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Fainting Passengers: The Role of Cabin Environment

ABSTRACT: Reported percentages of in-flight medical incidents caused by syncope, the medical term for fainting, vary between 15 % and 22 %. Syncope is usually a benign medical event, but it may cause fear and distress among passengers and the individual involved. Incorrectly diagnosed benign syncope may lead to unnecessary flight diversions. In this context, the incidence of in-flight syncope and possible relationships with cabin environmental and passenger factors were studied. In September 2005, questionnaires were handed out to the senior purser on all KLM long haul flights. Pursers were asked to record all cases of in-flight syncope and to answer questions concerning cabin climate. Literature data were analyzed concerning in-flight and passenger factors that may cause or elicit syncope. With a response rate of 79 %, 1625 forms were analyzed. The in-flight syncope risk was 3–9 per 1000 passenger flight hours, depending on type of aircraft. The frequency of syncopal events was weakly correlated with cabin climate conditions. Literature analysis provides evidence that hypoxia is a sufficient cause for syncope in a sub-set of healthy airline passengers. There is evidence that cabin pressure and temperature may contribute to the occurrence of syncope. The syncope risk appears to be higher aboard an aircraft than on the ground. Hypoxia is a sufficient cause for syncope in a sub-set of healthy airline passengers. Airline passengers may become considerably hypoxic due to reduced pulmonary ventilation caused by immobility, drowsiness, and gastro-intestinal distension. In-flight hypoxia may reach levels sufficient to cause syncope. High cabin temperature may further trigger this reaction.

KEYWORDS: in-flight syncope, cabin pressure, cabin temperature, passenger health

Introduction

Syncope is the medical term for fainting. It is defined as a sudden and brief loss of consciousness associated with a loss of postural tone, from which recovery is spontaneous [1]. Syncope is caused by temporary insufficient cerebral perfusion and is the most frequent cause of in-flight medical events (Table 1). The affected person presents with pallor, nausea, profuse perspiration, slow heart rate (bradycardia), rapid fall of blood pressure, and loss of consciousness. During the unconscious episode, which may last several minutes, convulsive movements and involuntary voiding of urine may occur. An in-flight syncopal attack may be elicited by hypoxia, high environmental temperature, gastro-intestinal distension, and standing up from a sitting or horizontal position [2]. The typical in-flight scenario is that after several hours in flight, the passenger leaves his seat, for instance, to use the lavatory, becomes pale and clammy with sweat and collapses on the floor in an apparent faint. This represents a medical emergency, with consequent disruption of service of cabin crew, fear and panic of other passengers, and personal distress for the affected passenger. In the majority of cases the patient recovers spontaneously within a few minutes.

TABLE 1—*Top six diagnoses of in-flight medical events.*

	Delaune et al. [4] $N=2279$, %	MedAire [5] $N=8400$, %	DeJohn et al. [6] $N=1132$, %
Syncope	15.2	21.5	22.0
Trauma	12.2	Not included	5.0
Gastro-intestinal	11.8	15.4	8.0
Cardio/chest pain	11.3	9.6	20.0
Respiratory	11.0	10.2	8.0
Neurological	6.5	8.7	12.0

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Syncope is also quite common in non-aviation settings. However, epidemiological incidence data are very scarce. Data from the Framingham study population demonstrate a first occurrence rate of 6.2 cases per 1000 patient years [3]. In the majority of cases where the cause was known, syncope is a benign medical event (vasovagal or orthostatic) and patients show full spontaneous recovery. Cardiac syncope, which was diagnosed in a minority of cases (9.5 %), has a less favorable prognosis, which is related to underlying cardiac disorder [3].

The incidence of in-flight syncope is not exactly known. Not every in-flight medical event is reported and the diagnostic nomenclature differs between countries and companies. Cultural medical differences may lead to different categorization of diagnoses. A benign syncope may also be categorized as "cardiac" or "neurological." In recent literature, presented in Table 1, the incidence of syncope ranges between 15.2 % and 22 % of all in-flight medical events, although some authors report incidences up to 35 % [7].

A benign in-flight syncope is often misdiagnosed to be a serious medical disorder (cardiac or neurological), even by medically educated passengers. In such cases the flight may be diverted to seek medical care at a nearby airport. Studying 2042 medical incidents, which led to 312 diversions, Sirven et al. [8] found that loss of consciousness or syncope was the medical event with the highest likelihood of diversion (71 %). The rate of diversions due to medical events is estimated at 1:12.6 events [6]. A diversion will incur added costs and causes irritation of fellow passengers, particularly when the affected passenger has fully recovered before landing. In Air France, unnecessary diversions represented 35 % of the diversions for medical reasons [9].

After reports of high rates of fainting passengers on a newly delivered aircraft type, KLM decided to conduct a survey in which occurrences of in-flight syncope on all KLM aircraft types on intercontinental flights were recorded together with subjective reports of cabin climate characteristics.

The present paper reports the results of this survey and a discussion of the possible roles of cabin environmental and passenger factors in the aetiology of in-flight syncope.

Method

In September 2005, questionnaires were handed out to the senior pursers of all intercontinental KLM flights. Questions were included about flight information, subjective assessment of cabin climate, and case details regarding fainting passengers. Fainting was defined as a sudden and brief loss of consciousness associated with a loss of postural tone, from which recovery is spontaneous. In conformity with epidemiological principles, the incidence of in-flight syncope has been calculated as the number of syncope events per 1000 h a passenger spends onboard an aircraft (=passenger (flight) hours).

Results

General Results

A total of 1625 usable forms were received in the period from Sep. 5 to 29, 2005. KLM had an average of 600 flights per week for these aircraft types, so response rate was calculated to be 79 %. KLM operated only one A330 in September 2005, and the number of flights with this type was very limited; therefore, it was decided to exclude the A330 flights from the analysis. The distribution of forms among aircraft types was 36.7 % (n=589) for B 747-400, 18.8 % (n=301) for MD-11, 23.0 % (n=370) for B 767, and 21.5 % (n=345) for B 777. The distribution of forms per aircraft type was almost identical to the distribution of flights per aircraft type. The majority of the flights were with a full cabin with every available seat occupied.

Subjective Cabin Climate

On 506 (29.7 %) forms, the cabin climate was judged as "bad." On 1050 (66.0 %) it was judged as "good." The distribution of subjective judgments of the cabin climate among aircraft types is shown in Table 2.

In case the cabin climate was judged as bad, respondents had to answer the question whether the temperature was too high or too low, and whether it was drafty or unstable. Results are shown in Table 3.

TABLE 2—*Distribution of cabin climate judgment per aircraft type.*

Type of aircraft	Good, %	Bad, %	Question not answered, %
747-400	56.9	39.2	3.9
MD11	77.4	18.3	4.3
767	76.8	17.8	5.4
777	53.0	43.5	3.5
Total	66.0	29.7	4.3

One common issue in free format comments was high temperature during boarding. In total, on 110 flights, the temperature was uncomfortably high during boarding of the passengers. In some cases, temperatures of 35–40°C were reported.

Other general issues that were mentioned for all aircraft types:

- It is cold at the door areas.
- Many symptoms are attributed to dry air.

Syncope

Syncope, commonly described as "fainting" has occurred on 71 flights. Average age of the "fainters" was 55.4 years (range: 35–75). Gender distribution showed no significant differences. Nationalities varied widely. On average, fainting occurred 4.5 h after take off. Knowing exact passenger numbers per flight, syncope ratio per passenger flight hour has been calculated. The results are shown in Table 4. Remarkably, none of the occurrences led to an unscheduled diversion of the flight.

Principal Findings

In this survey, it was found that the in-flight syncope risk ranges from 3 to 9 per 1000 passenger (flight) hours. There was a weak, but significant correlation between "bad" cabin climate and syncope ($r=0.11$; $p<0.0001$). The average of "bad" judgments of cabin climate over all aircraft types was 29.7 %. Although reference data are not available, we consider this percentage to be high. On almost one in every three flights there were problems with the temperature or other climate aspects. Comparing aircraft types, subjective climate was worst in 747 and 777: 39.2 % and 43.5 % respectively. The other types (767, MD-11) performed better, with around 20 % "bad" judgments.

TABLE 3—*Distribution of temperature complaints concerning "bad" cabin climate judgments.*

Judgment	*N*	Percent
Too hot	81	13.2
Too cold	110	17.9
Drafty	182	29.6
Unstable	241	39.2

TABLE 4—*Calculation of syncope ratio per aircraft types.*

Aircraft type	Average flight hours per flight	Number of flights	Number of passengers with syncope	Syncope ratio per passenger hour[a]
747	9.3	589	25	0.005
MD-11	6.8	301	18	0.009
767	5.9	370	7	0.003
777	9.6	345	21	0.006

[a]Passenger hour=hours a passenger spends onboard an aircraft.

Discussion and Conclusion

This is the first study in which incidence of in-flight syncope was systematically recorded. The scarcity of data on this issue is caused by the fact that large scale studies on passenger health and cabin climate are difficult to perform on regular and busy airline flights. In this study, data were collected by cabin crew during their onboard tasks. This led to inevitable limitations of the present survey. The response rate was 79 %. It is assumed that there was response bias towards flights with fainting passengers, or shortcomings of the cabin climate. No objective measurements of cabin climate, such as temperature, carbon dioxide, and relative humidity, could be accomplished on these crowded flights; therefore, all reports on cabin climate concern subjective judgments by the purser. Although no data concerning cabin pressure or cabin altitude were available, technical specifications dictate that cabin altitudes during these regular long haul flights ranged between 6500 and 8000 ft.

It was found that the in-flight syncope risk ranges from 3 to 9 per 1000 passenger hours. Data on the incidence of syncope in a ground based population are scarce and may underestimate the incidence in every day life, because it is likely that not every syncope will be reported. The incidence in a ground-based population is estimated at 6.2 per 1000 patient years, which can be calculated as 6.2 per 8 760 000 patient hours [3]. Although these data might underestimate the incidence in a ground based population and a comparison with our in-flight passenger data is methodologically difficult, the comparison with our in-flight passenger data indicates a very large difference. It appears that the in-flight syncope risk is much higher than in a ground-based population. To explain this difference, we examined the possible causal roles of cabin environmental factors and passenger factors.

Cabin Environmental Factors

Most jet airliners fly at cruise altitudes up to 45 000 ft, because flying at this altitude has many advantages, such as higher cruise speed, reduction of fuel consumption, and reduction of turbulence. Because atmospheric pressure decreases when altitude increases, the partial oxygen pressure also decreases. To maintain cabin pressure at a physiological acceptable level, most airliners are equipped with a pressurized cabin. At cruise altitude, cabin pressure in airliners is maintained at a level between 81.2 kPa and 75.2 kPa (cabin altitude 6000–8000 ft). At a cabin altitude of 8000 ft, the partial pressure of oxygen equals 15.7 kPa and the arterial oxygen pressure in healthy subjects will be 7.5 kPa, resulting in a haemoglobin-oxygen saturation ($HbSaO_2$) of 90 % (SD $\pm$ 1.9; range 85–93) after 30 min. of exposure [10]. This means that aircrew and passengers are subjected to a mild degree of hypoxia with consequent physiological, cognitive, sensory, and psychological effects. There is considerable inter-individual variation in the responses to a lowered partial O_2 pressure. There is evidence that ventilation is unstable during drowsiness before sleep onset [11]. Moreover, the lower ambient pressure in the cabin leads to gastro-intestinal distension (1.4$\times$ expansion at 8000 ft, according to Boyle's law), which might limit movements of the diaphragm. Therefore, pulmonary ventilation may be hindered. Significant lower $HbSaO_2$ levels (80 %) have been found in subjects, who were dozing off or sleeping during hypobaric chamber studies at simulated cabin altitudes of 8000 ft [12]. We conclude that considerable levels of hypoxia may occur in aircraft passengers.

There is convincing evidence that hypoxia is a sufficient cause for syncope in healthy individuals [2,13–15]. About 10 % of individuals (the so-called fainters [14]), reacts to hypoxia with a peripheral vascular dilatation instead of peripheral vascular constriction, which is the "normal" reaction to hypoxia. In susceptible individuals, hypoxia leads to an exaggerated physiological response, leading to syncope due to vascular collapse, bradycardia (too slow heart rate), or asystole (Bezoldt-Jarisch reflex [2]). Patients with hypoxic syncope fully recover when brought in Trendelenburg's position (supine on a surface inclined 45°, with the head at the lower end) and administration of supplemental oxygen [2].

It is interesting that the results of the present survey show evidence, although weak, for a relationship between high cabin temperature and the occurrence of syncope. High temperatures during boarding or during the flight may have caused vasodilatation of the skin blood vessels. High environmental and skin temperatures have been shown to increase the risk of syncope [16,17].

Passenger Factors

Immobility, sleeping, and drowsiness, as occur in passengers on long-haul flights, might hinder proper pulmonary ventilation, leading to significant levels of hypoxia. Contributing factors that are known to elicit a benign syncope are standing up from a sitting or supine position and digesting food, or the use of alcohol. In this context, it is interesting that in the present study fainting occurred on average 4.5 h after take-off. This is about the time that passengers are digesting their food and some of them are dozing off, which creates a condition of gastro-intestinal vasodilatation and distension together with a significant level of hypoxia. However, only susceptible passengers may faint due to these conditions. There is no convincing explanation of the difference in reaction to hypoxia between fainters and non-fainters, but it is likely that this is due to inherited factors (genetic polymorphism) [18,19].

Conclusion

The results of this study show that the syncope risk is higher aboard an aircraft than on the ground. The higher syncope risk found in airline passengers may be explained by a combination of environmental factors, such as cabin pressure and temperature, and passenger-related factors, such as immobility, food or alcohol consumption, drowsiness, and individual susceptibility.

Muhm et al. [20] suggested that an increase of cabin pressure may reduce discomfort of passengers on long haul flights. We surmise that increasing cabin pressures may also reduce the incidence of in-flight syncope and flight diversions.

Cases of in-flight syncope should be treated by bringing the patient in a supine position, preferably Trendelenburg's position, and administration of supplemental oxygen. When the patient has regained consciousness, one should ask the patient about the medical history. When the nature of pre-syncopal complaints and past medical history provide no hints for a cardiac or neurological cause, there is no need to divert the flight.

References

[1] Kapoor, W. N., "Syncope," *N. Engl. J. Med.*, Vol. 343, No. 25, 2000, pp. 1856–1862.
[2] Westendorp, R. G. J., Blauw, G. J., Fröhlich, M., and Simons, R., "Hypoxic Syncope," *Aviat Space Environ. Med.*, Vol. 68, 1997, pp. 410–414.
[3] Soteriades, E. S., Evans, J. C., Larson, M. G., Chen, M. H., Chen, L., Benjamin, E. J., and Levy, D., "Incidence and Prognosis of Syncope," *N. Engl. J. Med.*, Vol. 347, No. 12, 2002, pp. 878–885.
[4] Delaune, E. F. 3rd, Lucas, R. H., and Illig, P., "In-Flight Medical Events and Aircraft Diversions: One Airline's Experience," *Aviat Space Environ. Med.*, Vol. 74, No. 1, 2003, pp. 62–68.
[5] MedAire, "2002 Stats Reveal Most Common Inflight Medical Emergencies," http://www.medaire.com/2002_stat_nr.html(visited 29 October, 2007).
[6] DeJohn, C. A., Wolbrink, A. M., Véronneau, S. J., Larcher, J. G., Smith, D. W., and Garrett, J. S., "An Evaluation of In-Flight Medical Care in the U.S.," *Aviat Space Environ. Med.*, Vol. 73, No. 6, 2002, pp. 580–586.
[7] Donaldson, E. and Pearn, J., "First Aid in the Air," *Aust. N. Z. J. Surg.*, Vol. 66, No. 7, 1996, pp. 431–434.
[8] Sirven, J. I., Claypool, D. W., Sahs, K. L., Wingerchuk, D. M., Bortz, J. J., Drazkowski, J., Caselli, R., and Zanick, D., "Is There a Neurologist on this flight?," *Neurology*, Vol. 58, No. 12, 2002, pp. 1739–1744.
[9] Braak, L., "La Télémédecine. 21ème Forum Intégration Homme-Systèmes?," *Vols Très Long-Courriers: Facteur Humains Mis en Jeu*, Paris, France, 22 June 2005, Académie Nationale de l'Air et de l'Espace, Direction Générale de l'Aviation Civile, pp. 37–41.
[10] Simons, M., "Environmental Factors Influencing Flight Crew Performance," *Circular 229-AN/137*, International Civil Aviation Organization, Montreal, 1991.
[11] Thomson, S., Morrell, M. J., Cordingley, J. J., and Semple, S. J., "Ventilation is Unstable During Drowsiness Before Sleep Onset," *J. Appl. Physiol.*, Vol. 99, No. 5, 2005, pp. 2036–2044.
[12] Simons, R. and Krol, J., "Jet Leg, Pulmonary Embolism, and Hypoxia," *Lancet*, Vol. 348, 1996, p. 416.
[13] Henderson, Y. and Seibert, E. G., "Medical Studies in Aviation," *JAMA, J. Am. Med. Assoc.*, Vol. 71, 1918, pp. 1382–1401.
[14] Anderson, D. P., Allen, W. J., Barcroft, H. et al., "Circulatory Changes During Fainting and Coma

Caused by Oxygen Lack," *J. Physiol. (London)*, Vol. 104, 1946, pp. 426–434.
[15] Nicholas, R., O'Meara, P. D., and Calonge, N., "Is Syncope Related to Moderate Altitude Exposure?," *JAMA, J. Am. Med. Assoc.*, Vol. 268, No. 7, 1992, pp. 904–906.
[16] Sohar, E., Shoenfeld, Y., Shapiro, Y., Ohry, A., and Cabili, S., "Effects of Exposure to Finnish Sauna," *Isr J. Med. Sci.*, Vol. 12, No. 11, 1976, pp. 1275–1282.
[17] Cooper, K. E., "Some Responses of the Cardiovascular System to Heat and Fever," *Can. J. Cardiol.*, Vol. 10, No. 4, 1994, pp. 444–448.
[18] Halliwill, J. R. and Minson, C. T., "Cardiovagal Regulation During Combined Hypoxic and Orthostatic Stress: Fainters vs. Nonfainters," *J. Appl. Physiol.*, Vol. 98, No. 3, 2005, pp. 1050–1056.
[19] Garovic, V. D., Joyner, M. J., Dietz, N. M., Boerwinkle, E., and Turner, S. T., "Beta(2)-Adrenergic Receptor Polymorphism and Nitric Oxide-Dependent Forearm Blood Flow Responses to Isoproterenol in Humans," *J. Physiol. (London)*, Vol. 546, PT. 2, 2003, pp. 583–589.
[20] Muhm, J. M., Rock, P. B., McMullin, D. L., Jones, S. P., Lu, I. L., Eilers, K. D., Space, D. R., and McMullen, A., "Effect of Aircraft-Cabin Altitude on Passenger Discomfort," *N. Engl. J. Med.*, Vol. 357, No. 1, 2007, pp. 18–27.