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Aircraft Cabin Air Recirculation and Symptoms of the Common Cold

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AIRCRAFT CABINS MAY BE HIGH-risk environments for transmission of infectious diseases. Space confinement,¹ limited ventilation,^{2,3} prolonged exposure times, and recirculating air,⁴ all common to air travel, have been demonstrated to be risk factors for transmission of upper respiratory tract infections (URIs) in other settings. Several case reports detail outbreaks of influenza and tuberculosis aboard aircraft,^{5,9} but it is not known whether air recirculation increased rates of transmission. Air recirculation increases rates of transmission of viruses that cause the common cold in army barracks,⁴ but this possibility has not been studied in airplanes.

In the early 1980s, to enhance fuel efficiency, aircraft manufacturers began to build ventilation systems that recirculated cabin air. Older systems used 100% fresh air, compressed, humidified, and cooled by the engines in a process that consumed significant energy. Newer airplane models recirculate as much as 50% of cabin air, decreasing the engine's work. The recirculated air passes through high-efficiency particulate filters before mixing with conditioned fresh air to reenter the passenger compartment. However, any filter's ability to capture viruses is limited, even at peak function, and filters are rendered even less effective if bypassed, improperly used, or clogged by particulate matter.^{3,10}

Context In recent years, new commercial aircraft have been designed to recirculate approximately 50% of the cabin air to increase fuel efficiency. Some older aircraft use only fresh air. Whether air recirculation increases the transmission of infectious disease is unknown; some studies have demonstrated higher rates of the common cold among persons working in buildings that recirculate air.

Objective To evaluate the role of air recirculation as a predictor of postflight upper respiratory tract infections (URIs).

Design, Setting, and Participants A natural experiment conducted among 1100 passengers departing the San Francisco Bay area in California and traveling to Denver, Colo, during January through early April 1999, and who completed a questionnaire in the boarding area and a follow-up telephone interview 5 to 7 days later. Forty-seven percent traveled aboard airplanes using 100% fresh air for ventilation, and 53% traveled aboard aircraft that recirculated cabin air.

Main Outcome Measure Incidence of reporting new URI symptoms within 1 week of the flight.

Results Passengers on airplanes that did and did not recirculate air had similar rates of postflight respiratory symptoms. The rates of reporting a cold were 19% vs 21% ($P=.34$); a runny nose and a cold, 10% vs 11%, ($P=.70$); and an aggregation of 8 URI symptoms, 3% in both groups ($P>.99$). Results were similar after statistical adjustment for potential confounders.

Conclusion We found no evidence that aircraft cabin air recirculation increases the risk for URI symptoms in passengers traveling aboard commercial jets.

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Older aircraft that use only fresh air are being retired, and all new commercial aircraft are equipped to recirculate air. An evaluation of the differences between the effects of these 2 ventilation systems must be conducted before fresh air systems become obsolete. Our study aim was to evaluate the role of air recirculation as a predictor of postflight symptoms consistent with URIs.

METHODS

From January through early April 1999, we recruited subjects who were in designated passenger boarding areas at the San Francisco and Oakland, Calif, airports and who were en route to Denver, Colo. To sample evenly between airplanes that used fresh and recircu-

lated air, as well as to control for differences in aircraft, we targeted only certain airplane models. Boeing 737s and Boeing 727s have similar seating arrangements, cabin setup, seat density and pitch, cabin airflow patterns, and fuselage size, but 737s recirculate approximately 50% of the cabin air, whereas 727s use 100% fresh air. We also targeted flights using DC-10 models, equally sampling airplanes that used fresh and recirculated air. This infor-

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mation was provided to us by the participating airline.

To meet the inclusion criteria, subjects had to be 18 years or older, English speaking, willing to complete a brief questionnaire in the boarding area, and willing to complete a follow-up telephone questionnaire 5 to 7 days after the initial contact. They could not have engaged in air travel during the previous week (including a connecting flight on the interview day), have plans for additional air travel before the follow-up interview, or have a cold when the initial questionnaire was distributed. We attempted to recruit everyone who met our inclusion criteria in the boarding area during the hour before the flight. Participation implied consent, as approved for our study by the University of California, San Francisco, Committee on Human Research. A questionnaire collecting data on behaviors thought to be associated with URIs was then administered to willing and eligible participants in the boarding areas of these targeted flights. In an attempt to minimize bias, research assistants obtained information about the airplane model at the end of the preboarding recruitment period.

Follow-up of passengers in the Denver area occurred by telephone 5 to 7 days after the initial contact. This second questionnaire investigated possible URI symptoms during the week after the flight and subjects' knowledge and beliefs regarding the practice of air recirculation and the risk of URIs during air travel. To minimize bias, a separate group of research assistants who conducted the follow-up telephone interviews was blinded to aircraft type.

We assessed symptoms that suggested the presence of a URI by using the questionnaire developed by Jackson et al.¹¹ The least restrictive definition was self-report of a cold. The next most restrictive definition was the self-report of a cold and a runny nose, which is highly correlated with a clinical diagnosis of URI.¹¹ The most restrictive definition of URI was a Jackson score¹¹

(consisting of the sum of 8 respiratory symptoms, including headache, sneezing, chilliness, sore throat, malaise, nasal discharge, nasal obstruction, and cough, each measured from 0 to 3) that was higher than 13.

Most data are presented as simple percentages of nonmissing data. For some variables, data were missing for up to 30 passengers. Incidence of follow-up URI symptoms according to the 3 definitions was calculated for the 2 study groups: passengers on airplanes with partially recirculated air ventilation and those on airplanes with fresh-air ventilation. We used generalized estimating equations to examine the possibility that passengers on the same flight had unmeasured common exposures and were not completely independent.¹² The generalized estimating equations analysis estimated an interpassenger within-flight correlation of 0.02, which was not significantly different from zero. Therefore, simpler logistic regression models were used for most of the analysis. Dummy variables for flight week were used, and models were fit by using SAS PROC LOGISTIC and PROC GENMOD statistical software, version 8.1 (SAS Institute Inc, Cary, NC). We set statistical significance at $P \leq .05$.

RESULTS

Of those approached who qualified for the study, more than 90% agreed to participate. We enrolled 1501 participants and collected follow-up data on 1100 subjects (73% response rate). Respondents resembled nonrespondents, except the latter tended to have less child contact and to have been enrolled during February. Of the 401 nonrespondents, 337 (84%) were not reachable because of a lack of response to calls or incorrect contact information. The other 64 (16%) were disqualified from the study for having been inadequately screened on entry. A total of 516 (47%) of the 1100 respondents traveled aboard airplanes with fresh-air ventilation and 584 (53%) on airplanes with recirculated-air ventilation. There were 196 passengers on DC-

10s and 904 on 727 or 737 models. Of the 250 flights we studied, 114 (46%) used fresh-air ventilation systems, whereas the rest used recirculated air systems.

TABLE 1 compares the baseline characteristics of subjects flying on aircraft that recirculated cabin air with those flying on aircraft that used fresh-air ventilation. Subjects aboard airplanes that recirculated air were more likely to have sinus problems, to be older than 40 years, to be in first class, to have flown during March or April, and to have flown out of Oakland rather than San Francisco. Passenger density was not significantly different between aircraft types.

We performed univariate analyses of a variety of potential risk factors for the 3 definitions of URI symptoms to assess possible confounding. All 3 definitions were associated with having chronic URI symptoms, such as allergies, sinus problems, or asthma. Being female was predictive of the outcome of self-reported cold. Believing that air travel increases the risk of URI was not predictive of any of the 3 URI outcome measures.

We compared proportions of the 3 URI-symptom outcomes among passengers flying on airplanes with fresh-air and recirculated-air ventilation, without adjustment for group differences. There were no significant differences for any of the outcomes. Self-reported colds occurred in 21% of passengers in airplanes with fresh air and 19% of passengers in airplanes with recirculated air ($P = .34$). Self-reported colds and a runny nose occurred in 11% and 10% of these passengers, respectively ($P = .70$). Jackson scores higher than 13 occurred in 3% of both groups ($P > .99$).

We looked at odds ratios and 95% confidence intervals (CIs) for the 3 outcomes according to a multiple logistic regression analysis that included recirculation as a risk factor for postflight subjective cold and controlled for potential confounding variables that were not balanced in Table 1. These adjustments did not alter the finding that

cabin air recirculation was not a risk factor for developing the symptoms of a cold during the week after flight (TABLE 2).

COMMENT

We designed a natural experiment to compare outcomes for passengers flying on airplanes that used 100% fresh air vs airplanes that recirculated a substantial fraction of cabin air. The aircraft we selected were similar and flew identical routes. Since most passengers are unaware of whether a particular airplane recirculates or does not recirculate air when they make flight arrangements, the findings from this natural experiment resemble what would be found in a blinded clinical trial. Recirculation of cabin air did not emerge as a risk factor for the development of URI symptoms in our study. This finding assuages concerns regarding the risk of infectious diseases in recirculated cabin air¹³⁻¹⁵ and suggests that if there is a substantial increased risk of URI among flyers, the main route for transmission is not air recirculation.

There are, however, several limitations to this study. First, the study's size was limited, and the CIs reveal the possibility of having missed a modest effect. Second, the intergroup differences in some baseline variables were greater than expected. People aboard airplanes that recirculated cabin air were more likely to be older and have a history of sinus problems, characteristics that might make them more likely to report colds after flights.¹⁶ They were also more likely to have flown in March or April than in January or February and from Oakland rather than San Francisco. These differences, which reflect the fact that the unit of study was the airplane rather than the individual and that the type of airplane was not randomly allocated, did not alter the findings of the study, judging by statistical adjustment for the confounders and their clustering.

Another issue is the possibility of a dose-dependent effect of air recirculation that would become evident on flights that were longer than 2 hours. We were unable to study a longer flight

primarily because older airplanes that do not recirculate air are used almost exclusively on shorter routes.

The high incidence of subjectively reported postflight symptoms of URI in both groups may be in part due to a travel effect involving factors such as stress, sleep loss, crowding, and poor eating, which were not controlled for with this study design. The attack rate according to the most restrictive definition of URI symptoms (a Jackson score >13) revealed rates on the order of 3%, which are consistent with those of previous epidemiologic studies of URI incidence in people who were not travel-

ing by airplane.¹⁷⁻¹⁹ However, the Jackson questionnaire is a relatively nonspecific indicator of infection. In one study,¹⁹ only 40% of patients with clinical URIs by Jackson criteria had positive cultures by viral isolation and cell culture. Therefore, another limitation to this study was an inability to distinguish between true infection and nonviral causes of URI symptoms, such as barometric sinusitis, nasal irritation, and vasomotor rhinitis.

There are several unique aspects of this study. The natural experiment design takes advantage of passengers' lack of awareness of the air mixture used in

Table 1. Baseline Characteristics of Passengers Aboard Airplanes With Either Fresh or Recirculated Air

	Fresh, % (n = 516)	Recirculated, % (n = 584)	P Value
Health*			
Excellent	48	48	.28
Very good	42	41	
Good/fair	10	11	
History of allergies	39	41	.09
History of sinus problems	22	32	<.001
History of asthma	9	7	.17
Recent flu shot	25	30	.15
Sick contacts before first questionnaire	52	48	.14
Child contact before first questionnaire	18	20	.31
Age >40 y	49	58	<.001
Female	47	46	.56
Smoker	8	8	.88
First class	2	4	.05
Flight month			
January	43	16	<.001
February	28	21	
March/April	29	62	
San Francisco airport (vs Oakland)	79	51	<.001
Believe flying increases risk of upper respiratory tract infection	70	68	.32
Knowledge of practice of cabin air recirculation	63	67	.17
Ability to distinguish type of ventilation system (ie, fresh vs recirculated)	7	5	.13
Passenger density (passengers/100 seats)	78	77	.59

*Levels of health were self-reported in answer to the question "How do you describe your health."

Table 2. Multivariate Analysis of the Risk of Developing Cold Symptoms From Flying in an Airplane With Recirculated Air Compared With Fresh Air*

Symptoms of URI	No.	Odds Ratio (95% CI)	P Value
Reported a cold	215	0.97 (0.68-1.38)	.84
Reported a cold and runny nose	116	1.08 (0.70-1.67)	.72
Jackson score >13	36	0.99 (0.45-2.19)	.98

*CI indicates confidence interval. Multiple logistic regression analysis was adjusted for week of flight, prior contact with a sick person, sex, airport, preflight Jackson score, history of sinus disease or symptoms, history of asthma, history of allergies, and age.

different aircraft to replicate a blinded study. This study design would be difficult to duplicate. Airplanes with fresh-air ventilation systems have been retired from most major airline fleets, especially on longer flights, since the time of the study. Given recent events, gate access and airline participation would be difficult to obtain. We believe that this study was completed during a window of opportunity that is now largely gone.

In summary, we found no difference in the likelihood of self-reported

cold symptoms during the week after flight when comparing passengers traveling aboard aircraft using 100% fresh air with those traveling aboard aircraft that recirculate up to 50% of cabin air. It is encouraging that the now-widespread, fuel-efficient practice of air recirculation does not seem to increase the risk of transmission of URIs aboard aircraft on a 2-hour flight.

Author Contributions: *Study concept and design:* Zitter, Mazonson, Miller, Balmes.
Acquisition of data: Zitter.
Analysis and interpretation of data: Zitter, Mazonson,

Miller, Hulley, Balmes.

Drafting of the manuscript: Zitter, Mazonson, Hulley, Balmes.

Critical revision of the manuscript for important intellectual content: Zitter, Mazonson, Miller, Hulley, Balmes.

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