk determined by this study may be helpful in determining a quantified acceptable level of incapacitation risk for a pilot undertaking single pilot commercial air transport operations. Although it is often stated that the target incapacitation rate for single pilot operations should be of the order of 10 times less than for multi-pilot operations, i.e., 0.1%, this study demonstrates that the actual incapacitation rate is closer to 0.25% and this is associated with an acceptable commercial flight safety record. It has long been held that a rate of 0.1% is unachievable in all but the youngest subset of pilots. Although older pilots have a higher incapacitation rate, this has to be offset against their increased experience and it may be reasonable to set an upper limit of 0.5%, which is the expected incapacitation rate of a pilot under the age of 60.

This study demonstrates an increased risk of pilot incapacitation with age. The risk is small under the age of 40, increases over the age of 50, and rises steeply over the age of 60. This age trend is consistent with the view that the greatest risk factor for incapacitation is age.

Cardiovascular and cerebrovascular conditions led to 18 of the 36 incapacitations and 2 of the 4 sudden deaths. The emphasis placed on the prediction of sudden cardiac and vascular events by aviation regulators by screening for underlying coronary artery disease and predisposing factors for stroke appears to be well founded. The increased risk of incapacitation from these disorders with age is clearly demonstrated, although it is noteworthy that the youngest pilot to have a stroke was only 33. Cardiovascular and cerebrovascular conditions accounted for 20% (103+8/565) of the unfit notifications, but 50% of the incapacitations (18/36). The propensity of these conditions to adversely affect flight safety highlights their importance for clinical aviation medicine practice.

The power of this study is small but will be increased by continuing to gather data for the UK commercial pilot population. By determining the type of incapacitations occurring aviation medicine practitioners can concentrate on the prevention of those events that present the highest risk to flight safety. Some incapacitations, such as a first seizure with epilepsy, cannot be reliably predicted by any medical screening method. Aeromedical surveillance is only appropriate for potentially predictable conditions and the screening tools need to target the causes of incapacitations and impairments that are most likely to adversely affect flight safety.

The results of this study indicate that it is appropriate to concentrate surveillance on pilots at greatest risk of cardiovascular and cerebrovascular medical events, especially those over the age of 50. The high proportion of psychiatric disorders associated with MORS reports

reflects the need to monitor the mental health of pilots. Both serial examination with the same medical examiner and pilot education may be helpful in this regard. An increased emphasis on the health education and awareness of pilots may also encourage early symptom reporting. Fostering a relationship of trust with a medical examiner and promoting a culture of safety will aid prompt declaration of a decrease in medical fitness. All the incapacitations, impairments and MORS reported in-flight events reported in this study occurred in between, and despite, periodic medical assessments.

The periodic medical assessment provides an ideal opportunity for the medical examiner to highlight the greatest health risks for each individual pilot. This is likely to be of greatest benefit for pilots under the age of 40 who are least likely to experience an incapacitation but for whom prevention of future incapacitation would provide the most benefit for flight safety in the future. Ongoing monitoring of incapacitating events is essential to understand which type of medical conditions present the greatest flight safety risk and to focus efforts on reducing those risks.

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