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Original Article

A Prospective Population-based Study of Total Nasal Resistance in Korean Subjects

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Objectives. Rhinomanometry is a widely accepted method for objective assessment of nasal patency. However, few studies have reported the values of otherwise healthy population for nasal resistance in East Asians. The purpose of this study was to measure normal total nasal resistance (TNR) values in a large sample of Korean adults and to reveal parameters contributing to TNR values.

Methods. Subjects were enrolled from a cohort of the Korean Genome and Epidemiology Study. They were evaluated by anthropometry, questionnaire, and active anterior rhinomanometry at transnasal pressures of 100 and 150 Pascal (Pa).

Results. The study sample consisted of 2,538 healthy subjects (1,298 women and 1,240 men) aged 20 to 80 years. Normal reference TNR values were 0.19±0.08 Pa/cm^3/second at 100 Pa and 0.22±0.09 Pa/cm^3/second at 150 Pa. The TNR of women was significantly higher than that of men ($P<0.0001$). TNR decreased with increasing age in both genders ($P<0.05$). In women, lower body weight was related to increasing TNR. In men, current smokers had higher TNR than ex-smokers and never smokers.

Conclusion. The results of the present study provide information regarding the values of otherwise healthy population of TNR and parameters associated with TNR in Korean adults.

Key Words. *Adult, Body weight, Nasal obstruction, Reference values, Rhinomanometry, Smoking*

INTRODUCTION

Nasal patency is associated with multiple factors and is usually affected by characteristics of the nasal cavity, including anatomic factors related to the bony-cartilaginous nasal structure and physiologic factors related to the congestive state of the nasal mucosa (1). Information regarding nasal resistance is essential for management of anatomic and physiologic diseases of the nasal airway. However, there are often inconsistencies between subjective nasal obstructive symptoms and the objective appearance of the nasal cavity (2). Due to this discrepancy, objective diagnostic tools for the assessment of nasal patency or resistance are needed.

Values for nasal patency or resistance have been recorded using various techniques (3). Among them, acoustic rhinometry is useful for examining anatomical nasal obstruction and currently most common test in clinic. It is noninvasive, rapid and inexpensive test that measures cross-sectional area of the nose. Howev-

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er, the accuracy of acoustic rhinometry decreases as the distance from the nares increases and it has limited value for evaluating the severity of nasal congestion (4). On the contrary, rhinomanometry is more sensitive and specific for subjects with functional nasal obstruction. Therefore, it is considered as an excellent research tool and used for the present study (4, 5). Among several rhinomanometric methods, active anterior rhinomanometry (AAR) is the most frequently used for assessment of nasal patency and resistance in research and clinical applications (6). The Standardization Committee on Objective Assessment of the Nasal Airway also decided that AAR should be the method of choice for measuring nasal ventilation (7). Therefore, AAR is important tool for functional diagnostics of the nasal airway and may be used for screening of surgical patients and the investigation of surgical outcomes (8-11). However, there are few reports for the values of otherwise healthy population for nasal resistance in a healthy general East Asian population.

The purpose of this study was to investigate the values of otherwise healthy population for total nasal resistance (TNR) and parameters associated with nasal resistance by examination of the AAR of a large population-based sample of Korean adults.

MATERIALS AND METHODS

Subjects

The study subjects were selected among a cohort of the Korean Genome and Epidemiology Study (KoGES), which began in 2001 as an ongoing population-based cohort study of Korean adults aged 20 to 80 years (12). The majority of this cohort consists of middle-aged adults, with a minority of young adults and the elderly. Participants are evaluated biannually by routine assessment of anthropometry, medical history, a standardized questionnaire, blood pressure, spirometry, electrocardiography, and blood tests. Participants were asked if they had symptoms related to nasal disturbance (e.g., nasal obstruction, rhinorrhea, and sneezing) or upper airway infections and about any previous nasal surgery or medical treatment. Participants who had at least one nasal symptom or histories of nasal surgery or medical treatment were excluded from the study. All examinations, including rhinomanometric measurements, were performed by health professionals who were trained to follow a standardized protocol. The study protocol was approved by the Institutional Review Board of the Korea University Ansan Hospital. Informed consent was obtained from all study participants.

Rhinomanometry

The AAR was measured to determine nasal airflow and transnasal pressure values in the KoGES cohort. All measurements were performed using a rhinorheograph MRP-3100 (Nihon Kohden Co., Tokyo, Japan). Transnasal pressure represents the pressure difference between the choanal and atmospheric pressure. Prior to AAR measurement, subjects were asked to sit upright in a comfortable chair for at least 30 minutes in an air-conditioned room that was maintained at a constant temperature and humidity. The AAR technique was explained to each subject. Measuring AAR requires that one nasal cavity is occluded while the other cavity is left open for flow measurements. A nasal adapter of suitable size was inserted just inside the occluded nostril. A small bore silastic tube was connected to a pressure transducer, and then passed through the nasal adapter to just inside the external nare to record pressure. Subjects kept their mouths closed and were required to breathe quietly through the mask for several seconds. A rhinomanogram, which describes the relationship between inspiratory nasal airflow and transnasal pressure, was recorded for each nostril. Due to the nasal cycle, which is alternating and characterized by spontaneous natural congestion and decongestion of the nasal venous sinuses, the results of unilateral nasal resistance measurements may vary daily in the same subjects. Therefore, nasal resistances were measured for both nostrils at a transnasal pressure of 100 and 150 Pascal (Pa). The resistance of inspiratory airflow at each nostril was represented as a ratio between nasal airflow and the transnasal differential pressure as described by the following equation:

$$R = \Delta P / V$$

R: resistance (Pa/cm^3/second)
ΔP: transnasal differential pressure (Pa)
V: nasal airflow (cm^3/second)

Nasal resistance data were processed and estimated using an in-house computer program (NI-101, Nihon Kohden Co.) that interfaced with the rhinorheograph program. Flow-pressure curves were plotted on-line and the measurements were repeated until a stable curve was obtained. The AAR values for both nostrils were calculated to yield TNR according to the Standardization Committee on Objective Assessment of the Nasal Airway recommendations (6). The TNR was expressed in Pa/cm^3/second at a transnasal pressure of 100 Pa or 150 Pa. Values of TNR exceeding 1.0 Pa/cm^3/second were excluded due to the possibilities of structural or mucosal abnormality, although the questionnaire surveys should have ruled out nasal diseases.

Statistical analysis

The TNRs and other variables were expressed as mean±standard deviation. To find TNRs associated parameters, we performed stepwise linear regression. The relationships between the TNRs and age, according to gender, were analyzed using analysis of variance by Scheffe's method. Multiple linear regressions were performed for the relationships between log transformed TNR and height, weight, age, smoking status (current smoker, ex-smoker, and never smoker) and gender. All tests were two sided and P-values <0.05 were considered statistically significant. Statistical analyses were performed using SAS (SAS Institute, Cary, NC, USA).

RESULTS

Among the 3,320 participants, 782 were excluded due to nasal symptoms or histories of nasal surgery or medical treatment. A total of 2,538 (1,298 female and 1,240 male) participants were enrolled from May 2007 to February 2009. Ages ranged from 20 to 80 years and the mean age was 53.4±9.2 years (Table 1). TNR measurements are summarized in Table 2. The average TNR was 0.19±0.08 Pa/cm^3/second at 100 Pa and 0.22±0.09 Pa/cm^3/second at 150 Pa. The average TNR of women was higher than that of men (0.19±0.08 Pa/cm^3/second vs. 0.18±0.08 Pa/cm^3/second at 100 Pa, $P<0.0001$, 0.22±0.09 Pa/cm^3/second vs. 0.21±0.09 Pa/cm^3/second at 150 Pa, $P<0.0001$). TNR decreased significantly with increasing age in both genders ($P<0.05$). Stepwise linear regression showed that height, weight, age, smoking status, and gender were significantly associated with TNR values (Table 3). Increasing age was associated with decreasing TNR in both genders. Lower body weight was significantly associated with increasing TNR values only in women. Lower height was significantly associated with increasing TNR values only in men at 150 Pa. Current smokers tended to have higher TNRs than ex-smokers and never smokers only in men (0.19±0.09 Pa/cm^3/second vs. 0.18±0.07 Pa/cm^3/second vs. 0.17±0.07 Pa/cm^3/second at 100 Pa, $P=0.0013$ and 0.22±0.10 Pa/cm^3/second vs. 0.21±0.09 Pa/cm^3/second vs. 0.20±0.08 Pa/cm^3/second at 150 Pa, $P=0.0007$) (Table 4).

DISCUSSION

The results of the present study demonstrate that the values of otherwise healthy population for TNR in a large sample of 20 to 80-year-old Koreans were 0.19±0.08 Pa/cm^3/second (0.19±0.08 Pa/cm^3/second in women and 0.18±0.08 Pa/cm^3/second in men) at 100 Pa and 0.22±0.09 Pa/cm^3/second (0.22±0.09 Pa/cm^3/second in women and 0.21±0.09 Pa/cm^3/second in men) at 150 Pa; women had higher TNR values than men. Additionally, our results confirm that increasing age was associated with decreasing TNR in both genders. To our knowledge, this is the first large sampled community-based study to determine the values of otherwise healthy population for nasal resistance in East Asians.

There have been several studies reporting the values of otherwise healthy population for nasal resistance. Jones et al. (13) suggested that the normal range of TNR was 0.20 to 0.55 Pa/cm^3/second at a transnasal pressure of 150 Pa from a study of 59 healthy individuals. Cole (14) reported that the normal range of TNR was 0.20±0.05 Pa/cm^3/second at 100 Pa, and that it was approximately 25% greater at 150 Pa. The mean TNR of normal noses has also been reported as 0.31 Pa/cm^3/second (range, 0.13 to 0.84 Pa/cm^3/second) (15), 0.24±0.07 Pa/cm^3/second (16), and 0.23±0.006 Pa/cm^3/second (range 0.15 to 0.39 Pa/cm^3/second) (17) at 150 Pa. However, most previous studies reporting normal TNR values have been performed in small populations of European descent. Since facial anatomy exhibits significant geographic variation across human populations, assessments of

Table 1. General characteristics of the 2,538 subjects

Characteristics	Values
Age (yr)	53.4±9.2
Gender	
Women	1,298 (51.1)
Men	1,240 (48.9)
Smoking status	
Current smoker	449 (17.7)
Ex-smoker	529 (20.8)
Never smoker	1,560 (61.5)
Height (cm)	161.5±8.4
Weight (kg)	64.3±10.1
Body mass index (kg/m^2)	24.6±2.9

Values are presented as mean±SD or number (%).

Table 2. TNR according to gender and age in normal Korean subjects (n=2,538)

Valiables		No.	100 Pa TNR (Pa/cm^3/sec)	150 Pa TNR (Pa/cm^3/sec)
Gender				
	Total	2,538	0.19±0.08	0.22±0.09
	Women	1,298	0.19±0.08	0.22±0.09
	Men	1,240	0.18±0.08	0.21±0.09
	P-value		<0.0001	<0.0001
Age (yr)				
	20-39	108	0.21±0.08	0.24±0.09
	40-49	731	0.20±0.08	0.23±0.09
	50-59	1,120	0.19±0.07	0.22±0.08
	60-69	443	0.17±0.08	0.20±0.09
	70-80	136	0.17±0.07	0.20±0.08
	Trend *P*-value		<0.0001	<0.0001
Women				
	20-39	57	0.23±0.08	0.26±0.09
	40-49	387	0.20±0.08	0.23±0.10
	50-59	553	0.19±0.07	0.22±0.08
	60-69	217	0.18±0.08	0.21±0.09
	70-80	84	0.17±0.06	0.20±0.07
	Trend *P*-value		<0.0001	<0.0001
Men				
	20-39	51	0.19±0.07	0.22±0.08
	40-49	344	0.19±0.08	0.22±0.09
	50-59	567	0.18±0.08	0.21±0.09
	60-69	226	0.16±0.08	0.19±0.09
	70-80	52	0.16±0.08	0.19±0.09
	Trend *P*-value		0.0165	0.0161

TNR, total nasal resistance; Pa, Pascal.

Table 3. Multiple linear regression models for TNR in normal Korean subjects (n=2,538)

	Independent variable	log (TNR at 100 Pa)		log (TNR at 150 Pa)	
		Parameter estimates	*P*-value	Parameter estimates	*P*-value
Total	Intercept	-0.91±0.23	<0.0001	-0.73±0.22	0.0009
	Height	-0.0020±0.0015	0.17	-0.0022±0.0014	0.12
	Weight	-0.0020±0.00089	0.027	-0.0020±0.00086	0.024
	Age	-0.0070±0.00078	<0.0001	-0.0067±0.00075	<0.0001
	Smoke	0.044±0.012	0.0003	0.045±0.012	0.0001
	Gender	-0.080±0.024	0.001	-0.077±0.024	0.0012
Women	Intercept	-0.93±0.31	0.0032	-0.81±0.30	0.0078
	Height	-0.00088±0.0020	0.66	-0.00077±0.0019	0.69
	Weight	-0.0051±0.0012	<0.0001	-0.005±0.0012	<0.0001
	Age	-0.0066±0.0010	<0.0001	-0.0062±0.00099	<0.0001
	Smoke	0.051±0.031	0.10	0.055±0.030	0.066
Men	Intercept	-0.87±0.35	0.013	-0.64±0.34	0.061
	Height	-0.0039±0.0022	0.073	-0.0044±0.0021	0.040
	Weight	0.00083±0.0013	0.53	0.00083±0.0013	0.51
	Age	-0.0069±0.0012	<0.0001	-0.0068±0.0012	<0.0001
	Smoke	0.042±0.013	0.0017	0.043±0.013	0.0010

Values are presented as parameter estimates±SE.
"Smoke" refers to smoking status, defined as a current smoker, ex-smoker, and never smoker.
TNR, total nasal resistance; Pa, Pascal.

Table 4. TNR values according to smoking status

	TNR (Pa/cm^3/sec)	Smoking status			*P*-value
		Never smoker	Ex-smoker	Current smoker	
Total		1,560	529	449	
	100 Pa	0.19±0.08	0.18±0.07	0.19±0.09	0.39
	150 Pa	0.22±0.08	0.21±0.09	0.22±0.10	0.30
Women		1,259	13	26	
	100 Pa	0.19±0.08	0.20±0.08	0.22±0.09	0.13
	150 Pa	0.22±0.09	0.23±0.10	0.25±0.11	0.075
Men		301	516	423	
	100 Pa	0.17±0.07	0.18±0.07	0.19±0.09	0.0013
	150 Pa	0.20±0.08	0.21±0.09	0.22±0.10	0.0007

TNR, total nasal resistance; Pa, Pascal.

the values of otherwise healthy population for nasal resistance may also differ across populations. Ohki et al. (1) investigated dimensions of the external nose, nostrils, and nasal airflow resistances in healthy young adult subjects of European, East Asian, and African descent. The average nasal width and difference between dorsi-ventral and transverse nostril diameters are significantly different between these populations. The noses of European subjects were leptorrhine, African subjects were platyrrhine, and East Asian subjects were of intermediate dimension. Mean nasal resistances were lowest in subjects of African descent, highest in European descent, and intermediate in Asian descent. The present study demonstrated that average TNRs were 0.19±0.08 Pa/cm^3/second at 100 Pa and 0.22±0.09 Pa/cm^3/second at 150 Pa, relatively lower than reported in previous European studies (14, 15, 17). However, it is similar to Southeast Asian study (16) after consideration of age. This difference can be explained by the facts that the current study sample consisted of East Asians and was older than in previous studies, as increasing age is correlated with decreasing TNRs (18, 19).

Nasal resistance is highest in infants at approximately 1.2 Pa/cm^3/second and decreases to adult values at approximately 16 to 18 years of age, thereafter demonstrating a slow decline with increasing age (19). In healthy subjects, it has also been reported that nasal resistance declines with increasing age from 0.60 Pa/cm^3/second (age, 5 to 12 years) to 0.29 Pa/cm^3/second (age, 13 to 19 years), followed by 0.22 Pa/cm^3/second (age >20 years) in male subjects (18). In this study, the TNR also decreased with increasing age in both genders. These results can be interpreted as a consequence of the lower temperature and humidity, enlarged nasal cavity, and atrophic mucosal change that are characteristic of increasing age (20). Additionally, weak inspiratory forces in elderly subjects may also contribute to decreasing TNR as age increases.

In regards to the relationship between TNR and gender, previous studies have reported contradictory results. One study found that men had higher TNRs than women (18). However, other studies have reported that the average TNR of women was higher than that of men at 150 Pa (3, 15, 16). The current study also demonstrated that women have a higher TNR value than men. This may be related to the differences in anatomical, physiological, and hormonal factors between women and men.

The present study demonstrated that increased TNR values were associated with smoking status (current smoker>ex-smoker>never smoker) and low height at 150 pa in men, and low body weight in women, after adjusting for confounding factors; these findings are in agreement with prior studies (3, 15).

In women, a lower body weight was associated with increased TNR values, but smoking status was not. This may be due to errors related to the small number of smoking women in the current study sample. In men, a low body weight was not associated with TNR, but smoking status and low height at 150 pa were independently related to increased TNR. Suzina et al. (16) reported that height was significantly related to TNR, but the present study showed this relationship only in men at 150 Pa. These discrepancies in weight and height according to gender are unclear. However, it has been reported that nasal subcutaneous fat is important for the nasal structure (21). Since women have almost twice as much subcutaneous fat as men (22), women might response more sensitive to the change of weight but not to the height. Further study is needed to confirm the effects of height and weight according to gender on TNR.

One of the strengths of this study is that the study sample was large and included participants enrolled from a community-based, healthy general population. However, this study has limitations. The distribution of study subjects was relatively small in the 20 to 39-year-old range, as compared with the overall Korean population structure. As the KoGES focuses on disease in middle-aged adults, the composition of the study sample was likewise biased. Additionally, the mechanisms underlying various parameters' effects, according to gender, on TNR could not be elucidated.

In conclusion, the present study demonstrated the values of otherwise healthy population for TNR and parameters associated with increasing TNR in a large, community-based, East Asian sample. These results may contribute to the understanding of nasal patency and resistance and can assist the clinicians to diagnose, treat and follow-up the clinical course of nasal disease.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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