1. Title: **INITIATING ORAL BREATHING IN RESPONSE TO NASAL LOADING: ASTHMATICS VERSUS HEALTHY SUBJECTS**

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7. Running Title: Oronasal breathing in response to nasal loading

8. Key words: airway physiology, asthma, perception, upper airway loading

9. Manuscript word count: 4073

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ABSTRACT

Factors influencing nasal versus oral breathing in asthmatics are not well understood. We hypothesised that asthmatic subjects have enhanced perception of nasal threshold loads, and switch from nasal to oral breathing at a lower load than healthy subjects.

Fifteen mild asthmatic and 20 healthy control subjects breathed nasally via an inspiratory threshold loading device. Nasal loading was progressively increased until subjects switched to oral breathing. Load perception at switching was rated using a Borg scale. Nasal resistance was measured using posterior rhinomanometry. The protocol was repeated before after nasal decongestant in subgroups of 10 healthy control and 6 asthmatic subjects.

Inspiratory nasal resistance was within normal limits for most subjects and was not significantly different between asthmatics and healthy controls. Compared with controls, asthmatics switched to oral breathing at a significantly lower nasal load but rated "difficulty breathing in" at the same level. Decongestant significantly lowered nasal resistance but did not change the nasal load initiating switching in either subgroup.

Enhanced perception of nasal loading may trigger increased oral breathing in asthmatics, potentially enhancing exposure to non-conditioned inhaled gas and contributing to the occurrence and/or severity of bronchoconstrictive exacerbations.

INTRODUCTION

There are few studies that have examined route of breathing (ie nasal versus oral breathing) in asthmatics. One study from our laboratory demonstrated that during an asthma attack patients breathed oronasally, but changed to exclusive nasal

breathing post-recovery [1]. Breathing route may be important in asthma, since inspiration via the mouth bypasses the warming, humidification and filtering functions of the nasal passages, thus potentially exposing the lower airways to non-conditioned inhaled gas. In support of this, mouth breathing has been demonstrated to potentiate exercise induced asthma, whereas nasal breathing is protective [2]. Despite considerable research on the bronchoconstrictive pathways associated with oral inhalation of cold, dry gas [3,4], the underlying mechanisms that determine oral versus nasal breathing in asthmatics have received little attention.

During exercise, healthy subjects switch from nasal to oronasal breathing (switching point) at a minute ventilation that is related to the magnitude of the work of nasal breathing and/or the perceived level of exertion [5, 6, 7, 8]. However, during bronchoconstrictive episodes asthmatic subjects may reach work of breathing levels that trigger a switch to the potentially lower resistance oral pathway without the necessity for exercise. Asthmatics also often suffer from concomitant nasal disease [9] resulting in high nasal resistance, further contributing to the potential for an early switch to oral breathing. In addition, studies have identified altered load perception in asthmatics [10, 11, 12] raising the potential for underlying modification of breathing route responses to imposed internal or external loads through the perceived rather than the actual load.

Resting breathing route switching in response to respiratory loads has not been previously studied in asthmatics or in healthy subjects. In the present study of both mild asthmatic and non-asthmatic control subjects, we determined: 1) the magnitude of externally applied nasal inspiratory threshold loads associated with the onset of oral breathing at rest; 2) subject perception of the level of 'difficulty breathing in' at the

onset of oral breathing; and 3) the ability to modify subject breathing route responses to nasal loading using topical nasal decongestant.

METHODS

Subjects

We studied 15 non-smoking, mild, currently asymptomatic, asthmatic subjects, (13 females, 2 males; age: 35.9±3.4 years (mean±SEM); body mass index: 25.4±4.2 kg/m^2) each of whom reported a medical diagnosis of asthma. All reported wheezing and/or cough at least once per week, all used inhaled reliever medication (beta-adrenergic agonist), but none were currently using preventative medication (inhaled corticosteroids). At the time of study, subjects had not used bronchodilators in the previous 24 hours, and all were free of symptoms of respiratory tract infection for at least 4 weeks. Subjects with chronic nasal and/or sinus disease were included provided they had not used inhaled nasal corticosteroid medications for at least 4 weeks, and short-acting nasal decongestants for at least 24 hours.

Twenty non-smoking individuals (controls; 12 females, 8 males; age: 27.1±2.4 yrs; body mass index: 23.5±3.2 kg/m^2), each reporting no history of asthma or any nasal disease and no respiratory symptoms for at least 4 weeks, were also studied.

All subjects completed a screening questionnaire regarding anthropometric data and medical history relating to upper and lower airway disease, surgery and current medications. All were instructed not to ingest caffeine containing foods and drinks for at least 4 hours prior to the study. Subjects gave written, informed consent but were kept naive as to the specific purpose of the study. The protocol was approved by the Human Ethics Committee of the Western Sydney Area Health Service.

Experimental set-up

An FEV1 measurement (best of three reproducible manoeuvres) was obtained from each subject at the commencement of the study (Autospirometer AS-800; Minato Medical Science; Osaka, Japan).

Graded nasal inspiratory threshold loads were applied using an experimental-set up (Figure 1) modified from that designed by Chen et al [13]. Briefly, subjects breathed via a dual compartment face-mask (Hans Rudolph Inc. Kansas City, MO, USA) sealed to the face with a glycerin based polymer gel (Ultimate Seal, Hans Rudolph). Nasal ($\dot{V}$n) and oral ($\dot{V}$m) airflows were measured with separate pneumotachographs (Fleisch #2; Fleisch, Lausanne, Switzerland). Pressures at the nose (Pn) and mouth (Pm) were monitored with separate pressure transducers (±100 cm H2O; Celesco, Chatsworth, CA, USA). The oral pathway pneumotachograph was open to room air, while the nasal pathway pneumotachograph was connected to a non-rebreathing valve such that expiratory airflow was vented to the atmosphere. The inspiratory arm of the non-rebreathing valve was connected to a 3-way tap allowing nasal inspiration to occur directly from room air or via an inspiratory threshold loading device. There was no leakage detected between the nasal and oral compartments when subjects were instructed to breathe via the nose only.

The inspiratory threshold loading device consisted of a plastic pipe with side-holes of different diameters (2 to 21mm; Figure 1). Graded negative pressure was generated within the chamber (PIT) via an adjustable vacuum source and by occluding/unoccluding combinations of the side-holes. In this manner, a predetermined PIT could be generated. A pressure transducer (±100 cm H2O; Celesco, Chatsworth, CA, USA) monitored PIT adjacent to the inspiratory valve. Using this arrangement, inspiration could only occur when the subject had generated a

sufficiently negative Pn (the nasal load) to overcome the P$_{IT}$, thus allowing the inspiratory valve to open.

To reduce visual cues, the experimental set-up was screened from the subject, with only the face-mask being visible. To reduce auditory cues during the application of nasal loads, subjects listened to music via headphones.

Data were recorded, digitised at 400Hz (Maclab 1/16S, AD Instruments Pty Ltd, Castle Hill, Australia) and stored on a MacIntosh computer for later analysis (Chart software V2.6.1/s, AD Instruments Pty Ltd, Castle Hill, Australia).

Perception measurement

Subjects rated their perception of 'difficulty breathing in' using a modified Borg scale (14; Table 1).

Protocol

Following measurement of FEV1, subjects were fitted with the face-mask and two minutes of quiet tidal breathing data were obtained with the inspiratory arm of the non-rebreathing valve open to room air. Subjects were free to spontaneously choose breathing route. At the conclusion of this run-in period, subjects were instructed to commence breathing through their nose only. They were then given the following instruction:

"If at some stage you feel it would be comfortable to breathe through your mouth,

then open your mouth and breathe through the mask on your face".

The three way tap was then positioned to connect subjects to the inspiratory threshold loading device with a starting P$_{IT}$ of −0.35 cm H2O. A 'switch' to oral breathing was defined by the occurrence of at least 5 oral or oronasal breaths within the next 10 consecutive breaths following each load application. If there was no 'switch' to oral breathing, the next P$_{IT}$ level was applied. In this manner the P$_{IT}$ was

gradually decreased in ~1.25 cm H2O steps until a 'switch' was detected. The inspiratory threshold nasal load at which subjects switched to oral breathing was measured as the peak inspiratory Pn for the nasal only breath that immediately preceded the first oral or oronasal breath in the five breath 'switch' confirming sequence (see Figure 2).

Once a 'switch' had occurred, the subject was instructed to return to nasal breathing while the PIT level was maintained. Immediately following the first nasal only breath subjects were asked to rate their perception of 'difficulty breathing in' by pointing to their chosen score on a hard copy of the Borg scale. No marks were made on the Borg scale sheet, thus subjects were unable to view any previously chosen score. Once a perception score was recorded, the PIT was returned to the starting level and, after a two-minute rest period, the process was repeated until a total of three runs had been performed.

Measurement of nasal resistance

At the conclusion of the above protocol, a separate experimental set-up for standard posterior rhinomanometry was used to obtain pressure-flow data for the nasal passages [15]. Nasal resistance was then calculated at 0.4 l/sec of inspiratory airflow. Technically acceptable measurements of nasal resistance were obtained in 10 of the 15 asthmatic subjects and 13 of the 20 control subjects.

Nasal Resistance/Nasal Decongestant Studies

Following an acceptable measurement of baseline nasal resistance, topical nasal decongestant (2 sprays of 0.5 mg/ml oxymetazoline hydrochloride in each nostril; Schering-Plough) was then administered, followed fifteen minutes later by a second posterior rhinomanometry measurement. Technically acceptable nasal resistance measurements were obtained for subgroups of 10 control (2 males, 8

females, age 26.8±2.7years) and 6 asthmatic (all females; age 41.0±5.1 years) subjects. Switching load and perception data were then obtained as described in "Protocol' above.

Data analysis

Data from the three 'switching' runs were averaged to obtain individual subject values that were then pooled to obtain overall group mean±SEM values. These values were calculated for the main asthmatic and control groups, and for both the pre- and post-nasal decongestant conditions for the two sub-groups. Comparisons were made using paired and unpaired Students t-test for single comparisons and repeated measures analysis of variance (ANOVA) with Bonferroni's Multiple Comparison Test (post-hoc) for multiple comparisons. Linear regression analysis was used to test for correlations. Chi-square test with Yates' Correction for Continuity was used to compare resting breathing route usage with and without nasal decongestant administration. $P<0.05$ was considered significant.

RESULTS

Main Group Studies

In this section, data are presented from the main groups of 15 asthmatic and 20 healthy control subjects. The mean age of the two main groups was not significantly different ($P>0.05$). Group data are summarised in Table 2.

Spirometry

For both the control and asthmatic groups, FEV_1 was greater than 70% predicted in all subjects. For the two groups, mean FEV_1 values tended to be higher in the control subjects (97.8±4.5% predicted; mean±SEM) than in the asthmatics (86.7±3.7 % predicted) but this difference did not reach significance ($P>0.08$).

Nasal Resistance

Inspiratory nasal resistance values ranged from 0.9 to 6.4 cmH2O/l/sec in asthmatic subjects and from 1.7 to 4.9 cmH2O/l/sec in control subjects. When the group data were examined, there was no significant difference in baseline inspiratory nasal resistance between the asthmatic and control groups (Table 2).

Switching Load

A progressively increasing nasal inspiratory threshold load eventually initiated oral breathing in all asthmatic and healthy control subjects. The switching load (ie Pn) ranged from -2.2 to -29.3 cmH2O in control subjects and from -0.9 to -8.5 cmH2O in asthmatic subjects. Group median (interquartile range) values for intra-subject coefficients of variation for switching load across the three runs in each subject were 21.2% (10.7% to 28.5%) % in the controls and 20.3% (9.1% to 25.2%) in the asthmatics.

When the group data were examined, the level of load initiating switching for asthmatic subjects was only about 50% of that measured in the healthy control subjects (ie Pn values were significantly less negative in asthmatics compared with controls; see Table 2, Figure 3). There was no significant correlation between the magnitude of the nasal load initiating switching and baseline nasal resistance values within the asthmatic group (r=0.3, *P*>0.3). Within the control group, however, there was a weak but significant positive correlation between these two variables (r= 0.5, *P*<0.05).

Perception of 'difficulty breathing in'

At the nasal load initiating switching, both the asthmatic and the healthy control groups rated their perception of the 'difficulty breathing in' in the "slight" range. Perception ratings ranged from 0.0 to 1.5 a.u. in control subjects and from 0.5

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to 4.0 a.u. in asthmatic subjects. Intra-subject coefficients of variation ranged from 0.3 % to 5.2 % in controls and from 2.2 % to 2.3 % in asthmatics. When the group data were examined, there was no significant difference in perception ratings between the asthmatic and control groups (Table 2).

Route of Breathing at Rest (Run-in period)

During the run-in period, oronasal breathing was recorded in 47% of asthmatic subjects and 45% of control subjects. All other subjects breathed exclusively via the nose. Nasal resistance values for subjects breathing oro-nasally during the run-in period were not significantly different to those for subjects breathing exclusively via the nose for both the asthmatic (3.0±1.2 cmH2O/l/sec versus 4.2±0.9.cmH2O/l/sec, respectively; P> 0.3.) and control groups (2.5±0.3 cmH2O/l/sec versus 3.1±0.6.cmH2O/l/sec, respectively; P> 0.3).

Switching load values for subjects breathing oro-nasally during the run-in period were not significantly different to those for subjects breathing exclusively via the nose for both the asthmatic (-3.4±0.6 cmH2O versus -5.0±0.7 cmH2O, respectively; P> 0.06.) and control groups (-7.5±1.8 cmH2O versus -8.7±2.3 cmH2O, respectively; P>0.35). Perception ratings for subjects breathing oro-nasally during the run-in period were also not significantly different to those for subjects breathing exclusively via the nose for both the asthmatic (2.4±0.8 a.u. versus 2.4±0.6 a.u., respectively; P>0.5) and control groups (1.6±1.1 a.u. versus 0.8±0.3 a.u., respectively; P>0.3).

Nasal Decongestant Sub-Group Studies

In this section data are presented for 6 asthmatic and 10 healthy control subjects for whom technically acceptable measurements of nasal resistance were

obtained both before and after administration of topical nasal decongestant. See also

Table 2. The asthmatic group was significantly older than the control group (P<0.02).

Nasal Resistance

With administration of topical nasal decongestant, sub-group mean values for

nasal resistance fell significantly in both the asthmatic and control sub-groups (Table

2).

Route of Breathing at Rest (Run-in period)

Although topical nasal decongestant reduced the prevalence of resting

oronasal breathing to ~25% in both the asthmatic and control subgroups, this apparent

change did not achieve statistical significance (asthmatic subgroup: *P*>0.1; control

subgroup: *P*>0.4).

Switching Load

A progressively increasing nasal load initiated oral breathing in all asthmatic

and control subjects for the post-decongestant conditions. The nasal load initiating

oral breathing for asthmatic subjects was significantly lower than that for healthy

control subjects for both the pre- and post-decongestant conditions (Table 2).

However, for both asthmatics and controls, post-decongestant nasal load values were

not significantly different to pre-decongestant values (Table 2). There was no

significant correlation between nasal load magnitude initiating switching and nasal

resistance values within the asthmatic subgroup for either pre-decongestant (r=0.07,

P>0.8) or post-decongestant (r=0.2, *P*>0.6) conditions. However, for the healthy

control sub-group a significant correlation existed for the pre-decongestant condition

(r=0.7, *P*<0.02) but not for the post-decongestant condition (r=0.2, *P*>0.5).

Perception of 'difficulty breathing in'

Following nasal decongestant, both the asthmatic and the healthy control sub-groups continued to rate their perception of the 'difficulty breathing in' at the load initiating switching in the 'slight' range. Post-decongestant perception ratings were not significantly different to pre-decongestant values for both the control and asthmatic sub-groups (Table 2). There was also no significant difference for before and after decongestant values between the two sub-groups (P>0.1).

DISCUSSION

In this study of breathing route in mild asymptomatic asthmatic and healthy control subjects all with inspiratory nasal airflow resistance values < 6.5 cm $H_2O/l/s$, progressively increasing the magnitude of nasal inspiratory threshold loading resulted in a switch from exclusively nasal to oronasal breathing in all subjects. Compared with control subjects, asthmatic subjects switched at a significantly lower applied load but at a similar level of perceived breathing difficulty. Reducing nasal resistance using topical nasal decongestant did not alter the magnitude of the switching load.

Age and Gender

Asthmatic and control subjects were not individually matched for age and gender but group mean age was not significantly different between the asthmatic and control subjects for the main group. However, the asthmatic decongestant sub-group was older than the control decongestant sub-group. Both the main and sub-groups contained a majority of females. Consequently, it seems unlikely that subject age is an influence on the study results, at least for the main group, but our findings may be more reflective of responses for females than for males.

Nasal Airflow Resistance

In the present study pre-decongestant nasal resistance values for the asthmatic and control subjects were not significantly different and were both largely within the

reported range for normal subjects [16]. Thus, although approximately 80% of asthmatics suffer from nasal pathology [9] and have high nasal resistance values [17], this was not the case with the mild asthmatic group recruited for our study. Consequently, our findings apply to asthmatics with essentially normal nasal airflow resistance and may or may not extend to those with greater degrees of nasal obstruction.

For the control group, those with higher baseline nasal resistance values, even though within the normal range, tolerated higher loads before initiating oral breathing. This relationship was not present in the asthmatic subjects. The mechanisms associated with this relationship in healthy subjects, and its disruption in asthma, require further investigation, but we speculate that the sensory processing of respiratory loading may be modified by the chronic level of the loads associated with the disease processes of chronic asthma and/or allergic rhinitis

When topical nasal decongestant was administered, nasal resistance decreased to < 3.0 cm H_2O/l/s in both the asthmatic and healthy control subgroups but the nasal load initiating switching was not significantly different. In addition, the relationship between nasal resistance and the switching load, present in the control subgroup prior to decongestant administration, was now absent. Thus, within the range of nasal resistance values encountered in the present study, the onset of oral breathing in response to external nasal inspiratory threshold loading does not appear to be greatly influenced by baseline nasal resistance, although control subjects tend to tolerate higher loads before switching if their baseline nasal resistance is relatively higher (although still within the normal range). It should be noted, however, that the number of subjects in the present study is relatively small and the range of nasal resistance

values is both small and largely within normal the normal range. Consequently, our correlative based findings need to be interpreted with caution.

Nasal Inspiratory Threshold Loading

Application of even a relatively small load (~2.5 cm H_2O/L/s) to the nares of healthy subjects has been shown to increase inspiratory time and decrease minute ventilation [18]. Moreover, nasal route loading is associated with a larger reduction in ventilation than when the same load is applied at the mouth [19]. Given this impact on ventilation, switching to mouth breathing offers subjects the ability to maintain ventilatory levels with a potentially reduced work of breathing. The present study is the first to quantify the relationship between nasal inspiratory threshold load magnitude and the onset of oronasal breathing at rest in either asthmatic or healthy subjects. Compared with control subjects, asthmatic subjects switched at a significantly lower applied load but at a similar level of perceived breathing difficulty. Thus, asthmatics have an increased propensity to switch to oronasal breathing when faced with an increase in nasal load than do control subjects.

Breathing Route at Rest (Run-in period)

During resting tidal breathing, it is generally reported that healthy subjects breathe exclusively via the nose [20]. One study has associated an increased nasal resistance with a tendency to use oral route breathing [21], however, switching behaviour at rest has only been previously investigated in lambs [22] where complete nasal obstruction was required to induce oral breathing. The only study investigating breathing route in asthmatic subjects demonstrated that during an acute exacerbation of asthma subjects breathed oronasally but switched to nasal breathing post-recovery [1]. In the present study, there was no difference in resting breathing route between mild asymptomatic asthmatics and control subjects. Indeed, just under half of both the

healthy and asthmatic subjects had oronasal breathing at rest, with no significant change in resting breathing route after the administration of a topical nasal decongestant. Nasal pathway apparatus resistance and the mask itself may have influenced spontaneous breathing during the run-in, however, there was no oral breathing at the commencement of load application (ie all subjects were breathing nasally as instructed) ensuring uniform starting conditions for the loading challenge.

In the present study nasal resistance values were not significantly different between those breathing oro-nasally during the run-in and those breathing nasally. Consequently, nasal resistance does not appear to have influenced spontaneous breathing route. In turn, spontaneous breathing route did not influence the nasal load required to initiate oral breathing. These findings are, perhaps, not surprising since nasal resistance values in our subjects were all relatively normal.

Mechanisms Determining Breathing Route

Although the mechanisms that govern the use of nasal versus oral breathing remain uncertain, the level of work/power during nasal-only breathing is thought to be a key trigger for the onset of mouth breathing at least during exercise [6]. In humans, nasal temperature and/or pressure receptors [23, 24, 25] may play an important role in controlling shifts in breathing route. Furthermore, with mild to moderate inspiratory loading, mechanoreceptors in the lower airways are almost certainly stimulated [26] most likely resulting in feedback to higher centres in the brain. In the present study, the nasal load initiating switching was measured as the peak inspiratory nasal pressure at the onset of oral breathing. Thus, we speculate that pressure receptors in the nasal vestibule may play a role in the switch from nose to mouth breathing in response to an externally applied nasal load. This is supported by the failure of nasal decongestant to change the nasal load value initiating switching despite causing a reduction in nasal

resistance (and hence total load presented to receptors in the upper and lower airways and chest wall).

Perception of NITL magnitude

In the present study, both asthmatic and control subjects used a Borg scale rating of ~2 a.u. 'slight (light)' to describe their perception of 'difficulty breathing in' at the nasal load initiating switching. Consequently, it appears that when the opportunity to switch to oral breathing exists, neither control nor asthmatic subjects will tolerate even small nasal loads. However, since the asthmatic and healthy subject groups switched at a similar perception level, but at different load magnitudes, it seems that an asthmatics perception of 'slight difficulty breathing in' is altered from that of a non-asthmatic. Subjective perception of the degree of 'difficulty breathing in' against a nasal airway that is being progressively loaded, may be an important factor in determining the switch to oronasal route breathing. In asthmatic subjects, heightened perception of breathing difficulty may allow a perception trigger level for oral breathing to be reached at a lower actual load than is the case for control subjects.

Our finding suggesting that mild asymptomatic asthmatic subjects may have heightened perception to added external nasal loads has not been previously reported and contrasts with the results of studies investigating lower airway load perception. Eckert et al [27] and Julius et al [11] have shown that asthmatics experience blunted load perception when lower airway resistance is increased, particularly patients who have a low level of baseline lung function. Indeed, asthmatic children and adults with severe disease have been shown to have a reduced ability to detect oral threshold and resistive loads [10, 28] compared with a healthy control group. Our asthmatic subjects were only mildly asthmatic and were asymptomatic at the time of the study. Since

they did not have persistent lower airway obstruction, they may not yet have developed impaired load perception.

Finally, heightened sensitivity to an increase in nasal resistance (as with the application of a progressive nasal load) may actually contribute to a worsening of asthma. 'Slight' increases in nasal resistance may cause asthmatic subjects to prematurely switch to oral route breathing, thus by-passing the air-conditioning and filtering functions of the nose. This may result in the introduction of unfiltered, non-conditioned air into the lower airways, with possible drying of the airways and induction of a scenario of worsening asthma similar to the mechanisms involved in exercise-induced asthma. Cooler, dryer air entering the lower airways causes desiccation of the liquid lining the airways precipitating the release of inflammatory cell mediators and the subsequent development of an asthmatic response [29]. This may represent an important mechanism in the pathway to the development of chronic asthma.

In conclusion, the present study is the first to examine the propensity for externally applied nasal loads to initiate a switch in breathing route. Although graded inspiratory threshold nasal loading resulted in a switch from exclusive nasal to oronasal breathing in all subjects studied, the mild asymptomatic asthmatic subjects switched at a lower load than the healthy controls. Heightened sensitivity to nasal loading in mild asthmatic subjects may increase their susceptibility to switch from nasal to oral breathing, thus increasing their exposure to non-conditioned inhaled gas, which may potentially induce worsening bronchoconstriction. Given that the subjects in the present study did not have an abnormally high nasal airflow resistance, the potential for oronasal or indeed mouth breathing in the wider asthmatic patient group, where the prevalence of nasal airway disease is much higher, seems substantial.

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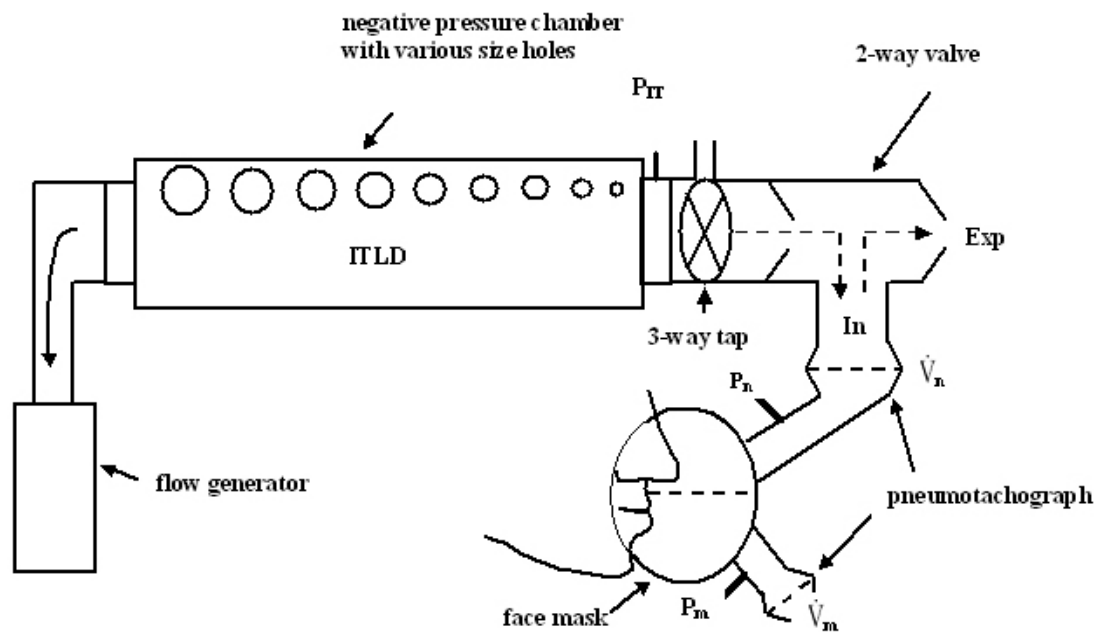
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Figure 1: Schematic diagram of the experimental set-up. Subjects breathed via a dual compartment face mask with the nasal compartment attached to a 2-way valve, the inspiratory port of which was connected via a 3-way tap to the inspiratory threshold loading device (ITLD). P_n, P_m = nasal, oral compartment mask pressure, respectively; $\dot{V}_n$, $\dot{V}_m$ = nasal, oral airflow respectively. Arrows within set-up identify direction of airflow. P_{IT} = inspiratory threshold pressure required to open inspiratory port of 2-way valve and was pre-set by selectively blocking known combinations of holes in the ITLD.
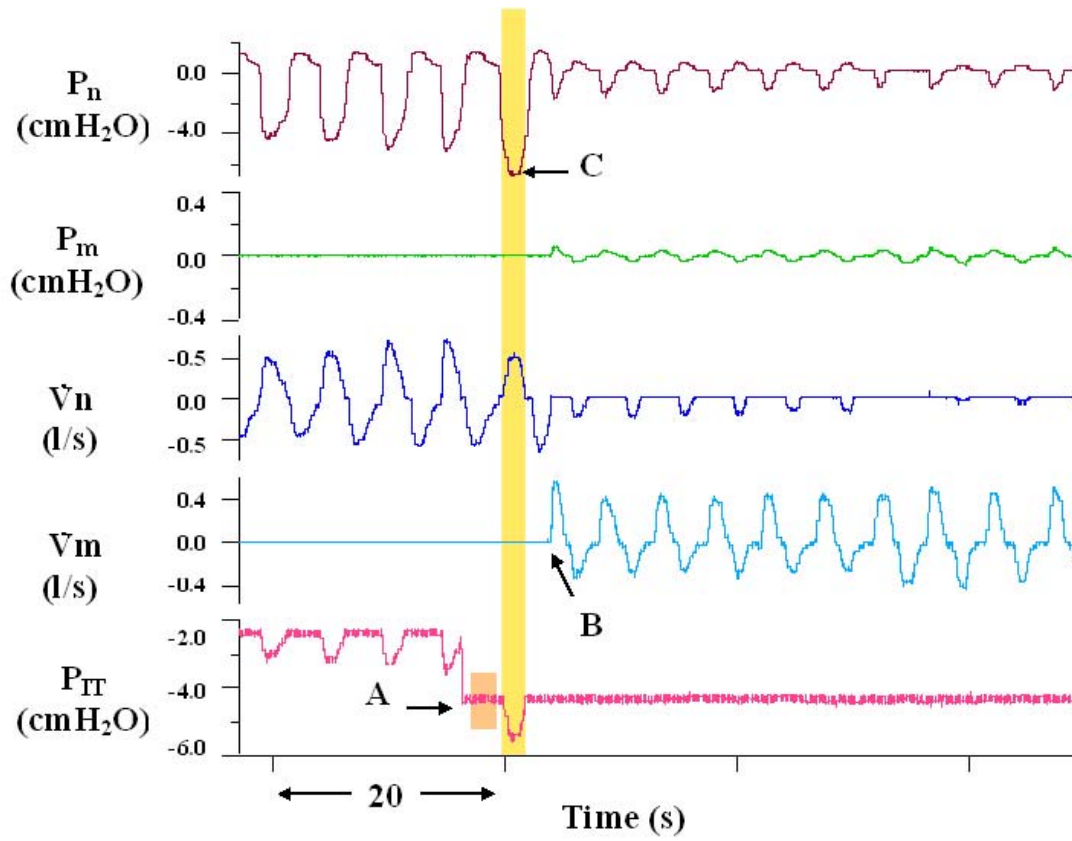
Figure 2: Representative tracing of nasal (P_n) and mouth (P_m) pressures, and nasal ($\dot{V}_n$) and mouth ($\dot{V}_m$) airflows in one asthmatic subject. P_{IT} = inspiratory threshold pressure. Inspiratory flow is in the upward direction. Note the change in P_{IT} at A triggers the onset of mouth breathing (B). The peak inspiratory P_n value for the last nasal inspiration prior to the onset of oral breathing (C) was defined as the nasal inspiratory threshold switching load.
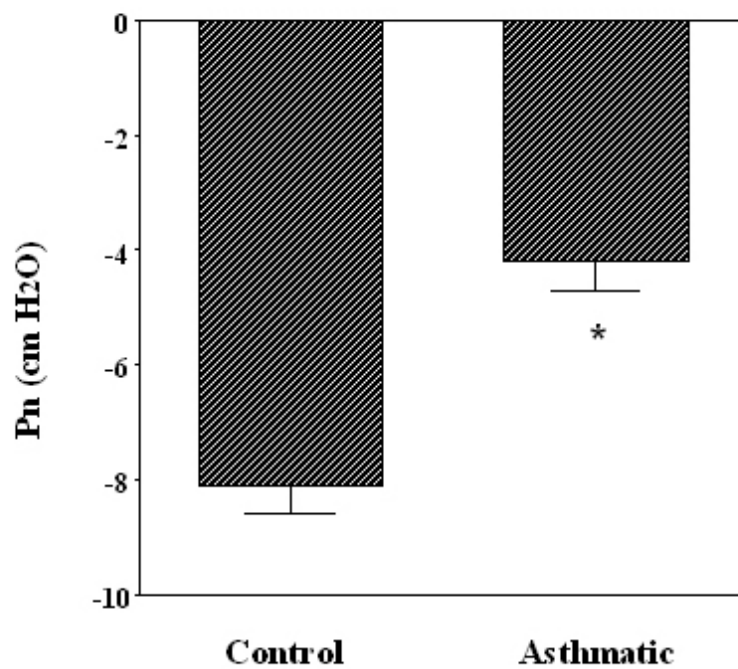
Figure 3: Group mean data for the nasal inspiratory threshold load (Pn) initiating a switch to oral breathing in control and asthmatic subjects. Bars = SEM, * $P<0.03$.

How much difficulty did you notice breathing in?

0	Not at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight (light)
3	Moderate
4	Somewhat severe
5	Severe (heavy)
6	

7   Very severe

8

9

10   Very, very severe (almost maximal)

- Maximal

Table 1: Modified Borg scale used to evaluate perception of "difficulty breathing in".

Main Group Data		
	Controls	Asthmatics
Nasal Resistance	2.6 ± 0.3 cmH20/l/sec (n=13)	3.3 ± 0.7 cmH20/l/sec (n=10)
Switching Load	-8.1 ± 1.4 cmH20 (n=20)	-4.2 ± 0.5 cmH20[*] (n=15)
Perception Rating	1.9 ± 0.3 a.u. (n=20)	2.2 ± 0.4 a.u. (n=15)
Subgroup Data		
	Controls (n=10)	Asthmatics (n=6)
Nasal Resistance	Pre: l2O/l/s Post H2O/l/s[+]	Pre: 4.9±0.8 cmH2O/l/s[*] Post: 2.3±0.4 cmH2O/l/s[+]

Switching Load	Pre: -7.7±1.6 cm H2O Post: -8.9±1.8 cm H2O	Pre: -3.5±1.5 cm H2O* Post: -3.9±1.8 cm H2O*
Perception Rating	Pre: 2.6±0.3 a.u. Post: 2.0±0.3 a.u.	Pre: 1.8±0.6 a.u. Post: 1.6±0.5 a.u.

Table 2: Group mean data ± SEM for nasal resistance, switching load and perception rating in the main and subgroup studies.

Pre = pre-nasal decongestant, Post = post-nasal decongestant;

[+] = P<0.05 compared with Pre, * = P<0.05 compared with control.