

ORIGINAL ARTICLE

AIRWAY DISEASES

Mouth breathing, another risk factor for asthma: the Nagahama Study

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Abstract

Background: Allergic rhinitis, a known risk factor for asthma onset, often accompanies mouth breathing. Mouth breathing may bypass the protective function of the nose and is anecdotally considered to increase asthma morbidity. However, there is no epidemiological evidence that mouth breathing is independently associated with asthma morbidity and sensitization to allergens. In this study, we aimed to clarify the association between mouth breathing and asthma morbidity and allergic/eosinophilic inflammation, while considering the effect of allergic rhinitis.

Methods: This community-based cohort study, the Nagahama Study, contained a self-reporting questionnaire on mouth breathing and medical history, blood tests, and pulmonary function testing. We enrolled 9804 general citizens of Nagahama City in the Shiga Prefecture, Japan.

Results: Mouth breathing was reported by 17% of the population and was independently associated with asthma morbidity. The odds ratio for asthma morbidity was 1.85 (95% CI, 1.27–2.62) and 2.20 (95% CI, 1.72–2.80) in subjects with mouth breathing alone and allergic rhinitis alone, which additively increased to 4.09 (95% CI, 3.01–5.52) when mouth breathing and allergic rhinitis coexisted. Mouth breathing in nonasthmatics was a risk for house dust mite sensitization, higher blood eosinophil counts, and lower pulmonary function after adjusting for allergic rhinitis.

Conclusion: Mouth breathing may increase asthma morbidity, potentially through increased sensitization to inhaled allergens, which highlights the risk of mouth-bypass breathing in the ‘one airway, one disease’ concept. The risk of mouth breathing should be well recognized in subjects with allergic rhinitis and in the general population.

It is well known that asthma is a multifactorial disease that is determined by various genetic and environmental factors. Currently, the presence of allergic rhinitis is considered a key factor for asthma onset and asthma exacerbations (1, 2), as demonstrated in the ‘one airway, one disease’ concept (3). The most important mechanism underlying this association is considered to be the nasal–lower airway interaction. This interaction may be bidirectional and vertical (4–6), with sys-

temic propagation of inflammation *via* producing Th2 cytokines and other mediators (7), which we have also shown in a diverse spectrum of asthma (8).

Allergic rhinitis is often accompanied by mouth breathing, which is anecdotally considered to increase asthma morbidity (7). Mouth breathing may bypass the protective functions of the nose, such as warming, humidifying, and filtering the air (9–11). In small studies of asthma, mouth breathing adversely

affected pulmonary function; mouth breathing potentiated exercise-induced bronchoconstriction in mild asthmatics (12), and enforced mouth breathing decreased pulmonary function (13). Thus far, however, the evidence regarding the impact of mouth breathing on asthma morbidity or allergic/eosinophilic inflammation is limited. Furthermore, there is no epidemiological evidence on the prevalence of mouth breathing. Therefore, we investigated the association between mouth breathing and asthma morbidity, allergic/eosinophilic inflammation or lower pulmonary function, while taking into account the effect of allergic rhinitis. This association would be important in view of its public health implications.

Materials and methods

Patients

The Nagahama Prospective Genome Cohort for Comprehensive Human Bioscience (the Nagahama Study) is a community-based prospective cohort study (14). This study contained a self-reporting questionnaire, blood tests, and spirometry test. A total of 9804 general citizens in Nagahama City in the Shiga Prefecture, Japan, were enrolled from November 2008 to November 2010. The subjects had no current serious diseases, were able to live independently, and participated in this study voluntarily. This study was approved by the ethics committee of the Kyoto University Graduate School of Medicine. Written informed consent was obtained from all participants.

Questionnaire

Allergic rhinitis, sinusitis, mouth breathing, asthma, pediatric asthma, chronic obstructive pulmonary disease (COPD), and sleep apnea syndrome were defined anamnestically by questionnaire. Frequency scale for the symptom of GERD (FSSG) scoring, which was developed by Kusano et al. in Japan, was also evaluated. Acid reflux-related, gastrointestinal dysmotility-related, and total scores were calculated by adding the points for the 7, 5, and 12 questions, respectively. Gastroesophageal reflux disease (GERD) was defined as a total score ≥ 8 , which is the recommended cutoff FSSG score for GERD (15).

Measurement

For blood tests, in addition to blood eosinophil counts and total serum IgE levels, specific IgE levels against common inhaled allergens, that is, house dust mite, grass pollens, mold, weed, Japanese cedar pollen, cat dander, and dog dander, were determined by ImmunoCAP® Specific IgE (Phadia, Tokyo, Japan). Sensitization was defined as positive when the allergen-specific IgE titer was 0.35 UA/ml or greater. Pulmonary function was measured using a computed spirometer with automated quality checks (SP-350 COPD; Fukuda Denshi, Tokyo, Japan).

Statistical analysis

Statistical analyses were performed using JMP version 10 (SAS Institute Inc., Tokyo, Japan). Logistic regression analysis

was used to estimate the odds ratio of clinical indices, including mouth breathing, for asthma morbidity, sensitization to house dust mite, blood eosinophilia ($\geq 250/\mu\text{l}$), and lower forced expiratory volume in 1-s (FEV_1 ; $<90\%$ predicted). The odds ratio for asthma of mouth breathing in combination with allergic rhinitis was estimated after adjustment for pediatric asthma. Results for two groups were compared using the Student's *t*-test and the chi-square test, as appropriate. The Bonferroni method was used to correct multiple comparisons. $P < 0.05$ was considered significant.

Results

A total of 9804 subjects were included in the current study, but one subject did not answer the question about mouth breathing. Mouth breathing was reported by 17% of all participants (Table 1), by 21% of the subjects with allergic rhinitis, and by 30% of the subjects with asthma. On multivariate analysis, mouth breathing was a risk factor for asthma, independent of allergic rhinitis, pediatric asthma, and blood eosinophilia (Table 2).

Because the frequency of mouth breathing was significantly higher in subjects with allergic rhinitis than in those without allergic rhinitis (21% vs 14%, $P < 0.0001$), we stratified patients according to the status of mouth breathing and allergic rhinitis to estimate the risk of asthma morbidity. The odds ratio of mouth breathing alone for having asthma was 1.85 (95% CI, 1.27–2.62, $P = 0.002$) and that of allergic rhinitis alone was 2.20 (95% CI, 1.72–2.80, $P < 0.0001$), as compared to the reference group 'no mouth breathing, no allergic rhinitis'. The odds ratio was additively increased to 4.09 (95% CI, 3.01–5.52, $P < 0.0001$), when mouth breathing and allergic rhinitis coexisted (Fig. 1).

To further clarify the effects of mouth breathing, associations between mouth breathing and allergic/eosinophilic inflammation in subjects without asthma were examined. The frequencies of allergic rhinitis and sensitization to house dust mite, and blood eosinophil counts were significantly higher, while FEV_1 was significantly lower in subjects with mouth

Table 1 Subject characteristics

Characteristic	Subjects ($n = 9804$)
Age (years)	53.5 $\pm$ 13.4
Sex (female, %)	67
Smoking status (never/ex/current, %)	65/21/14
Asthma (%)	4
COPD (%)	1
Allergic rhinitis (%)	35
Sleep apnea syndrome (%)	5
Sinusitis (%)	10
Mouth breathing (%)	17
Blood eosinophil counts (per μl)	155 $\pm$ 128
Sensitization to house dust mite (%)	28

Data are presented as mean $\pm$ standard deviation. COPD, chronic obstructive pulmonary disease.

Table 2 Factors associated with asthma

	Univariate analysis			Multivariate analysis		
	Odds ratio	95% CI	P value	Odds ratio	95% CI	P value
Gender (Female)	1.06	0.85–1.31	0.6	1.60	1.20–2.15	0.001
Age						
30–45 years (<i>n</i> = 3168)	Reference			Reference		
46–60 years (<i>n</i> = 2723)	0.90	0.70–1.16	0.42	0.77	0.56–1.01	0.06
61–75 years (<i>n</i> = 3912)	0.79	0.62–1.00	0.05	0.70	0.53–0.90	0.006
Body mass index (≥ 25 kg/m ²)	1.39	1.09–1.75	0.006	1.40	1.09–1.80	0.009
Allergic rhinitis (yes)	2.56	2.09–3.14	<0.0001	1.80	1.44–2.25	<0.0001
Blood eosinophilia ($\geq 250/\mu\text{l}$)	2.66	2.15–3.30	<0.0001	1.94	1.53–2.44	<0.0001
Serum total IgE	2.28	1.94–2.68	<0.0001	1.76	1.47–2.11	<0.0001
Pediatric asthma (yes)	9.35	7.00–12.57	<0.0001	7.21	5.19–9.92	<0.0001
Smoking history (≥ 10 pack – years)	1.17	0.94–1.46	0.17	1.24	0.92–1.67	0.16
Passive smoking (yes)	1.50	1.18–1.91	0.001	1.34	1.05–1.74	0.0002
FSSG score (≥ 8)	1.57	1.25–1.93	<0.0001	1.41	1.12–1.77	0.004
Sinusitis (yes)	2.11	1.63–2.74	<0.0001	1.68	1.27–2.20	0.0004
Mouth breathing (yes)	2.20	1.77–2.75	<0.0001	1.67	1.32–2.12	<0.0001

CI, confidence interval; FSSG, frequency scale for the symptoms of gastroesophageal reflux disease (15). FSSG details are shown in the text. Odds ratios are per IU/ml increase for serum total IgE, and per 15-year increase in age. For categorical variables, the group for which the odds ratio is shown is provided in brackets in comparison with their counterparts.

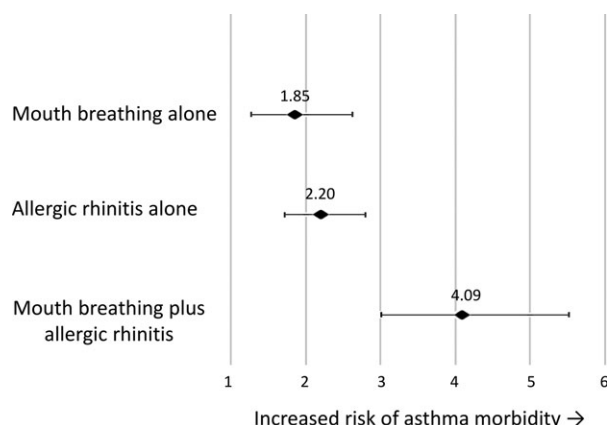


Figure 1 Risk of asthma morbidity according to the status of mouth breathing and allergic rhinitis. The odds ratios were estimated after adjustment for pediatric asthma. Odds ratios and 95% confidence intervals are presented.

breathing than in those without mouth breathing ($P < 0.0001$; Table 3). After the adjustment for allergic rhinitis, mouth breathing remained a risk factor for sensitization to house dust mite, blood eosinophilia ($\geq 250/\mu\text{l}$), and lower FEV₁ ($< 90\%$ predicted) in nonasthmatics (Table 4).

Discussion

To the best of our knowledge, this is the first epidemiological study that showed the prevalence of mouth breathing and its risk for asthma morbidity. Here, 17% of the general population answered that they usually breathed through the mouth, which was a risk factor for asthma morbidity independent of

several clinical indices. This risk may be crucial particularly in subjects with allergic rhinitis, because odds ratio of asthma was quadrupled when mouth breathing and allergic rhinitis coexisted, whereas odds ratio of asthma was almost doubled in case of allergic rhinitis alone. Furthermore, in nonasthmatic subjects, mouth breathing was associated with sensitization to house dust mite, blood eosinophilia, and lower pulmonary function after the adjustment for allergic rhinitis.

Allergic rhinitis is a well-known comorbidity of asthma and an independent risk factor for asthma onset (3). Epidemiological evidence for the coexistence of allergic rhinitis and asthma, and the similarities in terms of structural and immunological abnormalities between the two diseases yielded the concept of 'one airway, one disease' (1, 16). Nasal–lower airway interaction may augment Th2/eosinophilic inflammation systemically, as has been documented elsewhere (17, 18). In agreement with this concept, allergic rhinitis alone was an independent risk factor for asthma, with an odds ratio of 2.20 in this study.

We newly demonstrated that mouth breathing alone also increased the risk for asthma morbidity with an odds ratio of 1.85. Indeed, the prevalence of mouth breathing in subjects with asthma was as high as 30%, which was higher than that in subjects with allergic rhinitis at 21%. Furthermore, when allergic rhinitis and mouth breathing coexisted, the odds ratio was additively increased to 4.02. This increase might merely reflect severe nasal–lower airway inflammation due to severe allergic rhinitis, which emphasizes the importance of the treatment of allergic rhinitis to maintain the nasal airflow patency. However, the additive increase may indicate the risk of mouth breathing on its own for asthma morbidity. The mechanisms underlying the association between asthma and mouth breathing in the absence of allergic rhinitis remain unclear, but, as discussed below, the bypass of the protective

Table 3 Factors associated with mouth breathing in nonasthmatics

	Mouth breathing		P value
	Yes (n = 1512)	No (n = 7890)	
Blood eosinophil count (/μl)	173 ± 144	148 ± 120	<0.0001
Serum total IgE (IU/ml)	206 (0–9520)	175 (0–16700)	0.02
Sensitization to house dust mite (%)	33	26	<0.0001
Sensitization to cat dander (%)	6.4	4.5	0.002
Sensitization to dog dander (%)	5	7	0.003
Sensitization to grass pollens (%)	26	28	0.1
Sensitization to mold (%)	7.6	9.3	0.03
Sensitization to weed (%)	13	15	0.1
Sinusitis (%)	15	9	<0.0001
Allergic rhinitis (%)	42	33	<0.0001
%FEV ₁ (%)	102 ± 16	104 ± 16	<0.0001
%FVC (%)	103 ± 15	105 ± 15	0.0008
Sleep apnea syndrome (%)	9	4	0.018

Means ± standard deviations and medians (ranges) are presented. %FEV₁, percent predicted of forced expiratory volume in 1-s; %FVC, percent predicted of forced vital capacity.

Table 4 Risk ratio of mouth breathing for sensitization to house dust mite, blood eosinophilia (≥250/μl), and lower FEV₁ (<90% predicted) in nonasthmatics with adjustment for allergic rhinitis

	Odds ratio	95% CI	P value
Sensitization to house dust mite			
Allergic rhinitis	2.68	2.44–2.93	<0.0001
Mouth breathing	1.32	1.18–1.49	<0.0001
Blood eosinophilia			
Allergic rhinitis	1.57	1.40–1.78	<0.0001
Mouth breathing	1.45	1.25–1.66	<0.0001
Lower FEV ₁			
Allergic rhinitis	1.24	1.10–1.38	0.0002
Mouth breathing	1.28	1.11–1.46	0.0005

CI, confidence interval; FEV₁, forced expiratory volume in 1-s.

functions of the nose, such as warming, humidifying, and filtering the air, may play a role (9–11, 19). From another point of view, Hallani et al. (20) demonstrated that asthmatics had an increased tendency to switch to mouth breathing, potentially *via* an enhanced perception of nasal loading.

The adverse effects of mouth breathing on pulmonary function have been studied in patients with asthma. Exercise with mouth breathing induced greater bronchoconstriction than exercise with nose breathing in 12 children with asthma (12). Enforced mouth breathing at rest for 1 h significantly

decreased pulmonary function in eight patients with mild asthma (13). Furthermore, winter sports athletes, such as skaters and skiers, who inhale large volumes of cold air during exercise and thus easily switch from nasal to mouth breathing, show a high prevalence of airway hyper-responsiveness (21). Cold, dry air intake through mouth breathing might stimulate the airways and induce chronic airway inflammation (22, 23). Lastly, fine particulate matter (<2.5 μm) is deposited in the alveoli twice as great with mouth breathing as with nose breathing (19), which may increase the risk of peripheral airway inflammation.

In nonasthmatic subjects in this study, after the adjustment for allergic rhinitis, mouth breathing was associated with sensitization to common inhaled allergens, particularly sensitization to house dust mite, another well-known risk factor for asthma (24). In addition, mouth breathing in nonasthmatic subjects was associated with blood eosinophilia and lower FEV₁, which suggests that mouth-bypass breathing is associated with prodromal signs of asthmatic conditions. Thus, the risk of mouth breathing should be well recognized in the general population. Given that mouth breathing has a habitual aspect in a vicious cycle of orthodontic problems, including abnormal jaw development (25, 26), nasal breathing should be instructed from childhood. Orthodontic intervention may improve nasal airflow in mouth breathing children with maxillary constriction (27). In patients with symptomatic asthma, unfortunately, correcting mouth breathing to nasal breathing using mouth taping for 4 weeks was not successful in improving their asthma control (28), but the use of a nasal dilator overnight reduced nocturnal asthma symptoms in a small study (29).

As limitations of this study, the morbidity of asthma was estimated based on self-report of a physician diagnosis of asthma and not on medical records. Allergic rhinitis was based on self-report alone, and the use of intranasal steroid spray, which may have affected the nasal airflow patency, was not questioned. However, the prevalence of asthma and allergic rhinitis in this population was 4% and 35%, respectively, which is consistent with the reported morbidity of each disease in Japan (30, 31). As another limitation, the route of breathing was assessed only by self-reports and not assessed by an objective method, such as thermistor probe (32). Some subjects might not be aware of dysfunctional breathing patterns, particularly during sleep. Therefore, the incidence of mouth breathing might have been underestimated in this study. Despite these limitations, the current message would be important because mouth breathing on its own may raise asthma morbidity, potentially *via* increased sensitization to inhaled allergens and eosinophilic inflammation, as observed in nonasthmatic subjects. In a future study, the incidence of asthma onset in subjects with mouth breathing should be examined longitudinally.

Conclusions

Increased asthma morbidity and sensitization level to inhaled allergens in subjects with mouth breathing highlight the risk of mouth-bypass breathing in the ‘one airway, one disease’

concept. The risk of mouth breathing should be well recognized, particularly in subjects with allergic rhinitis, and also in the general population.

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Author contributions

Y. I. analyzed and interpreted the data and wrote the draft. H. M. analyzed and interpreted the data and wrote and edited the manuscript. Tad. N., Y. K., K. M., I. I., T. O., and K. A. contributed to collecting data and critically revised the

manuscript. S. M., Y. T., K. T., K. B., A. S., S. K., R. Y., Tak. N., F. M., A. N., K. C., and M. M. contributed to the design of the study, recruited patients, acquired the funding, and critically revised the manuscript.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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Appendix 1

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