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Changes in ocular and nasal signs and symptoms among air crew in relation to air humidification on intercontinental flights

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Objective This study evaluates the influence of air humidification in aircraft on symptoms, tear-film stability, nasal patency, and peak expiratory flow.

Methods Commercial air crew (N=71) were given a medical examination during eight flights from Stockholm to Chicago and eight flights in the opposite direction. Examinations were done onboard one Boeing 767 aircraft equipped with an evaporation humidifier in the forward part of the cabin. The investigators followed the air crew, staying one night in Chicago and returning with the same crew. Four of the flights had the air humidification device active in-flight to Chicago and deactivated when returning to Stockholm. The other four flights had the inverse humidification sequence. The humidification sequence was randomized and double blind. Hygienic measurements were performed.

Results The humidification increased the relative air humidity by 10% in the 1st row in business class, by 3% in the last row (39th row) in tourist class, and by 3% in the cockpit. Air humidification increased tear-film stability and nasal patency and decreased ocular, nasal, and dermal symptoms and headache. The mean concentration of viable bacteria [77–108 colony-forming units (cfu)/m^3], viable molds (74–84 cfu/m^3), and particulate matter (1–8 μg/m^3) was low, both during the humidified and nonhumidified flights.

Conclusions Relative air humidity is low (10–12%) during intercontinental flights and can be increased by the use of a ceramic evaporation humidifier, without any measurable increase of microorganisms in cabin air. Air humidification could increase passenger and crew comfort by increasing tear-film stability and nasal patency and reducing various symptoms.

Key terms aerospace medicine; aircraft; airline crew; bacteria; dermal symptoms; indoor air pollution; molds; nasal congestion; ocular symptoms; tear-film break-up time.

An aircraft is the most common vehicle for long- and medium-distance transportation. According to statistics from the world's airline companies, a total of 1670 million passengers was transported in 2000. The number of passengers on intercontinental flights fell by 2.2% in 2001, after the September 11 events (1). The cabin environment is characterized by a low relative air humidity, typically between 5–25% (2–6). The longest exposure to dry air occurs during intercontinental flights, at cruising altitude (5). Previous studies of commercial aircrew have found a high prevalence of eye, nose, and throat symptoms (7–8), attributed to environmental tobacco smoke (9) or ozone (8) in the cabin. These exposures are rare nowadays, since smoking is not allowed on board and ozone converters are common. In contrast, low air humidity is still common on all intercontinental flights, but there is little empirical knowledge on the health effects of low air humidity in aircraft (10).

Controlled experimental field studies on office or hospital workers have shown that air humidification during winter may decrease dryness symptoms when relative humidity is increased from 20–30% to 30–40% (11–16). There may also be indirect negative health aspects of air humidification (17) that are related to microbial contamination in humidifiers (18). Recently, objective methods for studying environmental effects have been developed (9, 19–20) for use in studying physiological affects on the nose (21) or eyes (9, 16). In a recent air humidification study, an increase in relative air humidity from 35% to 43% caused a decrease in dermal symptoms but no detectable influence on the tear-film break-up time, nasal patency, or other symptoms

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(11). Air humidification in commercial aircraft has been tested by some airline companies, but there are no publications available on this topic.

The aim was to study the health effects of air humidification on airline crew working on intercontinental flights. The main focus was on ocular, nasal, and dermal effects, but other symptoms that could indirectly be affected by low air humidity were also included. Since low air humidity can indirectly influence other factors, the following hypotheses were tested: an increase in relative air humidity onboard can reduce ocular, dermal and airway symptoms, headache, and tiredness and increase tear-film break-up time, nasal patency, and peak expiratory flow.

Study population and methods

Participants in the in-flight investigation and study design

The research team made eight two-way trips (December 2001–October 2002) direct from Stockholm to Chicago and back directly to Stockholm, following the same aircrew back after one night in Chicago. All of the studies were done on the same aircraft personnel and the aircraft was equipped with a ceramic air humidifier and operated by the Scandinavian Airlines System (SAS). On each flight, there were eight cabin attendants and three pilots, all of whom were invited to participate in the study (N=88). In eight cases, the same persons had already participated on a previous flight, and were excluded, leaving a study population of 58 cabin attendants and 22 pilots (N=80), and 71 (89%) participated in both flight directions. SAS failed to install the 220 V AC-converter onboard three flights. On these flights, we could not perform acoustic rhinometry. The flights to Chicago were during the day, while the flights back were at night, according to the Swedish time zone. Four flights were performed with the air humidification device turned on inflight to Chicago and turned off in the opposite direction. The other four flights had the inverse humidification sequence. The humidification sequence was randomized, and no information on the sequence was given to the cabin attendants or the medical investigators (double-blind study). The captain would have been able to gain information on the status of the air humidification device from the flight log but was asked not to do so until he had returned to Stockholm.

Assessment of personal factors and symptoms

The participants were given a medical examination on board during the latter part of the 8- to 9-hour flight. The participants were interviewed by a physician or a nurse about allergy, occupation, and smoking habits. Atopy was defined as a current history of allergy to tree or grass pollen or furry animals. Current symptoms onboard were reported in a self-administered questionnaire that was handed out by the physician. The questionnaire was based on a previous questionnaire (9), but modified to harmonize with a larger EU-funded study on the cabin environment. It contained 23 symptom questions asking for the degree of symptoms on a 6-grade scale. No symptom was coded "0", very slight symptoms were coded "1", slight symptoms were coded "2", moderate symptoms were coded "3", strong symptoms were coded "4", very strong symptoms were coded "5", and unbearable symptoms were coded "6". The questionnaire asked about symptoms during a specific flight. In addition, there were questions on the amount of water and nonalcoholic beverages consumed during the flight. Musculoskeletal symptoms, stomach symptoms, and nausea or motion sickness were not included in the analysis.

Aircraft characterization

The same aircraft type (Boeing 767–300), with a total of 204 seats, was used on all of the flights. It has a cabin volume of 428 m^3 and a calculated ventilation capacity of 1320 l/s. The ventilation system normally provides approximately 50% recirculated air to the passenger cabin, leading to about 15 turnovers of fresh air per hour in the cabin or about 10 l of outdoor air per passenger and second. Occasionally, the pilot can shut off the recirculation fans for shorter periods, the result being a 100% fresh air supply and a twofold increase in the outdoor air flow. The air exchange rate in the cockpit is about 60 turnovers per hour. The ventilation or air conditioning system was equipped with a catalytic ozone converter, a high-efficiency particle air filter, and a charcoal filter. The air humidification device was a ceramic evaporation humidifier installed in the forward part of the aircraft, before the first row in business class. So that an accumulation of condensed water could be avoided in the wall construction, the exhaust air was dehumidified by means of a sorption dehumidifier.

Methods used to measure climate and air pollution in the cabin and at the crew hotel

In-flight measurements were performed in parallel with the medical investigation in the first row (business class) and last row (tourist class) (row 39), in the cockpit, and in the crew hotel in Chicago. Pumped air sampling was performed only in the cabin. Temperature, relative air humidity, and carbon dioxide were measured with a Q-Trackt™ IAQ Monitor (TSI Incorporated, St Paul, MN, USA) at a sampling of 1-minute average intervals. Particles were measured with both a P-Trak™ (model 8525

ultrafine particle counter, TSI), measuring particles in the size range of 0.02 to 1 μm, and a Dust-Trackt™ (model 8520, TSI), measuring particles approximately in the range of 1–10 μg (PM_{10}). The instruments were calibrated by the Swedish service laboratory for TSI equipment.

Airborne microorganisms were sampled on 25-mm nucleopore filters with a pore size of 0.4 m (1.5 l/min; 4-hour sampling time). The total concentration of airborne molds and bacteria was determined by the CAMNEA method (22). Viable molds and bacteria were determined by incubation on two different media. The detection limit for viable organisms was 30 colony-forming units (cfu) per cubic meter of air. Formaldehyde was sampled on glass fiber filters impregnated with 2,4-dinitro-phenylhydrazine (23) (0.2 l/min; 4-hour sampling time) and analyzed by liquid chromatography. Volatile organic compounds of possible microbial origin (MVOC) were sampled on charcoal tubes (Anasorb 747, SKC Inc, Eighty Four, PA, USA) (0.2 l/min; 4-hour sampling time). The tubes were desorbed by 2 milliliters of methylene chloride and analyzed by gas chromatography–mass spectrometry (GC-MS) with selective ion monitoring (24). The following 15 compounds were measured: *n*-butanol, isobutanol, 3-methyl-1-butanol, 2-methyl-1-butanol, 2-pentanol, 1-octene-3-ol, isobutylacetate, ethyl isobutyrate, ethyl 2-methylbutyrate, 2-hexanone, 2-heptanone, 3-octanone, dimethyldisulfide, 3-methylfuran, and 2-pentylfuran. The total concentration of the selected MVOC was calculated by adding the concentrations of detected MVOC, excluding the butanols.

Medical examinations

Acoustic rhinometry (Rhin 2000, SR Electronics, Lynge, Denmark) was performed at the end of the flight, the participant sitting after 5 minutes of rest, as previously described (9, 19–20). The minimal cross-sectional areas (MCA) on each side of the nose were measured from 0 to 22 mm (MCA1) and from 23 to 54 mm (MCA2) from the nasal opening. The volumes of the nasal cavity were measured from 0 to 22 mm (Vol1) and from 23 to 54 mm (Vol2). The mean values were calculated from three subsequent measurements on each side of the nose and presented as the sum of the values from the right and left sides. The tear-film break-up time was estimated with two methods, self-reported break-up time or measured break-up time. The break-up time measures the time a person can keep the eyes open without pain when watching a fixed point (20). The method has been used for cabin attendants (9), and it correlates well with the fluoresceine method (25). Tear-film stability was also observed directly, using a small eye microscope (Keeler Tearscope Plus, Keeler Ltd, Windsor, Berkshire, UK) without the addition of fluoresceine. The tearscope investigation was performed 1–2 minutes after the break-up time measurement. In addition, peak expiratory flow was measured.

Statistical analysis

The material was divided into two groups depending on the humidification sequence. For descriptive purposes, the prevalence of the participants with moderate to unbearable symptoms (coded 3–6) was calculated. For each symptom, the difference in the symptom scores was calculated, subtracting the symptom score on the flight back from Chicago to Stockholm from the symptom score obtained on the flight from Stockholm to Chicago. The differences in the clinical parameters were calculated in a similar manner. Finally, the group differences in the change in the symptom score or clinical parameter were tested with the use of the Mann-Whitney U-test. For the hygiene data, the differences in the concentrations of microorganisms and MVOC between the humidified and unhumidified flights were calculated with the use of the Mann-Whitney U-test, irrespective of the humidification sequence. Two-tailed tests and a 5% level of significance were used.

Results

Among the 71 participants, 75% were cabin attendants, 57% were women, 30% were current smokers, 15% had a history of atopy, and 3% (1 person) had physician-diagnosed asthma (3%). The mean age was 42 (SD 9) years. There were no significant differences in the prevalence of personal risk factors between the two groups, with a different humidification sequence, and the mean age was the same (table 1). To make the two groups

Table 1. Personal factors among the participants (N=71)—no significant differences, by Fisher's exact test.

Flight humidification conditions	Cabin attendant (%)	Female (%)	Current smokers (%)	Hay fever (%)	Fury pet allergy (%)	Doctor's diagnosed asthma (%)
Humidification to Chicago and no humidification from Chicago (N=38)	79	61	29	11	5	0
No humidification to Chicago(N=33) and humidification from Chicago	70	48	32	9	6	3

comparable, we excluded the person with diagnosed asthma.

The mean temperature was 23°C in the 1st row, 22°C in the 39th row, and 23°C in the cockpit . The temperature did not differ between the control and humidified conditions. Most of the flights were fully occupied. The mean carbon dioxide concentrations were 1100–1200 ppm in the cabin and in the 1st and 39th row, and about 800 ppm in the cockpit. When the air humidification device was active, the relative humidity increased by an average of 10% in the 1st row, 3% in the 39th row, and by 3% in the cockpit (table 2). The mean PM_{10} (particulate matter approximately in the range of 1–10 µm) concentration was 6 µg/m^3 in the 1st row during the control conditions and 1 µg/m^3 during the humidified conditions ($P<0.01$) The mean concentration of ultra-fine particles in business and tourist class were numerically lower during the humidified conditions (table 2). The concentration of ultrafine particles showed more variation from flight to flight. High concentrations of ultrafine particles, up to 300 000 particles/cm^3, were measured during one flight, when the aircraft was flying behind another aircraft at cruise level. Two other flights showed increased levels of ultrafine particles during 0.5–2 hours, without any clear reason. Finally, a regular, but moderate increase in ultrafine particles (10 000–20 000 particles/cm^3) was observed when bread was heated during the preparation of meals. At the crew hotel in Chicago, the concentration of PM_{10} was 4 µg/m^3, and the concentration of ultrafine particles was 1460 particles/cm^3. The mean concentration of viable bacteria (77–108 cfu/m^3) and viable molds (74–84 cfu/m^3) in the cabin was low during both the humidified and nonhumidified flights (table 3). The detected species included *Cladosporium species*, *Alternaria species*, *Penicillium species*, and yeast. There was a numerical

Table 2. Indoor climate, particles, and formaldehyde concentrations [a] during humidified and unhumidified conditions. (PM_{10} = particulate matter approximately in the range of 1–10 µm, UFP = ultrafine particles)

Location of humidifier	Temperature (°C)		Relative humidity (%)		Carbon dioxide (ppm)		PM_{10} (µg/m^3)		UFP (counts/cm^3)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Business class (row 1)										
Humidified	22.9	22–24	22	21–25	1160	1080–1300	1	1–2	230	100–210
Control	23.0	22–24	12	10–14	1120	940–1320	6	5–7	370	160–570
Tourist class (row 39)										
Humidified	22.1	21–26	14	11–15	1200	960–1400	5	4–8	190	60–330
Control	21.6	21–23	11	10–12	1160	1060–1300	5	2–7	580	50–2800
Flight deck										
Humidified	23.2	22–25	13	9–17	830	760–960	.. [b]	.	.. [b]	.
Control	23.2	22–25	10	6–15	800	710–1000	.. [b]	.	.. [b]	.

[a] The formaldehyde concentrations were below the detection limit (<3 µg/m^3) in all of the samples.
[b] Not measured.

Table 3. Microbiological exposure measurements (N=30) in the cabin, during humidified and nonhumidified conditions—a total of 20 measurements of MVOC, 5 measurements in each group. (Max = maximum, VOC = volatile organic compounds, MVOC = volatile organic compounds of possible microbial origin)

Location of humidifier	Microorganisms								Microbial VOC (MVOC)											
	Viable bacteria (cfu/m^3)		Total bacteria (1000/m^3)		Viable molds (cfu/m^3)		Total molds (1000/m^3)		*n*-Butanol (µg/m^3)		Iso-butanol (µg/m^3)		1-octene-3-ol (µg/m^3)		3-methylfuran (µg/m^3)		3-methyl-1-butanol (µg/m^3)		Sum of MVOC (µg/m^3) [a]	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Business class (row 1)																				
Humidified (N=7)	69	120	21	37	84	120	14	12	0.28	0.53	1.54	3.00	0.011	0.04	0.004	0.006	2.06	5.29	2.29	5.44
Control (N=8)	108	330	26	69	80	165	24	31	0.30	0.35	2.36	4.04	0.023	0.07	0.006	0.008	2.02	4.54	2.43	5.53
Tourist class (row 38)																				
Humidified (N=7)	77	130	13	55	78	130	8	27	0.29	0.53	1.64	2.25	0.018	0.05	0.004	0.007	1.99	3.03	2.32	3.72
Control (N=8)	101	230	22	120	74	115	16	73	0.28	0.36	1.86	4.37	0.017	0.05	0.007	0.010	2.09	5.41	2.47	6.50
Total concentration (N=30)	90	330	21	120	79	165	16	73	0.29	0.53	1.85	4.37	0.017	0.07	0.005	0.010	2.04	5.41	2.38	6.50

[a] Sum of 12 identified MVOC, excluding isobutanol and *n*-butanol.

decrease in the molds, bacteria , and MVOC by 50–80% during the humidified flights, but no difference was observed for the air concentrations of molds, bacteria, or MVOC between the measurements made in the 1st row and those made in the 39th row. At the crew hotel, the concentration of viable molds and bacteria were 290 cfu/m^3 and 150 cfu/m^3, respectively. The total concentration of bacteria was 15 000/m^3, and total concentration of molds was below the detection limit (<10 000/m^3).

The prevalence of moderate to unbearable symptoms was high, during both the humidified and the unhumidified conditions. Ocular symptoms, dry lips, throat dryness, skin dryness, and tiredness were the most common. The highest prevalence of symptoms was observed during the control flights back from Chicago (night flights), while the lowest prevalence was found on the humidified flights to Chicago (day flights) (table 4). When the changes in the symptom scores were compared in relation to the humidification sequence, many symptoms decreased when the air humidification device was active. The average magnitude of the reduction was 0.5–1.0 points on the 6-point scale when the humidifier was active, as compared with when it was inactive. The reduction was significant for dry eyes (P=0.006), watery eyes (P=0.04), eye irritation (itching, burning) (P=0.05), sneezing (P=0.03), nasal obstruction (P=0.02), skin dryness (P=0.002), facial irritation (itch, rash) (P=0.03), and headache (P=0.01) (table 5). In addition, there was an improvement of tear-film stability by 2–3 seconds, as measured by the tearscope method (P<0.001), and an increase in the minimum cross-sectional area (MCA_1) by 5–7% during the humidified conditions. No significant effect was observed for the peak expiratory flow, and the liquid intake was the same during flights with and without air humidification (table 6).

Discussion

We found that a moderate increase in relative air humidity with air humidification decreased the occurrence of ocular, nasal and dermal symptoms, and headache. Moreover, there was an increase in tear-film stability and nasal patency in the proximal part of the nose. This is the first intervention study on the health effects of air humidification in aircraft.

The strengths of this study were that it was experimental, blinded, and each participant was examined twice in the investigation, during humidified and non-humidified conditions. Selection bias was less likely since the participation rate was relatively high (87%). Recall bias due to an awareness of exposure might have affected the symptom reporting, but, in this study, neither the medical investigation team nor the air crew knew when the air humidification device was active. Twenty different symptoms and seven clinical parameters were investigated. Since several statistical tests were carried out, some findings could have been due to mass significance, but there was a consistent pattern in the findings. The main effects were observed for the eyes and upper airways (nose) and for skin dryness. This finding is biologically plausible. Moreover, the statistical significance levels were below 0.01 for many findings. Thus we do not believe that our overall conclusions are seriously biased by selection, response errors, or chance findings.

A large proportion of the participants reported symptoms during both the humidified flights and the control flights. This finding agrees with those of previous studies on aircrew (26, 7–9). The prevalence was highest on flights back from Chicago without air humidification. One explanation could be that these flights took

Table 4. Prevalence of symptoms among the nonasthmatics (N=70) during the humidified and unhumidified conditions.

Flight conditions	Prevalence of moderate, strong, very strong or unbearable symptoms (%)																			
	Dry eyes	Watery eyes	Eye redness	Swollen eyelids	Eye irritation [a]	Runny nose	Nasal itching	Sneezing	Nasal obstruction	Dry lips	Dryness in the throat	Sore throat	Cough	Difficulties in breathing	Dry skin	Facial skin irritation [b]	Ear problem [c]	Sinus pain	Headache	Tiredness
Humidification to Chicago (N=38)	39	5	18	3	18	16	11	8	11	50	21	3	5	0	32	3	5	3	3	26
No humidification from Chicago (N=38)	66	22	24	11	47	21	21	16	24	63	45	18	5	3	61	24	8	5	8	50
No humidification to Chicago (N=32)	28	13	16	6	9	22	6	16	22	31	25	19	9	3	47	19	6	0	9	16
Humidification from Chicago (N=32)	27	12	16	3	21	6	9	6	12	21	12	12	0	0	27	9	3	0	0	39

[a] Itching, burning.
[b] Itch, rash.
[c] Pressure, pain.

place during the night, according to the Swedish time zone, and thus the crew could have been more affected by jet lag. We could show that some symptoms were reduced after the air humidification was turned on, despite a moderate increase in the relative air humidity on board (3–10%). The air humidifier was the most efficient in the business section, near the air humidifier. The lower efficiency in the back of the cabin was probably due to the condensation of humidity in the cold wall of the aircraft. Our results agree with those of other experimental studies with air humidification in hospitals and offices (12–15), but these experiments were performed at higher air humidity levels (20–30%).

The concentration of airborne molds and bacteria in the cabin was low, both before and after the air humidification. This finding agrees with those of previous studies, reporting low levels of viable molds and bacteria in cabin air, typically 10–300 cfu/m^3 (6, 27–29). Air humidifiers can spread airborne microorganisms to the indoor air (17–18). Spray humidifiers are the most risky, while steam humidifiers ensure that the vapor is sterile. In our ceramic humidifier, the supply air is fed through a ceramic material, and the water slowly evaporates while it is transported by gravitation down on the ceramic surface, which is completely dry in the lower part. When the humidifier is not used, it is completely dry, and there should be little risk of microbial growth. The humidifier consumes about 200 liters of water per flight, from the ordinary water system on board. It is therefore important that the water has good quality from a microbial point of view.

In conclusion, relative air humidity is low during cruise conditions on intercontinental flights and can be slightly increased by the use of a ceramic evaporation

Table 5. Change of in the symptom score among the nonasthmatics (N=70) in relation to the humidification sequence—difference expressed as the symptom score on the flight back to Stockholm minus the symptom score on the flight to Chicago.

Symptom	Humidification to Chicago and no humidification from Chicago (N=38)		No humidification to Chicago and humidification from Chicago (N=33)		Two-tailed P-value [a]
	Mean change in symptom score	SD of change	Mean change in symptom score	SD of change	
Dry eyes	0.82	1.11	–0.09	1.38	0.006
Watery eyes	0.68	1.31	0.03	1.02	0.04
Eye redness	0.24	1.34	0.00	1.00	NS
Swollen eyelids	0.42	1.24	0.25	0.95	NS
Eye irritation (itching, burning)	0.82	1.44	0.16	1.57	0.05
Runny nose	0.26	1.03	–0.38	1.79	NS
Nasal itching	0.46	1.24	–0.13	1.31	NS
Sneezing	0.37	1.00	–0.41	1.16	0.03
Nasal obstruction	0.68	1.38	–0.19	1.45	0.02
Dry lips	0.34	1.17	–0.25	1.41	NS
Dryness in the throat	0.53	1.72	–0.19	1.15	NS
Sore throat	0.61	1.35	0.03	1.38	NS
Cough	0.05	1.06	–0.41	1.16	NS
Difficulties in breathing	0.24	0.68	–0.13	0.61	NS
Dry skin	0.50	1.47	–0.66	1.49	0.002
Facial skin irritation (itch, rash)	0.38	1.34	–0.34	1.00	0.03
Ear problem (pressure, pain)	–0.03	0.64	–0.10	1.14	NS
Sinus pain	0.11	0.72	–0.19	0.54	NS
Headache	0.26	1.03	–0.47	1.08	0.01
Tiredness	1.16	1.00	0.65	1.38	NS

[a] Calculated with the use of the Mann-Whitney U-test.

Table 6. Physiological signs and liquid intake among the nonasthmatics (N=70) during the humidified and nonhumidified conditions. (BUT = tear-film break-up time, MCA_1 = anterior minimum cross-sectional area, MCA_2 = posterior minimum cross-sectional area, Vol_1 = anterior nasal volume, Vol_2 = posterior nasal volume, PEF = peak expiratory flow)

Flight conditions	BUT (tearscope)		Self-reported BUT(s)		MCA1 (cm^2)		MCA2 (cm^2)		Vol1 (cm^3)		Vol2 (cm^3)		PEF (ml/s)		Liquid intake (l/flight)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Humidification to Chicago and no humidification from Chicago																
To Chicago (N=38) [b]	7.7	2.6	9.4	10.1	1.10	0.22	1.16	0.28	4.02	0.51	9.82	2.74	519	119	0.85	0.44
From Chicago (N=38) [b]	5.0	2.2	7.8	9.2	1.05	0.27	1.10	0.24	3.92	0.79	9.07	3.14	510	119	0.89	0.44
No humidification to Chicago and humidification from Chicago																
To Chicago (N=32) [c]	7.3	3.8	12.0	12.0	1.05	0.25	1.35	0.37	3.92	0.73	10.33	2.08	535	110	0.99	0.54
From Chicago (N=32) [c]	9.2	10.0	11.4	11.2	1.12	0.30	1.35	0.38	4.06	0.91	9.62	3.04	522	111	1.01	0.44
2-tailed P-value [a]	<0.001		NS		0.02		NS		NS		NS		NS		NS	

[a] Calculated with the use of the Mann-Whitney U-test comparing the differences in the changes between the two groups, differences expressed as the parameter value on the flight back to Stockholm minus the value on the flight to Chicago.
[b] 36 subjects participated in BUT(s), 24 in BUT (tearscope), 16 in rhinometry, and 38 in the measurement of peak expiratory flow.
[c] 30 subjects participated in BUT(s), 29 in BUT (tearscope), 27 in rhinometry, and 30 in the measurement of peak expiratory flow.

humidifier without any measurable increase in microorganisms in cabin air. An increase in the relative air humidity on intercontinental flights could be beneficial from a health point of view since tear-film stability and nasal patency are increased and headache and ocular, nasal, and dermal dryness symptoms are reduced.

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