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Ambient cold air decreased nasal mucosa blood flow measured by laser Doppler flowmeter*

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SUMMARY

Background: *With its potentially conflicting physiological roles of both air-conditioning and body-heat recovery, the response of nasal mucosa blood flow (NMBF) to ambient cold air is not well understood.*
Objective: *To evaluate the NMBF in response to cold ambient air.*
Methods: *The NMBF was continuously measured by laser Doppler flowmetry in nine participants exposed to different air temperatures (24°C and 4°C).*
Results: *The NMBF significantly decreased at 4°C compared with that at 24°C ($p < 0.01$).*
Conclusion: *The response to ambient cold air in the nasal microcirculation is similar to that of the body-surface blood vessels, suggesting that body-heat recovery rather than air-conditioning is the predominant function.*

Key words: blood flow, nasal mucosa, inferior turbinate, low temperature, human

INTRODUCTION

In our previous study, we found that lowering temperature decreased the isometric tension recorded in isolated turbinate mucosa [(1)]. In the above experimental setting, such tension changes were deemed to be a reflection of vasodilation or vasoconstriction of the nasal mucosa [(2)]. If the tension decreases as the nasal mucosa temperature drops, it may suggest vasodilation of the nasal mucosa with resultant increased blood flow in response to cold air temperature in vivo. Exposure to cold causes cutaneous vasoconstriction to reduce body-heat loss, whereas the nasal cavity warms up the inspired cold air. With its potentially conflicting physiological roles of both air-conditioning and body-heat recovery, the response of the nasal mucosa blood flow (NMBF) to cold ambient air is not well understood. In the literature, NMBF decreased when cold stimuli were applied to the forehead [(3)] and feet [(4)]. However, the response of the NMBF to ambient cold air had not been investigated. Thus, the aim of the study is to elucidate the response of the NMBF to ambient cold air.

METHODS

Participants

The study was performed with nine healthy participants, (4 women and 5 men, aged 38 to 22 years, mean age 29 years). They were taking no medication before the study and had a normal rhinoscopic examination. All participants had neither symptoms of the common cold nor of allergic nasal disease. No physical activity was allowed before the test.

Blood flow measurement

The participants were asked to remain in an upright sitting position while the NMBF was recorded. The laser Doppler flowmeter (Periflux 4001, Perimed, Sweden) with the standard probe was applied at a right angle to the anterior part of the inferior turbinate mucosa. Gentle placement of the probe without pressure is important to avoid compression of the superficial blood vessels. The probe was held immobile and in position by attachment to a head mirror modified with stationary metal bars. The participants were asked to sit quietly and breathe normally exclusively through the nose for 10 minutes in a room held at a temperature of 24°C with 65% humidity. Then the participants moved to the cold-air room (4°C), which was 3 meters away from the 24°C room, with continuous measurement of NMBF. The participants were asked to wear a jacket before entering the cold-air room.

Statistical analysis

Results were expressed as mean ± SEM. Student's paired t-test was used for statistical evaluation. The difference was assumed to be significant at $p < 0.05$.

RESULTS

All the tests in the nine participants were conducted smoothly without any difficulty. Although there were some variations between each participant, the value of the NMBF at 4°C was lower than that at 24°C for each individual (Table 1). The average value of the NMBF at 24°C was 306.1 ± 182.5 (arbitrary

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Table 1. The gender, age, nasal mucosa blood flow (NMBF) in 24°C and 4°C, and difference of the 9 subjects.

No.	Gender	Age	NMBF in 24°C	NMBF in 4°C	Difference
1	M	38	219	66	153
2	F	22	503	305	198
3	F	30	571	385	186
4	M	34	423	311	112
5	M	27	163	57	106
6	M	29	212	99	113
7	F	24	120	59	61
8	F	30	201	110	91
9	M	31	84	27	57

units); and the average of the NMBF at 4°C was 188.9 ± 143.4. The NMBF at 4°C was significantly decreased when compared with that at 24°C ($p < 0.01$; Figure 1).

DISCUSSION

The effects of ambient temperature on the nose have been the subject of numerous studies [5,6]. However, the response of human NMBF to cold ambient air was rarely explored. The microvasculature of the nose consists of dense subepithelial fenestrated capillaries; highly developed venous sinusoids which, when overdistended, may lead to nasal obstruction; and arteriovenous anastomoses, which are believed to be important in air-conditioning [7]. At present, there are two techniques that are useful for measuring the microcirculatory parameters of the NMBF: the radioactive Xenon washout method and laser Doppler flowmetry [8]. The radioactive Xenon washout method involves the injection of a Xenon tracer into the nasal mucosa. Theoretically, increases in NMBF generate more rapid decreases in the radioactivity recorded by a gamma counter in front of the nasal cavity. The disadvantages of the Xenon washout method in detecting NMBF include the pain reflex evoked by the injection needle, which may activate the sympathetic nervous system and trigger unwanted vasoconstriction in the nasal mucosa, and injection-induced swelling of the nasal mucosa. On the other hand, the laser Doppler flowmetry method involves laser light emitted by the transmitting fiber that is scattered and partly absorbed by the nasal mucosa. Some of the light hits the moving red blood cells within the blood vessels, producing a change in wavelength (Doppler shift effect); while light that hits motionless objects is unchanged. The frequency and magnitude distribution of these changes in wavelength are directly related to the number and velocity of the blood cells in the tissue sample. The information is gathered by a receiving fiber, converted into an electronic signal, and analyzed (Figure 2). The advantages of laser Doppler flowmetry include noninvasiveness and its ability to provide a dynamic impression of mucosal blood flow response to specific provocation challenges over time.

In our previous study, we demonstrated that moderate cooling (24°C) enhanced the in vitro vascular contractile responsiveness of the nasal mucosa, suggesting a similar vascular response to cooling between the nasal mucosa and the cutaneous blood vessels [9]. In this study, we demonstrated that the NMBF decreased as the ambient air temperature dropped from 24°C to 4°C. The decreased NMBF at low temperature may facilitate heat recovery because it leads to a greater temperature difference between the turbinate mucosa and the expiratory airflow. Thus, cooling the warm expiratory air may be regarded as an important factor for heat recovery [10]. The nose acts as a heat conservation mechanism in cold environment by cooling of the expired air as it travels toward the outside. One study indicated that cold inspired air was rapidly warmed in the nose [6]. Another study revealed that nasal airflow resistance was not affected by a change in the temperature of the inhaled air only [5], whereas a warm environment caused a fall and a cold environment possibly caused a rise in

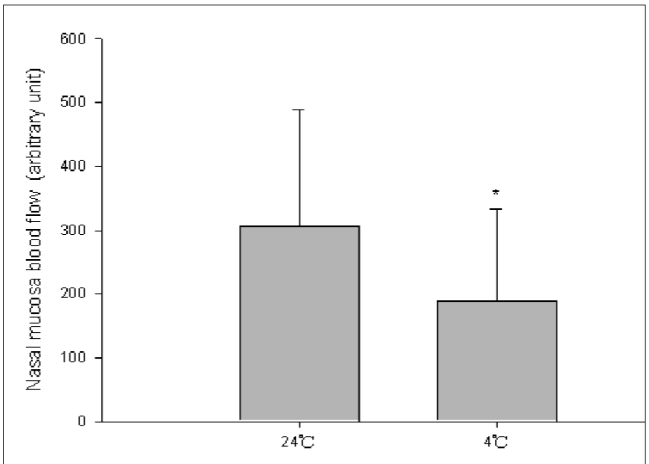

Figure 1. The average of nasal mucosa blood flow in different temperature measured by laser-Doppler flowmeter. Each point represents mean ± SEM (n = 9). The difference of the means was statistically significant.

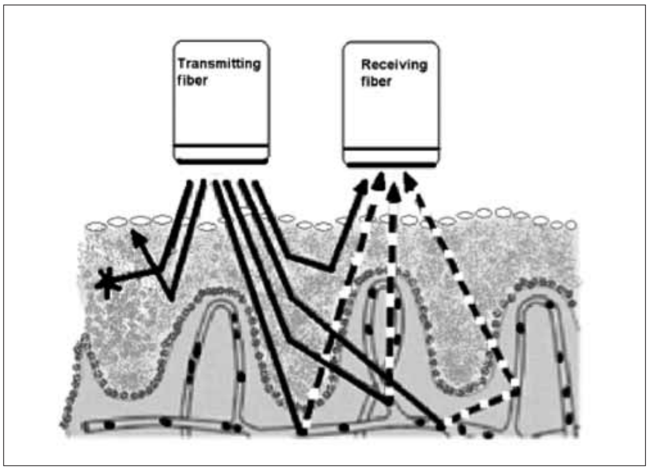

Figure 2. Theory of laser Doppler flowmeter. The laser light hit the moving red blood cells within the blood vessels and thus have a change in wavelength (Doppler shift effect, dotted line) while light hitting motionless objects is unchanged (solid line).

nasal airflow resistance. No effect on the lower airways was observed with inspired air temperature. Nevertheless, decreased NMBF in cold environments also leads to further cooling of the nasal airway, which compromises nasal defense mechanisms against infection and, theoretically, causes increased susceptibility to viral infections of the upper-respiratory tract [11]. A moderate fall in nasal flow rate of the nose was observed with temperature below 23°C. Cold air might cause an increased susceptibility to airborne infection. The infection might result through impaired mucociliary function or resort to mouth breathing secondary to increased nasal airflow resistance [5]. Also, rhinoviruses have been shown to be associated with about half of all common colds throughout the year [12]; and lower airway temperatures will facilitate their replication [13]. Therefore, it appears that decreasing the NMBF in cold environments is a trade-off between body-heat recovery and susceptibility to viral infections of the upper respiratory tract. Interestingly, one study suggested that warming of the feet elevates the surface temperature of the nasal mucosa, which is believed to be associated with mucosal vasodilation, and leads to a reduced response to challenge with nasal allergens [14]. It seems that keeping the feet warm can also keep the nose warm and, thus, enhance the appropriate immune response of the nasal cavity. Our study demonstrated that the response of NMBF to cold air is similar to that of the body surface. Further study is needed to elucidate the detailed mechanism responsible for this response.

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