ORIGINAL ARTICLE

Detection of the Nasal Cycle in Daily Activity by Remote Evaluation of Nasal Sound

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Objectives: To detect the nasal cycle in healthy subjects while they were performing their daily activities, using the Odiosoft-Rhino (OR) software program and to investigate the ability of the OR program to perform this procedure.

Design: Prospective analysis.

Setting: Tertiary referral center.

Patients: Twenty healthy adult volunteers.

Interventions: Investigation of the nasal cycles of volunteers by the OR program every 30 minutes over a period of 12 hours on 4 different days in the same week. Each subject performed expiration every 30 minutes into a microphone, and the nasal sounds were recorded separately for each nasal cavity.

Main Outcome Measures: The OR data collected during 12 hours for 4 days were analyzed for cyclic nasal obstruction.

Results: The nasal sounds were calculated for each of the nasal cavities and a 2000- to 4000-Hz frequency interval was used for evaluation. In all of the individuals investigated in this study, a cyclic change of nasal patency was detected by the OR program. All of the data were calculated to be significantly different for each nasal cavity ($P < .05$ for all comparisons). Changes of nasal sounds and comparison of the 2 sides demonstrated that the total amount of cyclic changes ranged between 30 minutes and 2 to 2.5 hours.

Conclusions: With the help of the OR program, we detected the nasal cycles in all of the volunteers, and the periods were not less than 30 minutes or more than 2.5 hours. Because the data collection period was long and the patient compliance was maximal, we believe that the results in the study are more reliable and natural.

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SPONTANEOUS, RECIPROCAL changes in nasal patency are termed *the nasal cycle*. The nasal cycle is caused by decongestion and congestion of cavernous tissues of the nasal mucosa,[1] which is probably regulated by the hypothalamus.[2] The ideal cycles have identical periods in the right and left sides of the nose with a duration ranging from 30 minutes to 6 hours, but 180° out of phase.[3] The functional significance of the nasal cycle is not known, and textbooks and published literature on the nose cannot exactly explain this phenomenon.[4,5] It may have a role in humidification or as a defense function of the nose. By effecting nasal airflow, especially the degree of turbulence, the nasal cycle may play a role in the respiratory function of the nose.[1,6] The nasal cycle can be demonstrated in most awake and sleeping adults.[7] After the first detection of the nasal cycle by Kayser[8] in 1895, many studies were performed to detect the presence of the nasal cycle using rhinoscopy, congestion scoring, mirror fog tests, optical instruments, thermography, magnetic resonance imaging, acoustic rhinometry (AR), rhinoresistometry, and rhinomanometry (RMM).[1,3,9,10]

The software program Odiosoft-Rhino (OR) investigated in this study seems to be a useful and handy method to measure nasal obstruction by evaluating the nasal airflow from the nasal sounds generated during respiration. The computerized analysis of the nasal sound reflects the nasal airflow and may be used in a variety of nasal diseases and for screening purposes, and it may lead to a new diagnostic method.

In this study, the nasal cycle was objectively investigated by the OR program in 20 healthy volunteers working in call centers of 3 different companies at intervals of 30 minutes over 12 hours on 4 different days in the same week while they were performing their daily activities, and the collected data were transferred to investigators' computers via the Internet for processing. In this way, the degree of nasal obstruction over a 12-hour period and for 4 days was monitored without disturbing the activities of the volunteers, and all the data were collected via the Internet in the form of "wav" files.

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METHODS

The nasal cycle in each nasal cavity of 20 healthy adult volunteers (11 men and 9 women) was investigated using the OR program. During the selection of the volunteers, an e-mail invitation was sent to 1962 people, and 38 subjects who met the inclusion criterion listed below were enrolled in the study:

1. Subjects had to have a body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) of 22 to 25.
2. Subjects had to be nonsmokers.
3. Subjects had to work in an office in which the temperature and humidity of the air were stabilized at 22°C to 25°C and 50% to 60%, respectively, by a central air conditioning system.
4. Subjects who worked 12-hour shifts and used a computer could not leave the office except 2 times for meals.
5. Subjects could not have nasal breathing problems or a history of nasal trauma, nasal surgery, allergic rhinitis, nasal polyps, use of nasal medications or steroids, recent or recurrent upper respiratory tract infections, or any other health problems.

The subjects were advised to visit their ear, nose, and throat physicians, and endoscopic nasal examinations were performed. Among these volunteers, those who had no nasal complaints and who had normal nasal examination findings were invited to our department and underwent AR, RMM, prick test, and nasal smear tests for assessment of eligibility. The study was explained to these subjects, and informed consent was obtained from each volunteer. Also, our local ethical board approved the human subjects research protocol. Among these 38 volunteers, 20 subjects with no nasal symptoms or complaints and whose nasal examinations and tests were within reference range were selected. After the selection of the subjects, an external 16-bit sound card (AC-XGWDM Audio; Yamaha, Hamamatsu, Japan) and an OR microphone were sent to each of them with a video recording that explained how to adjust and use the sound card and the microphone and make the recordings.

A test battery was applied every 30 minutes over a period of 12 hours on 4 different days in the same week. Each subject performed a nonforced expiration every 30 minutes into the microphone, and the nasal sounds were recorded separately for each nasal cavity. The microphone was situated 1 cm away from the nostril, and the other nostril was occluded with the subject's thumb, avoiding distortion of the shape of the nose. The recordings were collected for 4 different days in the same week (24 recordings per day), and the data were sent to us via the Internet for analysis. After each recording, all of the subjects were asked to mark the visual analog score (VAS) of nasal obstruction on a 0- to 10-cm scale.

Odiosoft-Rhino is a new PC-based software program, which was programmed by using object-oriented programming (Visual Basic 6.0; Microsoft Inc, Redmond, Washington). The device analyzes nasal sound generated during both inspiration and expiration using the fast Fourier transform (FFT), which mathematically splits the signals into frequencies and displays the input and output waveforms and spectra, as well as calculates the magnitude and phase of the transfer function. During the data collection, we used a microphone that has a low-pass filtered with a cutoff frequency at 10 Hz and a high-pass filtered at 150 Hz and is amplified by 20 dB. The nasal sounds generated during the nasal airflow are captured via this microphone, and a computer analyzes the acquired data from each nasal cavity separately. The microphone converts sound into voltage. The 16-bit Yamaha sound card that is connected to the microphone samples the signals representing the sounds of nasal airflow and acts as a very fast digital voltmeter. This voltmeter measures the voltage from 11.025 up to 44.100 bits per second (bps). Analog signals of nasal sounds are recorded as small wav files, and the sound signals are represented as a combination of sine waves of various frequencies. The FFT of a digital signal can be calculated by using the divide-and-conquer method. In OR, this parameter (sampling frequency) is set to 44.100 bps (the sampling was executed at 44.100 bps). Three consecutive nonforced, but fast, expirations are recorded within 2 to 3 seconds, and each measurement is converted into a 16-bit number. Then, the recorded values with the best sound sample rates (44 100 bps) that do not exceed the upper and lower reference lines are chosen for evaluation. With this program, the spectral analysis of the nasal sounds was performed at frequency intervals of 200 to 500 Hz, 500 to 1000 Hz, 1000 to 2000 Hz, 2000 to 4000 Hz, and 4000 to 6000 Hz for each of the nasal cavities and a 2000- to 4000-Hz frequency interval was used for evaluation because this frequency range was found to be more sensitive in differentiation between normal and diseased nasal cavities.[11,12] Low nasal sound shows the patency of the nasal cavity, meaning the active phase of the nasal cycle, whereas high nasal sound dictates nasal obstruction that shows the passive phase of the nasal cycle. The analysis of the collected data was performed by using *t* test, 1-way analysis of variance and Bonferroni tests.

RESULTS

The ages of the 20 subjects who were enrolled in the study ranged from 24 to 30 years with a mean (SD) age of 27.2 (2.7) years. The BMI of the volunteers was 22 to 25. The mean VAS of nasal obstruction was 2.3 (1.5). The physical examination results and nasal examination findings for all subjects were within reference range. In these patients, according to AR, the minimum cross-sectional area detected in the distance between 0 and 22 mm was 0.4 to 0.5 cm with volumes of 1.9 to 2.4 mm^3. Rhinomanometric findings were 350 to 450 mL^3/s in expiration, and there was no significant difference between AR and RMM findings ($P > .05$). The nasal sounds were calculated at frequency intervals of 200 to 500 Hz, 500 to 1000 Hz, 1000 to 2000 Hz, 2000 to 4000 Hz, and 4000 to 6000 Hz for each of the nasal cavities. We used 2000- to 4000-Hz frequency interval findings of each nasal cavity for the evaluation of nasal cycle changes, and these were called "nasal sound."

In the first recording of each day, the nasal cavities with low nasal sound levels in decibels were classified as group A, and the nasal cavities with high nasal sound levels were classified as group B. This grouping was based on the intensity of the nasal sound (high or low nasal sound) that was generated in nasal cavities but not on an individual basis (**Figure**). As a result of sound processing with the OR program, the nasal sounds ranged from a mean (SD) of 9.09 (1.65) dB to 14.71 (0.85) dB for each nasal cavity (**Table 1**). At the various time periods between groups A and B, measured VAS values were in the range of the mean value of the VAS of nasal obstruction. There was no statistically significant difference between the VAS of nasal obstruction of low and high nasal sound intensities measured by the OR program ($P > .05$). All of the nasal cavities investigated in this study demonstrated a cyclic change of nasal patency that was detected by OR. The data acquired from groups A and B at 30-minute intervals over 12 hours for

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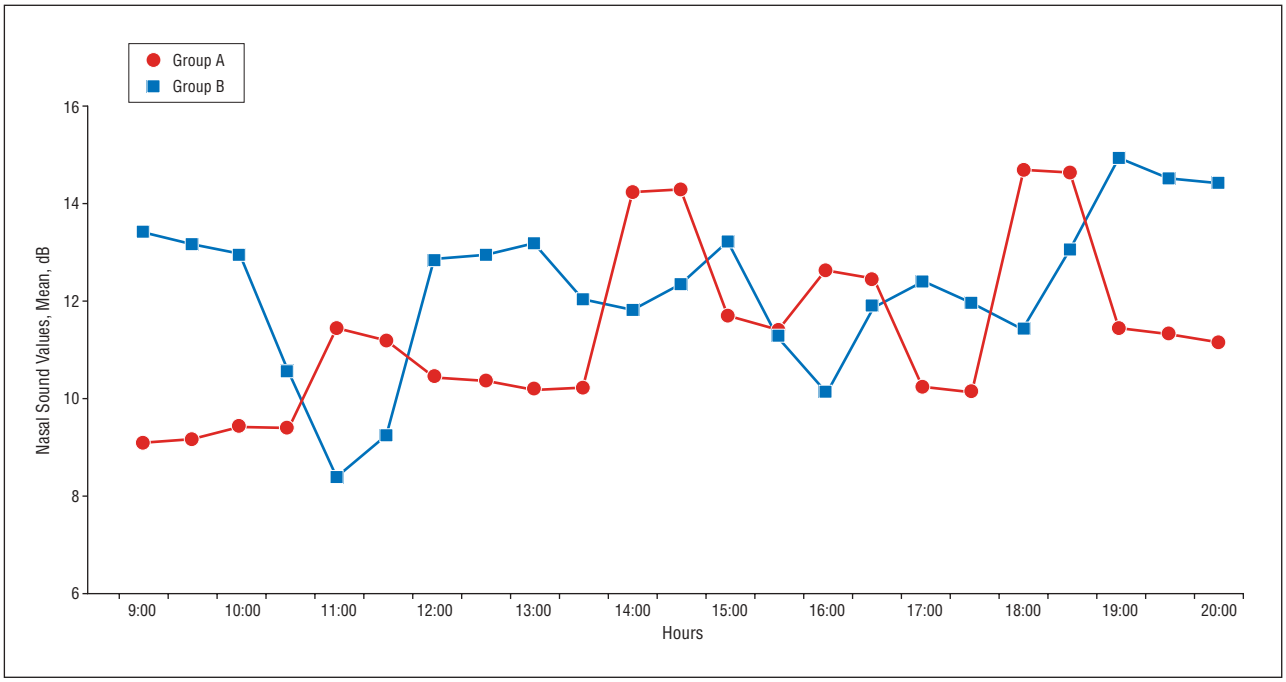

Figure. Changes of mean nasal expiratory sounds in 30-minute intervals among group A (those with nasal cavities with low nasal sound levels in decibels) and group B (those with nasal cavities with high nasal sound levels in decibels).

Table 1. Mean (SD) Values of Nasal Sound Detected by the Odiosoft-Rhino Software Program in Decibels[a]

	Total		Female		Male	
Hours	Group A	Group B	Group A	Group B	Group A	Group B
9:00	9.09 (1.65)	13.40 (1.01)	9.18 (1.25)	12.81 (0.91)	9.10 (0.73)	13.22 (0.83)
9:30	9.16 (1.75)	13.15 (1.45)	9.25 (0.58)	12.55 (0.78)	9.35 (0.45)	13.55 (0.58)
10:00	9.43 (0.66)	12.98 (0.71)	9.37 (0.80)	12.37 (0.88)	9.55 (0.51)	13.75 (0.44)
10:30	9.40 (0.86)	10.55 (1.25)	11.42 (1.56)	10.14 (1.45)	11.15 (0.56)	10.25 (1.46)
11:00	11.50 (1.19)	8.31 (2.49)	12.20 (1.36)	9.12 (1.34)	12.00 (0.75)	7.50 (0.51)
11:30	11.20 (0.80)	9.25 (1.37)	11.02 (1.21)	11.27 (1.23)	10.95 (0.27)	9.95 (0.84)
12:00	10.43 (1.34)	12.87 (1.07)	11.37 (1.25)	13.75 (1.34)	9.50 (0.51)	12.05 (0.78)
12:30	10.35 (1.22)	12.95 (0.43)	11.50 (0.24)	13.55 (1.09)	9.67 (0.43)	12.43 (1.45)
13:00	10.16 (0.98)	13.17 (1.73)	11.62 (1.47)	13.25 (1.06)	9.95 (0.55)	12.65 (1.54)
13:30	10.20 (1.35)	12.02 (1.50)	12.02 (1.11)	12.71 (0.61)	11.66 (0.49)	11.56 (0.67)
14:00	14.26 (0.75)	11.84 (1.43)	13.72 (0.71)	11.18 (1.75)	13.16 (0.85)	10.75 (1.12)
14:30	14.30 (0.65)	12.34 (1.03)	10.56 (0.45)	11.98 (1.34)	11.58 (1.12)	10.95 (0.65)
15:00	11.68 (1.59)	13.25 (1.25)	9.52 (1.24)	12.75 (1.12)	9.75 (0.44)	11.75 (0.54)
15:30	11.43 (1.25)	11.24 (0.98)	10.98 (1.67)	10.45 (1.32)	10.99 (0.57)	11.05 (0.85)
16:00	12.65 (1.03)	10.06 (1.21)	11.81 (0.65)	9.62 (1.14)	13.50 (0.65)	10.50 (0.60)
16:30	12.45 (1.25)	11.87 (0.76)	11.01 (0.87)	11.07 (1.23)	12.75 (0.43)	11.32 (0.79)
17:00	10.26 (1.31)	12.40 (1.10)	10.87 (1.40)	12.81 (1.21)	9.25 (0.40)	12.00 (0.73)
17:30	10.15 (0.80)	11.95 (0.63)	12.95 (1.32)	12.25 (0.67)	11.05 (1.26)	11.10 (0.75)
18:00	14.71 (0.85)	11.43 (0.89)	13.93 (1.06)	11.87 (1.33)	12.5 (0.41)	9.50 (0.80)
18:30	14.65 (0.58)	13.05 (1.34)	12.01 (0.25)	12.98 (1.61)	11.23 (0.98)	10.98 (1.68)
19:00	11.43 (1.36)	14.93 (1.10)	10.12 (1.62)	14.62 (1.14)	10.75 (0.35)	14.25 (0.30)
19:30	11.36 (0.76)	14.50 (0.32)	10.52 (0.35)	14.72 (0.97)	10.66 (0.65)	13.95 (1.43)
20:00	11.18 (0.89)	14.43 (0.84)	10.67 (1.08)	14.87 (0.71)	10.51 (0.52)	14.23 (0.53)

[a] Subjects with nasal cavities with low and high nasal sound levels in decibels, were classified as group A and group B, respectively.

4 different days in the same week were significantly different from each other (see **Table 2** for *P* values). This shows that within a given time, the calculated value in one nasal cavity is statistically different from the other nasal cavity, demonstrating the phase difference and the presence of a nasal cycle. After each measurement, each volunteer recorded the VAS of nasal obstruction. There was no significant difference between male and female volunteers regarding the duration of cyclic changes. Regardless of the groups, all of the individuals demonstrated cyclic change in nasal resistance varying between 30 minutes and 2 to 2.5 hours, but the cycling pattern was irregular. **Table 3** and **Table 4** show the 30-minute changes of nasal sounds and comparison of the 2 sides.

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Table 2. Mean (SD) Difference Between the Nasal Cavities of Groups A and B in Each Measurement Period Demonstrates the Presence of the Nasal Cycle in Each Nasal Cavity[a]

	Total			Women			Men		
Hours	Mean	*t*	*P* Value	Mean	*t*	*P* Value	Mean	*t*	*P* Value
9:00	−4.312 (2.342)	−10 391	<.001	−3.625 (1.872)	−5048	<.001	−3.812 (1.715)	−8812	<.001
9:30	−3.125 (1.434)	−4365	<.001	−2.125 (1.554)	−5465	.001	−3.455 (1.525)	−6051	<.001
10:00	−2.125 (1.12)	−10 649	<.001	−2.001 (1.366)	−5855	<.001	−2.222 (1.215)	20 125	<.001
10:30	1.67 (0.876)	6.45	<.001	0.834 (1.635)	2948	.001	3.234 (1.426)	5427	<.001
11:00	3.187 (1.362)	5360	<.001	1.875 (1.349)	2724	.01	4.501 (0.894)	20 125	<.001
11:30	2.567 (0.368)	20 376	.001	−2.265 (1.635)	−7562	.001	2.424 (0.434)	20 488	<.001
12:00	−3.250 (1.323)	−5954	<.001	−3.250 (1.323)	−5954	<.001	−0.531 (0.212)	2236	.04
12:30	2.289 (1.298)	6913	<.001	−2.146 (1.692)	−7487	<.001	−1.345 (1.815)	−4129	.001
13:00	−1.312 (1.745)	−4244	.001	−1.625 (1.784)	−3122	.003	−2.115 (1.987)	−2015	.095
13:30	3.456 (1.543)	6877	<.001	1.492 (0.785)	3733	.002	1.527 (2.201)	3585	.001
14:00	1.531 (0.924)	6903	<.001	2.312 (1.301)	7103	<.001	1.512 (0.815)	3873	.002
14:30	−2.998 (1.776)	−7589	<.001	1.498 (2.212)	3775	.001	2.292 (1.261)	6992	.001
15:00	1.437 (2.198)	3698	.001	1.875 (1.091)	2423	.03	1.990 (0.812)	2155	.04
15:30	−1.599 (1.721)	−3012	.003	2.124 (1.301)	6998	<.001	3.224 (1.401)	5523	.001
16:00	2.593 (1.562)	9388	<.001	2.187 (1.054)	4593	<.001	2.612 (1.312)	10 112	<.001
16:30	2.345 (1.409)	10 112	<.001	1.556 (0.905)	3912	.002	−1.124 (0.376)	−3988	<.001
17:00	−2.343 (1.824)	−7266	<.001	−1.937 (1.515)	−3081	.008	−2.365 (1.732)	−7602	<.001
17:30	−2.597 (1.656)	−7602	<.001	−3.348 (1.388)	−6,043	<.001	−1.877 (1.441)	−2996	.008
18:00	2.625 (0.659)	22 502	<.001	−1.937 (1.432)	−3183	.006	2.500 (0.894)	11 180	<.001
18:30	0.925 (0.511)	3152	<.001	−3.136 (1.114)	−5866	<.001	1.653 (1.142)	7035	<.001
19:00	−1.062 (0.479)	−4062	<.001	1.125 (0.625)	4712	<.001	−0.512 (0.344)	−2025	.045
19:30	−3.429 (1.775)	−476	.003	0.887 (0.495)	3025	<.001	−1.892 (1.487)	−2997	.008
20:00	0.752 (1.436)	2953	.006	0.233 (1.312)	0.615	.52	0.885 (0.415)	2852	.008

[a]The measurements indicate a significant difference between nasal cavities.

Table 3. Mean Difference of Measurements in 30-Minute Intervals for the Left Nasal Cavity

	Total		Women		Men	
Hours	Mean Difference	*P* Value	Mean Difference	*P* Value	Mean Difference	*P* Value
9:00-9:30	−0.355	>.05	−0.192	>.05	−0.454	>.05
9:30-10:00	−0.388	>.05	−0.212	>.05	−0.466	>.05
10:00-10:30	−0.367	>.05	−0.189	>.05	−0.442	>.05
10:30-11:00	−0.412	>.05	−0.218	>.05	−0.469	>.05
11:00-11:30	−2.076	<.001	1.634	.005	−2.455	<.001
11:30-12:00	0.389	>.05	−0.250	>.05	−0.450	>.05
12:00-12:30	0.270	>.05	−0.259	>.05	−0.435	>.05
12:30-13:00	−4.100	<.001	−2.100	<.001	−3.665	<.001
13:00-13:30	0.289	>.05	−0.555	>.05	0.243	>.05
13:30-14:00	−4.288	<.001	−2.100	<.001	−3.665	<.001
14:00-14:30	0.315	>.05	−0.546	>.05	0.265	>.05
14:30-15:00	2.586	<.001	4.200	<.001	3.415	.003
15:00-15:30	−0.450	>.05	0.270	>.05	−0.250	>.05
15:30-16:00	0.435	>.05	0.438	>.05	−0.540	>.05
16:00-16:30	2.393	<.001	0.942	.02	4.252	<.001
16:30-17:00	−0.418	>.05	−0.228	>.05	−0.456	>.05
17:00-17:30	−0.972	.03	−2.291	<.001	−3.755	<.001
17:30-18:00	−0.425	>.05	0.249	>.05	−0.267	>.05
18:00-18:30	3.287	.005	3.812	<.001	1.755	<.001
18:30-19:00	−0.530	>.05	0.419	>.05	0.440	>.05
19:00-19:30	0.390	>.05	0.414	>.05	−0.556	>.05
19:30-20:00	0.251	>.05	−0.555	<.05	0.243	<.05

COMMENT

Cyclic congestion and decongestion and, thereby, the cyclic changes in the airflow within the nose, are known collectively as the nasal cycle. The nasal cycle was first described in the literature in 1895.[8] It was reported that nearly 80% of adults could be shown to have cyclical changes in the mucosa of the nasal cavity, although the cycle could be easily overridden by physical and environmental factors.[13] We were able to detect classical cyclic changes of nasal resistance in all of our subjects. It

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Table 4. Mean Difference of Measurements in 30-Minute Intervals for the Right Nasal Cavity

	Total		Women		Men	
Hours	Mean Difference	*P* Value	Mean Difference	*P* Value	Mean Difference	*P* Value
9:00-9:30	0.422	>.05	0.444	>.05	–0.533	>.05
9:30-10:00	0.415	>.05	0.430	>.05	–0.547	>.05
10:00-10:30	0.409	>.05	0.418	>.05	–0.559	>.05
10:30-11:00	0.430	>.05	0.452	>.05	–0.527	>.05
11:00-11:30	4.672	<.001	3.250	<.001	–2.450	<.001
11:30-12:00	–0.300	>.05	0.500	>.05	–0.600	>.05
12:00-12:30	–0.342	>.05	–0.212	>.05	–0.467	>.05
12:30-13:00	4.698	<.001	3.273	<.001	–2.423	<.001
13:00-13:30	0.378	>.05	0.399	>.05	–0.542	>.05
13:30-14:00	1.334	.007	2.075	<.001	1.915	<.001
14:00-14:30	–0.465	>.05	0.245	>.05	–0.271	>.05
14:30-15:00	3.192	<.001	2.134	<.001	1.250	<.001
15:00-15:30	–0.543	>.05	0.398	>.05	0.421	>.05
15:30-16:00	0.408	>.05	0.420	>.05	–0.534	>.05
16:00-16:30	–2.343	<.001	–3.187	<.001	–1.500	<.001
16:30-17:00	–0.454	>.05	0.239	>.05	–0.288	>.05
17:00-17:30	–3.500	<.001	–2.750	<.001	–4.750	<.001
17:30-18:00	–0.303	>.05	0.510	>.05	–0.608	<.05
18:00-18:30	–1.412	.003	–1.575	.008	–1.000	.02
18:30-19:00	–0.391	>.05	–0.205	>.05	–0.441	>.05
19:00-19:30	–0.361	>.05	–0.173	>.05	–0.438	>.05
19:30-20:00	0.500	>.05	–0.254	>.05	0.423	>.05

is generally accepted that the nasal cycle has a periodicity that ranges from 30 minutes to 6 hours, and in most normal individuals, because the total resistance and airflow remain constant, it is not recognized.[3] In our study, the periodicity was between 30 minutes to 2 to 2.5 hours.

Complex procedures, such as AR or RMM, can assess the nasal cycle. It can also be identified with inexpensive and handheld nasal peak-inspiratory-flow meters.[14] In 1982, Hasegawa[15] postulated a study with a nasal resistance meter, calculating unilateral nasal resistance and detecting postural variations in nasal resistance and concluding that a decrease in sympathetic tone to the nasal mucosa caused postural variations in unilateral nasal resistance in the congested side.

In AR, the nasal cavity can be investigated by acoustic reflections, and the method gives information about cross-sectional areas and nasal volumes within a given distance.[3] In their study with AR, Gungor et al[3] investigated nasal cycle by measuring volume and cross-sectional area every 15 minutes for 4 hours along with VAS in 10 adult subjects and detected classical cycle in some of them. Huang et al[10] investigated pattern, duration, and amplitude of nasal cycle by AR and RMM every 10 minutes over 6 hours before and after application of a nasal decongestant. After 37 measurements with AR, RMM, and VAS, they found a spontaneous fluctuation in nasal patency with irregular pattern, frequency, and amplitude that can be abolished by the application of nasal decongestant.[10] Lang et al[1] investigated turbulent airflow during the nasal cycle using endoscopy, rhinoresistometry, and AR in 10 healthy subjects every 20 minutes over a time period of up to 15 hours and demonstrated a periodic change in the turbulence behavior of the airflow in addition to well-known cyclic changes in flow resistance and nasal width. They[1] concluded that the combination of rhinoresistometry and AR provided insight into nasal physiologic characteristics and the nasal cycle. Hanif et al[16] used a portable spirometer to study nasal cycle. They performed hourly measurements over a 5-hour period in 6 subjects and compared spirometric measurements with posterior RMM measurements. They concluded that spirometry had considerable advantages over RMM owing to portability and ease of use with similar results.

The OR software program is a new method to assess the nasal airflow by performing the spectral and frequency analysis of nasal sounds.[17] With this method, sound frequency and intensity can be calculated. Frequency measurements can be performed for each of the nasal cavities, and sound intensity can be displayed for each frequency interval. Because the diameter of the nasal airway is the most important factor that determines the type of nasal airflow (laminar or turbulent) and is reflected as a change in the sound of the airflow, processing the nasal sounds is a way of evaluating nasal obstruction. The OR program is a sensitive method in the evaluation of nasal airflow in normal subjects and in patients with allergic rhinitis compared with AR.[11,18] Furthermore, this method can be effectively used in patients with septum deviation.[19] The study regarding the comparison of the OR program and RMM in normal subjects demonstrated the effectiveness and usefulness of the device.[12] The OR equipment consists of a desktop or laptop computer and a microphone; because the device is portable, it is not mandatory to use it only in clinics. It is also suitable for screening. The acquired data in the OR program in the form of wav files can be shared with other clinicians via an Internet connection.[20]

In this article, we used the advantage of the portability of the OR program and transferred the data via the Internet. With these advantages and the setting of the

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study, the volunteers continued their working activities, and the nasal sounds that were produced by the airflow through the nasal cavities were recorded in the subjects' working environment and sent to us via the Internet for processing. This way, we achieved long data collection periods without disturbing the subjects. The measurements were performed every 30 minutes over a 12-hour period on 4 different days in the same week, resulting in 96 measurements for each subject. When compared with other studies of the nasal cycle, our study had the longest duration with maximum volunteer compliance. With 96 measurements for each subject, we demonstrated the presence of periodic increase and decrease of nasal resistance with the phases ranging between 30 minutes and 2 to 2.5 hours in each subject. The significant difference in nasal sounds detected in the study proves significant changes in the volumes of nasal airways ($P < .05$ for all comparisons). In the previous studies regarding the nasal cycle, the periods of data collection were not standard. Because the other investigators' methods of measurements were disturbing for the subjects, the data collection periods were either short[3] or irregular.[1]

It is generally accepted that 80% of the population experiences a regular cyclic change in nasal resistance, but there has also been a report[21] that only 21% of 52 volunteers exhibited a cyclic nasal airflow change. In our study, we detected cyclic changes in nasal resistance in each subject's recording, but these changes were in irregular patterns. For example, none of the patients demonstrated regular, 1-hour cycles during the recordings, but for a given subject, the cycles ranged from 30 minutes to 2 hours. In our study, the pattern of the individual cycle did not depend on food ingestion or any definite time of the day (eg, morning, noon, or afternoon), but was totally variable and at random. The reason why each subject experienced variable cyclic changes regarding the duration of each cycle must be studied in more detail.

Also, there is not a consensus about the phase length of the cycle. It is reported to be 30 minutes to 6 hours in the literature, but this is a wide range, which may be due to the nonstandardized environments in which the tests were performed. Our data define the cycle as being not less than 30 minutes and not more than 2.5 hours. We think that our findings are more accurate owing to long measurements, sensitivity of OR, and the subjects being in their natural environments.

In conclusion, this study implies that the OR program can effectively be used to detect and evaluate the nasal cycle objectively. The device can be used in clinics as well as the patient's own environment. In the modern world, because the individual's time is very valuable, remote diagnosis and screening of some physiologic functions or diseases during patients' daily activities in their own environments may lead to more valuable results and save time and money. With the help of the OR program, we detected the nasal cycle in all of the volunteers, and the periods were neither less than 30 minutes nor more than 2.5 hours. Because the data collection period was long and the patient compliance was maximal, we believe that the results in this study are more reliable and natural.

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