

Increased net water loss by oral compared to nasal expiration in healthy subjects*

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SUMMARY

Aim of the study: To compare the difference in respiratory water loss during expiration through the nose and through the mouth, in healthy subjects.

Methods: The study included 19 healthy, non-smoking volunteers without any present history of non-infectious rhinitis, presenting with symptoms of rhinitis, asthma or previous nasal surgery. Nasal and oral expiratory breath condensates were collected using a breath condenser during tidal respiration at indoor resting conditions. During the nasal breath condensate sampling, the subjects were breathing into a transparent face mask covering the nose and the mouth with the mouth closed. During the oral breath condensate sampling, the subjects inhaled through the nose and exhaled through a mouthpiece connected to the condenser. The air flow during the sampling was assessed with a dry-spirometer connected to the condenser. Sampling was stopped after 100 litres of expired air for each breathing mode. Nasal sampling was done before and after decongestion of the nasal mucosa with oxymetazoline, 0.5 mg/ml. The effect on the nasal mucosa was assessed with acoustic rhinometry.

Results: The mean loss of expired water was 42% less by nasal expiration before decongestion than by oral expiration (1.9×10^3 g/Lmin compared to 2.7×10^3 g/Lmin, $p < 0.001$). The mean expiratory minute ventilation was 9.0 L/min by nasal respiration and 9.8 L/min by oral respiration. Decongestion of the nasal mucosa showed a mean increase of the cross-sectional area at 4 cm from the nostril (1.44 to 1.67 cm², $p = 0.0024$), but there was no effect on the net water loss (1.9×10^3 g/Lmin vs 1.9×10^3 g/Lmin).

Conclusion: This study showed that the net water loss increased by 42% when the breathing mode was switched from nasal to oral expiration during tidal breathing in healthy subjects. Increased water and energy loss by oral breathing could be a contributing factor to the symptoms seen in patients suffering from nasal obstruction.

Key words: condensation, nasal, oral, water loss, acoustic rhinometry

INTRODUCTION

One of the most important functions of the nose is to warm and humidify the inhaled air before it reaches the lung. This mechanism depends on the blood flow of the nasal mucosa and on the heat and water recovery from expired air [1].

Several clinical studies have evaluated the humidifying capacity of the nasal mucosa during inspiration but there is little data on the nasal capacity to recover water during expiration [2]. The amount of water that is being condensed from the warm air passing through the nose during expiration depends on the temperature of the nasal mucosa. In vivo measurements during quiet expiration have shown that the mean temperature of the nasal mucosa is 34.4 C during normal in-door conditions [1]. In a theoretical model of the heat and water exchange in the respiratory tract, Tsu et al. [3] predicted the respiratory

water loss (RWL) to be 0.298g/min at 34°C during nasal breathing while it would be 63% higher during oral breathing (0.487g/min). This estimation was not supported by the clinical results from a small study on 4 subjects where the difference in water loss between nose and mouth breathing was only 5% [4]. Data from interviews with a large number of subjects suffering from nasal congestion, however, show that thirst is a common problem among patients with nasal congestion indicating a more pronounced water loss when breathing through the mouth than through the nose [5].

Sampling of exhaled breath condensate is a comparatively new method where exhaled air is cooled and the humidity in the air is condensed into water [6]. This method has predominantly been used for analyses of inflammatory markers and pH in orally exhaled air from the lower respiratory tract. In the pre-

sent study we have used this method to collect and compare the amount of exhaled breath condensates from the nose and mouth during quiet breathing.

The aim of the present study was to determine *in vivo* the net water loss between nasal and oral expiration in a group of healthy subjects.

MATERIALS AND METHODS

The study was approved by the local ethics committee at the Sahlgrenska University Hospital, Göteborg, Sweden.

Study population

The study population consisted of healthy volunteers (n=19, 11 females, 8 males). Subjects were given spoken and written information and were included after written consent. Exclusion criteria were current smoking, a history of perennial nasal allergy or nasal hyper reactivity, previous nasal surgery, asthma or present nasal medication. Subjects with a history of hay fever were not excluded as the study was performed out of the pollen season.

Sampling

Breath condensate was collected with an Eco Screen breath condenser (Jaeger, Würzburg, Germany). The breath condenser was fitted with a two-way, non-re-breathing valve connected to a mouthpiece or a face mask (depending on the sampling mode) and a dry spirometer (Jaeger). Exhaled air from the subject was led into a Teflon coated, aluminium lamellar tube with a polyoxymethylene container at the bottom end. The vapour of the exhaled air was condensed in the collection tube, embedded in the condenser at a temperature of -20°C. The collection tube was weighted before and after the measurement (Scales PL 602-S, Mettler Toledo, Stockholm, Sweden) and the weight was registered with an accuracy of 0.00g.

The amount of collected breath condensate was calculated as the gain in weight between the two weightings and registered in grams.

Sampling of exhaled breath condensate was made during three different breathing modes:

1. Inspiration and expiration through the nose before decongestion of the nasal mucosa.
2. Inspiration and expiration through the nose, 10 minutes after decongestion of the nasal mucosa with oxymetazoline 0.5 mg/ml, 1ml/nostril.
3. Inspiration through the nose and expiration through the mouth.

The subjects were asked to breathe quietly and in a similar manner through the three measurements (nasal breathing, decongested nasal breathing, and oral breathing).

Orally exhaled breath condensate is usually collected using an oral cannula that the subject breathes into. Because a face mask was used for the nasally exhaled breath condensate, we compared the amount of orally exhaled breath condensate col-

lected using a nose clip and face mask to that using an oral cannula, during 100 L of tidal breathing, in a series of 8, before the study began. We found an average of less than 1% more condensate using the cannula than using the face mask and a nose clip. The cannula was selected for the orally exhaled breath condensate in this study because it is easier for the subject to breathe orally into a cannula than to breathe with an open mouth into a face mask wearing a nose clip. The risk of air leakage is also less using a cannula than using a nose clip inside a mask.

The total expired volume in litres and the accumulated time of the expirations in minutes were registered by the spirometer connected to the breathing valve of the condenser, Eco Screen® (Jaeger). The spirometer was calibrated before each measurement session using a 3L calibration syringe (Hans Rudolph Inc, Kansas City, USA). Each condensation was stopped at a total expired volume of 100L and the subjects were instructed to maintain total expiration time between the measurements in order to maintain a similar expiratory minute volume.

Acoustic rhinometry

Intranasal geometry was assessed with acoustic rhinometry (Rhinometrics®, Copenhagen, Denmark) before and after decongestion of the nasal mucosa. The probe was fitted with anatomical nosepieces, one for each side (Rhinometrics®). The probe was handheld and Vaseline gel was used to seal between the nosepiece and the nostril. The subjects were sitting in a supine position. Three similar recordings were made while the subjects were holding their breaths, and a mean of the three recordings was used for the calculation.

The nasal mucosa was decongested with oxymetazoline 0.5 mg/ml droplets (Nezeril®, Astra, Sweden), one pipette (1ml) in each nostril. The nose was considered decongested after 10 minutes.

Within subject variation was evaluated in a series of repeated measurements on 2 subjects. Recordings were made four times during one day with a 2h interval. In some of the measurements the order between nasal and oral expiration was reversed.

Statistical analyses

Since the total condensate collected depends on the total expired volume and the time duration of the expirations (the time the expired air was in contact with the condenser) we created a formula for the condensate production.

$$\text{condensate production} = \frac{\text{produced condensate (g)}}{\text{total expired volume (L)} \times \text{total expiration time (min)}}$$

Comparison between nasal and oral condensate volumes and acoustic rhinometry data were made with student's t-test (SAS, soft ware package).

Table 1. Baseline data.

	Men	Women	Total/mean
n	8	11	19
Age	40.4 years	45,5 years	43,3 years
BMI	24.7 kg/m ²	22,9 kg/m ²	23,6 kg/m ²
Hay-fever	1	8	9

Table 2. Mean cross-sectional area and mean condensate production in g/Lmin exhaled air. (BD=before decongestion, AD= after decongestion, Prod diff= production difference).

	cm ²	g/Lmin	p value
Cross-sectional area 4cm BD	1,44		
Cross-sectional area 4cm AD	1,67		
Difference Cross-sectional area 4 cm	0,23		0,0024
Nasal prod BD		1,9*10 ⁻³	
Nasal prod AD		1,9*10 ⁻³	
Prod mouth		2,7*10 ⁻³	
Prod diff before and after decon		0.0*10 ⁻³	n.s
Prod diff nose before decon and mouth		0,8*10 ⁻³	<0.001

RESULTS

Baseline data for the subjects are shown in Table 1. The mean age of the subjects was 43.3 years and the mean Body Mass Index (BMI) was 23.6 kg/m². Nine subjects had a history of hay fever, but none had any present nasal symptoms because the study was done out of the pollen season. The individual production of exhaled condensate is shown in Figure 1. Due to technical failure the data concerning nasal production after decongestion for individual 1 was lost. All subjects had had a higher production of oral exhaled breath condensate than nasal exhaled breath condensate before decongestion. Mean expiratory condensate for the three different breathing modes and the data on acoustic rhinometry are shown in Table 2. There was a significant increase in nasal mean cross sectional area at 4cm from the nostril after decongestion (1.44 vs 1.67 cm², p=0.0024) measured by acoustic rhinometry, but no difference between mean nasal exhaled breath condensate production before and after decongestion (1.9x10⁻³ vs 1.9x10⁻³ g/Lmin, ns). There was a significant difference in mean oral exhaled breath condensate production compared to nasal exhaled breath condensate production before decongestion (2.7x10⁻³ vs 1.9x10⁻³ g/Lmin, p<0.001). The oral exhaled breath condensate production thus was 42% higher than the nasal exhaled breath condensate production before decongestion. The mean expiratory flow rate was 9.0 L/min for nasal expiration before decongestion and 9.8 L/min for oral expiration.

DISCUSSION

In this study on healthy subjects, the expiratory loss of water was 42% higher when exhaling through the mouth compared to exhaling through the nose during tidal respiration. Water recovery in the nose during expiration is considered to be an important part of normal nasal function, but has to our knowl-

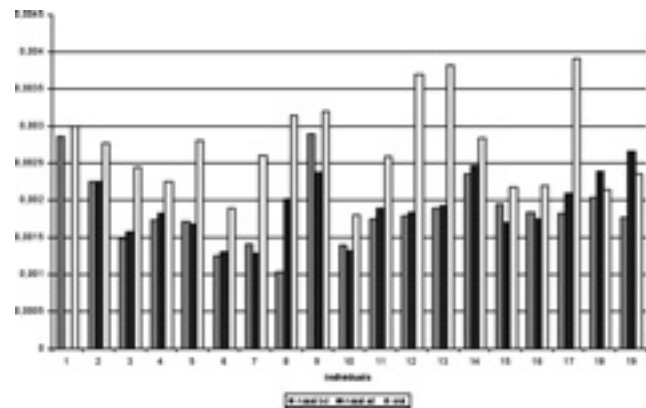


Figure 1. The condensate production (g/minL) exhaled air from nose before decongestion= bd, after decongestion= ad and from the mouth= oral. Missing data column 1.

edge not been thoroughly evaluated in a clinical study before. Using breath condensation we found a loss of expiratory water that was 8 times higher than previously found in a small study of 4 individuals. Compared to the previously predicted theoretical model of tidal respiration by Tsu et al. [3], both the nasal condensate rate and the oral condensate rate were lower, but even though the difference in water loss between nasal and oral expiration was lower than predicted (42% vs 63%), the study confirms that the nose has a significantly higher ability to recover water from exhaled air than the oral route.

In absolute terms the loss of water during quite oral expiration compared to nasal expiration is small (111g/24h) and can easily be compensated for by drinking. If, however, mouth breathing increases, as in sleep or physical activity, there may be a bigger impact on the water homeostasis. Patients with perennial rhinitis, having persistent nasal obstruction and habitual snorers who predominantly expire through the mouth often complain of dryness of the mouth, especially at night and in the morning. Dryness of oral mucosa decreases the barrier function and increase the risk for secondary morbidity. Dryness of the oral cavity is also a well known risk factor for caries.

This is the first study to our knowledge where a condenser for exhaled breath condensate has been used to address the physiology of nasal water exchange. In the study we could readily collect nasal breath condensate by fitting the condensate analyser with an anaesthetic face mask covering the mouth and the nose. Since breath condensate is predominantly water, we decided to weigh the accumulated breath condensate.

It has been predicted that the breath condensate collected during tidal breathing depends on the volume of the expired air and the time that the expired air is in contact with the condenser. It has recently been shown with orally exhaled breath condensate that the minute volume is important for the volume of breath condensate collected [7]. In this study we thus used a fixed volume of 100L of expired air and the subjects were encouraged to maintain a constant breathing mode

through all three measurements which resulted in a similar expiratory flow rate between nasal and oral expiration (9.0 vs 9.8 L/min).

It has been suggested that increased swelling of the nasal mucosa, insulates the warm air-stream from the capillary vessels of the nasal mucosa, and thus, the condensation is more effective due to a cooler mucosal surface. In this small sample of healthy subjects we did not find a difference in the volume of condensate before and after decongestion of the nasal mucosa.

All the subjects in this study were measured in the same order according to their breathing mode, beginning with nasal expiration before decongestion, followed by nasal expiration after decongestion and finally oral expiration. In order to evaluate if the order of breathing mode affected the obtained volumes, 2 subjects made repeated measurements during a day with a reversed order of breathing in half of the measurements, but this did not affect the relative volumes between nasal and oral exhalation.

In this study we have used sampling of exhaled breath condensate to measure the loss of expiratory water during nasal and oral expiration and we found a 42% lower loss of water during nasal expiration.

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