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The Journal publishes original research papers, review articles, technical notes and professional evaluations covering the diverse range of topics which impinge on environmental health including; occupational health and safety, environmental protection, health promotion, housing and health, public health and epidemiology, environmental health education, food safety, environmental health management and policy, environmental health law and practice, sustainability and methodological issues arising from the design and conduct of studies.

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# Common cold transmission in commercial aircraft: Industry and passenger implications

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## Abstract:

An impression exists among frequent fliers that colds and flu are more prevalent after flying than from normal ground level exposures. A recent, well designed survey of adult passengers on 2½ hour flights established that an average of 20% self-reported colds were experienced by these travellers when questioned 5 to 7 days after the flight. We have taken the details of these survey results and compared them with the relevant frequency of colds, 2.2, or 2 to 4 colds per person year, experienced by ground level adults by converting these to common units. When the scenarios of 6 days, 24 hours, or 5 hours were taken as the relevant flight exposure times to colds, passenger transmission rates for colds of 5, 23, and 113 times the normal daily ground level transmission rate were obtained. Primarily for internal verification purposes annual infection rates were also calculated by a somewhat different method to give aircraft transmission rates of 12, 60, and 350 colds/person year for the same flight exposure scenarios. Recent published tuberculosis transmission rates are also compared and found to be substantially greater for aircraft passengers than for ground level adults. This revealed an exception for cockpit crew for whom tuberculosis transmission could not be demonstrated, which we attempt to explain.

As a result of this analysis, recirculation of aircraft air was confirmed not to be a significant factor. However, reduced resistance to infection from the usual very dry cabin air and fatigue, coupled to the small cabin air space per person, and low outside air replacement rates of newer aircraft could have contributed to the very high cold transmission rates observed.

**Key words:** Aircraft cabin air quality; colds; environmental health; ground level transmission; tuberculosis.

## Introduction

There is a widespread public belief that commercial aircraft travel increases the risk of developing upper respiratory tract infections. Such colds also are thought to be more common in passengers today because of the greater use of recirculated cabin air for ventilation.

Interestingly, a recent survey of the subsequent cold development of 1,100 passengers, flying from San Francisco Bay, California to Denver, Colorado in aircraft using either 100 percent fresh air or some recirculated cabin air, conducted by Zitter and colleagues (Zitter *et al*, 2002), permits both of these widely held beliefs to be evaluated.

## Are Aircraft Passengers More Susceptible to Colds?

The frequency of upper respiratory tract infection in non-fliers must be established before it can be determined whether, or not, flying increases susceptibility to colds. Fortunately, Reid and coworkers (1953) studied upper respiratory tract infections in 131 Greater London adult daily bus or train commuters, finding that they experienced an average of 2.2 colds per year (Table 1.0)(Reid *et al*, 1953). Similarly, Fendrick and coworkers (2003) conducted a nationwide telephone survey of 4,051 United States households, during the period November 3, 2000 to February 12, 2001, in an attempt to establish the annual incidence of colds. They concluded that the average American experiences some 2.5 colds each year (Fendrick *et al*, 2003). This figure, similar to that of London commuters, is consistent with the US National Institutes of Health's estimate that the average American adult of working age should expect to catch between 2 and 4 colds each year (NIH, 2001).

Taken together these three sources suggest that the normal adult catches 0.6 to 0.8 colds per 100 days, or roughly 1% per person day. Given this rate of

**Table 1.0 Reported Transmission Rates for Colds by Ground Level Adults**

Circumstances	Incidence of colds as specified	Exposure time scenarios	Infection rate, colds/person year
<b>Normal Ground Level Experience:</b>			
131 adults of Greater London	2.2 colds/person year all daily commuters to work by bus, rail and underground tracked for 1 year (Reid <i>et al</i> , 1953)	Bus commuters: 257 h/year (11 d/year) from ca. 70 min/day × 200 d/year ÷ 60 min/h Train commuters: 367 h/year (15 d/year) from ca. 110 min/day × 200 d/year ÷ 60 min/h	2.2 (actual experience)
Telephone survey of 4051 U.S. households in 2000-2001 for self-reported incidence of viral respiratory tract infections	Average of 2.5 colds/person year	Results correlated with absenteeism estimates from National Health Interviews Survey data (Fendrick <i>et al</i> , 2003)	2.5
Average for healthy American adults, children and the elderly excluded (IH, 2001) Winter infection rate about twice the summer rate.	2-4 colds/person year Winter: 6 months @ 4 colds/year gives 2 colds Summer: 6 months @ 2 colds/year gives 1 cold	Winter: 4 colds/person year Summer: 2 colds/person year	3.0 (year round average)

infection by the 200 or so viruses known to cause common colds, it might be expected that some 1% of working adults would become infected on any given day. It is recognized, of course, that the incidence of upper respiratory tract infection may show geographical and temporal variation, altering from place to place and throughout the year. However, there is little available data that suggests major spatial or seasonal differences in cold incidences.

Ideally, surveys of the impact of air travel on the transmission of colds should be conducted using a large sample of passengers supplying cold incidence information for several weeks prior to and after flying. Probably because such a survey would be expensive and time consuming, it has yet to be undertaken. Nevertheless, the data on subsequent colds developed by 1,100 aircraft passengers, flying between San Francisco Bay and Denver, suggests that air travel increases susceptibility to upper respiratory tract infections. The 2½ hour flight itself represented 4 to 5 hours of associated exposure to which must be added the 5 to 7 days that passed after flights were concluded but before cold data were collected (Zitter *et al*, 2002). As shown from the available information from London commuters (Reid *et al*, 1953) and Fendrick and colleagues' (2003) US nationwide telephone survey, a similar sized hypothetical control group of non-flyers would normally have experienced a 4% incidence rate for "new" colds during such a time period. This compares with the 20% incidence rate for upper

respiratory tract infections experienced by those flying between San Francisco Bay and Denver. Although Zitter and coworkers (Zitter *et al*, 2002, Zitter, 2002) attempted to explain away this apparently greater susceptibility to cold infection by aircraft passengers by claiming that their survey had been conducted at the height of the cold season, their argument seems unconvincing and it is more likely that the public perception that flying promotes colds is correct.

It is possible to use Zitter and colleagues' data (Zitter *et al*, 2002) to examine in more detail the hypothesis that flying promotes cold transmission. If, for example, flight exposure is considered to be the entire 6 day period between passenger boarding and subsequent interview then the cold transmission rate can be calculated at 3.33% per day, roughly 5 times that of the normal daily non-flying transmission rate.

If, however, flight exposure time is viewed as one 24-hour day, then such aircraft travel appears to result in a 16.5% infection rate per day. To calculate this the average ground level cold transmission rate of 0.7% per day must be multiplied by 5 to represent the time elapsing after flight but before telephone survey and subtracted from the 20% cold incidence rate recorded by Zitter and colleagues (20%/day - 3.5%). Under these assumptions, the flight cold transmission rate would appear to be some 23 times that normally experienced by ground level adult commuters.

**Table 2.0 Survey Measured Cold Transmission Rates by Aircraft Passengers**

Circumstances	Specified incidence of colds* by passengers	Exposure time scenarios	Infection rate, colds/person year
<b>Self Reported Incidence of Colds (least restrictive criteria)</b>			
1100 passengers surveyed, flights during Jan-April, 1999, San Francisco & Oakland to Denver, CO, children < 18yr excluded (Zitter <i>et al</i> , 2002)	19-21%*, self reported 5-7 days after initial survey contact	i Sweeping, (0.2 colds/person 6d) ÷ 6 × 365 d/year	12.2
		ii Conservative, ((0.2 colds/person day - (5 × 0.7%/d)) × 365 d/year	60
		iii Focussed, ((0.2 colds/person 0.2 d × 5) - (6 × 0.7%/d)) × 365 d/year	350
* Colds or related symptoms (Zitter <i>et al</i> , 2002).			

In contrast, if it is assumed that any air travel-related increase in cold incidence stems only from the 5 hours spent boarding, deplaning, and in the aircraft, then the transmission rate for this period is 15.8%/0.2d (20%/6d - (0.7% × 6d)) for the air travel itself. Multiplying by 5 gives a daily transmission rate of 79%/day (15.8%/0.2 day × 5), which amounts to 115 times (79%/day ÷ 0.7%/day) the normal daily ground level experience. Analysis at this level of exposure clearly confirms that the colds transmission risk during travel as an aircraft passenger is very high. For internal verification of our methods, and not intended to reflect realistic yearly extrapolations, these daily estimates of transmission rates have also been calculated on an annual basis by a somewhat different method (Table 2.0). These results are entirely consistent with the calculations on a daily basis.

Even using Zitter and coworkers' (2002) most restrictive criteria to identify which passengers subsequently developed colds, flying between San Francisco Bay and Denver still appears to have been associated with an infection rate of 15 times (10.8%/day ÷ 0.7%/day) the daily ground level transmission rate, equivalent to 56 colds/person year on an annual basis.

## Does Aircraft Cabin Air Recirculation Increase Cold Susceptibility?

Interestingly, the passenger survey conducted by Zitter and coworkers suggests that cabin air recirculation has little impact on the incidence of

colds. Nineteen percent of passengers on aircraft that recirculated cabin air, for example, developed post-flight respiratory symptoms compared to twenty-one percent of those flying on aircraft that did not (P = 0.34). The figures for reported runny noses and colds were similarly non-significant (P = 0.70) at 10% and 11% respectively. It would appear, therefore, that the public belief that recirculating air in passenger aircraft increases the incidence of upper respiratory tract infections may be incorrect.

However, a higher than normal viral load is likely to be experienced by aircraft passengers and cabin crew as a consequence of the much lower rate of outside air ventilation per person in modern aircraft than for any other ground level or transport public space (Hocking, 1998, 2001). To illustrate, other public spaces routinely provide 7 to 14 L/s of outside air per person, while aircraft built in the 1980s and 1990s supply those flying with only an average of 4.8 L/s (Hocking, 2002). It seems inevitable that this reduced rate of provision of outside air in more modern aircraft has been associated with a decline in quality and a rise in viral load.

Support for a contribution to high colds transmission rates from low outside air flow rates in aircraft is provided by recent experiments involving occupants of an office building who were unaware of ventilation changes (Wargo *et al*, 2000). Outside air flow rates were varied between 3, 10, and 30 L/s per person for 4.6 hour periods. At the lowest flow rates occupants had the perceptions of higher intensity of odour and of less fresh, drier air, and also found it more difficult to think. They also generally felt in poorer health at the low flow rates than at the higher levels of provision of outside air, that is they suffered the symptoms of sick building syndrome.

## Possible Causes of the Elevated Incidence of Colds by Aircraft Passengers

Aircraft with full passenger loads provide the smallest volume of available air per person of any public space (Hocking, 1998). As a result, the transmission risks of microbiota between overlapping personal airspaces, and from direct person-to-person contact are substantial. Experts in aerospace medicine agree that transmission of contagious diseases like upper respiratory tract infections is facilitated by person-to-person contact in an enclosed space, such as an aircraft passenger cabin (American Medical Association, 1998; Aerospace Medical Association, 2002; Rayman, 2002). Clearly this pathway could be a contributing factor to the high cold transmission rates observed.

If the greater incidence of colds suffered by aircraft passengers were due to exposure to a generally higher than normal viral load, one might expect that there would be a statistically significant increase in colds amongst those passengers breathing recirculated cabin air, but as already described this appears not to be the case (Zitter *et al*, 2002). It seems more likely, therefore, that the higher incidence of colds reported by recent aircraft passengers, may be due to a decline in their ability to resist infection while flying. The natural human defence system against colds is known as the Mucociliary Clearance System, which consists of a layer of thin mucus that is kept in motion by beating cilia. This protective system traps viruses and bacteria and moves them from the nose and throat to destruction by acids in the stomach. However, when the air is dry, the mucus becomes too thick to be effectively moved by the cilia. This leaves more viruses and bacteria to cause upper respiratory tract infections. The typical relative humidity in aircraft cabins for flights over an hour is below 10% for most of the journey, often dropping to less than 5% on longer flights. It has been shown experimentally, using saccharin, that under these conditions the Mucociliary Clearance System either slows dramatically or stops (Barry *et al*, 1997, Salah *et al*, 1988). This would suggest that it is the low relative humidity in aircraft cabins that increases susceptibility to colds rather than a higher viral load in the air.

There is growing evidence in the literature to support the belief that bacteria and viruses are more likely to cause infection during air travel. To illustrate, tuberculosis is caused by the bacterium *M. tuberculosis* and an active carrier of this pathogen would be expected to infect roughly ten people a year (Shnayerson & Plotkin, 2002). However, on a flight from Paris to New York in the Fall of 1998, a Ukrainian passenger with active, drug-resistant TB infected 13 other passengers who sat in his vicinity (Shnayerson & Plotkin, 2002). In this case bacterial

transmission on board an aircraft (type not identified) was evidently far higher than typical ground level experience.

Similarly, a Boeing 747-400 aircraft on a 14 hour flight carried 308 passengers, one of whom suffered from highly infectious tuberculosis (Wang, 2000). It proved possible to subsequently contact and test 277 of these passengers, 9 of whom showed conversion. In 3 of these 9 contacts the possibility of transmission from the index patient could not be ruled out (6 had one or more other risk factors). Nevertheless, flight exposure-related TB conversion in this event appears to have been some 1.3% (3/225), much higher than the normal ground level transmission.

## Implications and Suggestions

Taken as a whole, the evidence appears to suggest that aircraft passengers do indeed develop colds with a higher than normal frequency in the week following their flights. However, this seems more likely to be due to the depressed humidity of cabin air or to an inadequate provision of outside air, than to its recirculation. Substantial overlap of personal air spaces causing mixing of these, and high person-to-person contact could also be factors, as explained earlier. It would be possible, although not simple, to conduct survey tests of each of these hypotheses to determine the possible significance of these air quality variables. Aircraft specially modified to increase the relative humidity of the cabin air to the normal comfort level of about 20% (Wang, 2000), both with an outside airflow of 7.1 L/s person (15 cfm/person), and with an airflow of 3.5 L/s person (7.5 cfm/person, about one-half of the office building standard) would be needed. These aircraft should be operated on a common route to that used by conventionally-equipped aircraft to minimise other variables. An attempt to correlate colds transmission with the lengths of flights of aircraft using the same amounts of outside airflow per person and humidity could also provide useful answers (Nagda and Hodgson, 2001). To be meaningful, these research projects would need to be on at least the scale of the impressive survey conducted by Zitter and colleagues (Zitter *et al*, 2002).

If one or both of the humidity or outside airflow hypotheses were found to be correct, improving these aircraft cabin air quality factors may prove to be extremely beneficial in lowering the incidence of in-flight, or post-flight infections. Promise of the potential benefit from increased humidity is seen from the anecdotal reports of the apparent effectiveness of the use of personal nasal mist dispensers such as Rhinaris, or Otrivin, or even a mist dispenser containing distilled water, or of antiseptic creams such as Secaris, in reducing the incidence of

flight-related illness (Ross, 2002; Nykodym, 2002). The wearing of an appropriate, well fitted filter face mask, which became commonplace during the Severe Acute Respiratory Syndrome (SARS) outbreak of Spring 2003 (Zurer, 2003), would also have maintained a much more humid breathing micro-environment for the wearer (Hocking, 2002).

Superficially, it would appear to be relatively simple to increase the humidity of aircraft air. However, as found by British Airways during humidification experiments conducted on Boeing 747-100/200 aircraft in the 1980s, problems arose, mainly from solutes blocking water passageways and spray bars, (Bagshaw, 2003) (De Ree *et al*, 2000). Not infrequently during these tests, solutes also caused the air conditioning system to spray small white pellets along with the air supply, particularly to the flight deck. As a result of these difficulties, it was only possible in this study to maintain the mean relative humidity above 10% for three of the twelve British Airways flights (De Ree *et al*, 2000). This marginal increase meant that no conclusions could be drawn on the effectiveness of humidification from these tests.

It is possible that the humidification problems could be solved, without introducing new difficulties, by using de-ionised water. However, even using such essentially solute-free water, there could still be operational difficulties associated with the raising of cabin humidity, such as the risks of moisture condensation and freezing already occasionally observed on the very cold inner surfaces of aircraft pressure shells at cruising altitudes (Sloan, 1999). Also the potentially increased operating cost of a reduced payload equivalent to the mass of water required for the in-flight humidification process itself, would have to be considered to safely test this option.

Fuel costs for the compression of outside air to cabin pressures are estimated to be US\$0.33 per hour to provide 7.2 L/s person (15 cfm/person) and US\$0.22 per hour to provide 4.7 L/s person (10 cfm/person), based on a jet fuel cost of US\$0.52/L (Hocking, 2002). In 1984, it was estimated that the fuel for aircraft ventilation amounts to 1 to 2% of the total operating fuel costs (Lorango & Porter, 1984). Some years ago, the Douglas and Boeing aircraft companies reported 0.0009 or 0.015 US gallons of jet fuel per hour was required for each cubic foot per minute of outside air supplied for ventilation of aircraft (NRCC, 1986). With the improved overall efficiencies now achieved by the newer fan jet engines, the present ventilation fuel consumption should have dropped to somewhat less than these figures. To provide some recent perspective to the older figures, the fleet-wide specific total fuel consumption figures of 5.2 and 6.2 L/100 passenger km have been reported recently by Lufthansa, and the Scandinavian Airlines System, respectively (Lufthansa, 2000; SAS, 2000).

## Conclusions

Fendrick and coworkers recently calculated an US \$80 average cost of respiratory tract infection (Fendrick *et al*, 2003). This suggests that, given the relatively low expense, increasing air humidity in passenger aircraft would have a very positive benefit to cost ratio. Clearly, the issues discussed in this article are of considerable economic significance. If, in future studies, a substantial reduction of colds transmission were observed from the resumption of increased outside air flows, and/or from an increase of the relative humidity to the 20% comfort level (Wang, 2000), then the societal cost saving from adoption of such strategies would be far higher than the societal costs of implementing these air quality improvement measures.

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