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Methods for standardization of nasal mucosa decongestion in man

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SUMMARY

As physical exercise has been shown to reduce nasal breathing resistance, the effect of physical exercise on the nasal mucosa congestion was studied, using rhinostereometry, an optical measurement method. Submaximal physical exercise as well as oximetazolinechloride sprayed into the nose, caused mucosal decongestion but the stimuli were not strong enough invariably to produce maximal mucosal decongestion as studied in 16 volunteers at repeated tests. Maximal physical exercise as well as oximetazolinechloride applied to the mucosa on a soaked piece of cottonwool, caused a considerable (0.5–4.1 mm) decongestion. Furthermore, in each of the 8 studied volunteers the final position of the mucosal surface was the same in repeated tests. Thus, this mucosal surface position can be considered as the state of maximal decongestion and can in physiological and pharmacological studies be used as reference position.

INTRODUCTION

It is a common experience that nasal breathing resistance decreases during strenuous physical exercise. This phenomen has been the subject of scientific studies the results of which have been utilized for the standardization of rhinomanometric procedures (Broms, 1980). This decrease in nasal resistance is probably mainly caused by the decongestion of the nasal mucosa, effectivated by the constriction of the capacitance vessels (Änggård et al., 1974). No studies have yet been published on the magnitude and reproducibility of the mucosal decongestion during physical exertion.

Rhinostereometry, a newly invented optical measurement method with a high degree of accuracy, allows the registration of the alteration in the surface position of the nasal mucosa (Juto et al., 1982). In the present study, this technique was used to assess the changes in mucosal congestion during submaximal and maximal physical exercise. For reference purposes, mucosal decongestion during exercise was compared to that obtained by the local nasal application of an oximetazolinechloride solution.

MATERIAL AND METHODS

Rhinostereometry is based on an optical system whereby the optical axis and a

narrow plane of focus are used to establish a three-dimensional co-ordinate system. In practice, the conditions for this are obtained by a microscope used in ear surgery fixed to a micrometer table and movable in all three dimensions. The test subject is exactly and reproducibly attached to the apparatus by an individually adapted plastic teeth splint. The nasal cavity is viewed through the microscope. The position of the nasal mucosal surface in the plane of focus is determined by the calculation of the distance between the mucosal surface and the optical axis. Decreasing distance shows decongestion and increasing distance shows congestion of the mucosa. The accuracy limit of the method is ± 0.27 mm (Juto et al., 1982). In the present study polycaprolactone was used for the plastic splints individually formed to fit the teeth of the upper and lower jaws of the test subject.

Volunteers

Twenty-one volunteers, eleven male and ten female, between 20–40 years of age participated in the experiments. All volunteers were clinically healthy and showed no signs of respiratory infection or allergy.

Submaximal physical exercise test

Sixteen volunteers, nine male and seven female, took part in the study. The mucosa on the medial side of the inferior nasal concha was examined. The position of the mucosal surface was determined immediately before the test subject mounted an ergometric bicycle. At a subjectively suitable effort level, the subject reached a steady pulse rate of 150/minute after pedalling for 2–4 minutes. Within 30 seconds of the termination of physical exercise, the position of the mucosal surface was again determined. The position of the mucosa was subsequently followed every minute during congestion until steady state was reached, which occurred within 10–25 minutes. By this time, the volunteers showed no remaining signs of their recent physical exertion. The same test procedure was again repeated. Each subject was examined on at least two different days and on each of these days three or more examinations were made. In two tests in each volunteer, the nose was occluded by tape during the exercise to reveal the effect of the airstream on the mucosa.

Maximal physical exercise test

Eight volunteers, four male and four female, 20–40 years of age, took part in the study. The mucosa of the medial side of the right inferior nasal concha was examined. In three of the volunteers (nos. 11, 15 and 16) the mucosal area studied was the same as that in the submaximal exercise test.

The position of the mucosa was determined immediately before the subject mounted the ergometric bicycle. ECG electrodes were applied for the continuous monitoring of the heart activity. The men started on the 50 watt and the women

on the 30 watt effort level. The volunteers worked at each effort level for 6 minutes and the position of the mucosal surface was determined within 20 seconds of the termination of the work session at each effort level. The test continued until the subject was too exhausted to perform any more work. The test was repeated with each volunteer at intervals of 1–3 months.

Oximetazolinechloride tests

Oximetazolinechloride, 0.5 mg/ml, was sprayed into the right nasal cavity of the 16 volunteers taking part in the submaximal exercise test. The same mucosal area as on that occasion was examined. The position of the mucosal surface was determined every minute during decongestion until steady state was reached.

An oximetazolinechloride solution, 0.5 mg/ml, was applied to the nasal mucosal surface by means of a saturated piece of cottonwool in the 8 volunteers who had taken part in the maximal physical exercise tests several days previously. The cottonwool was placed between the right inferior nasal concha and the septum and there maintained for 15 minutes. The position of the mucosal surface was determined repeatedly until steady state was reached.

RESULTS

Submaximal physical exercise

The position of the medial mucosal surface of the inferior nasal concha immediately before each physical exercise experiment varied in each volunteer. The mean value and range for the determined distances, mucosal surface - optical axis, for each subject are given in Table 1. The mean value of the standard deviations regarding all 16 subjects was 0.8 mm and the range 0.1–1.5 mm.

Submaximal physical exercise caused a mucosal decongestion in all the volunteers (0.0–4.1 mm). However the position reached, expressed as the distance to the optical axis, in each volunteer varied to a greater or lesser extent between the experiments. The mean value for the standard deviations regarding all 16 subjects was 0.4 mm and the range 0.1–0.9 mm. In only two volunteers, nos. 7 and 13, were the mucosal positions after each physical exercise experiment the same in respect of the limits of accuracy of the method used.

Occlusion of the nostril on the observed side during exercise did not have any noticable effect on the degree of mucosal decongestion.

Maximal physical exercise

In each of the eight volunteers the position of the mucosal surface immediately prior to physical exercise varied between the tests (Table 2). The exercise to maximum effort (Table 2) caused a maximal mucosal decongestion in all but one subject (no. 21) (range 0.5–4.1 mm). The final position of the mucosal surface of

Table 1. The distance between the mucosal surface on the medial side of the right (left*) inferior concha and the optical axis during rest, after submaximal physical exercise and after oximetazolinechloride spray in the nostril. n denotes the number of tests and SD the standard deviation.

	volunteer no.															
	1	2	3	4	5	6	7	8*	9	10	11	12	13*	14	15	16
The mucosal position during rest																
n	11	12	12	13	10	12	6	10	12	6	9	11	6	12	14	19
mean (mm)	4.3	1.7	4.8	2.9	3.5	3.7	1.9	5.5.	3.4	2.7	4.4	5.8	3.5	4.1	2.3	2.6
range (mm)	3.3–	0.7–	2.9–	2.7–	1.5–	2.2–	1.1–	4.6–	2.7–	1.7–	3.7–	4.5–	1.3–	3.2–	0.8–	0.6–
	4.7	2.6	6.2	3.0	4.2	5.2	2.8	5.9	4.0	4.2	5.2	6.5	5.1	4.8	3.2	4.5
SD (mm)	0.5	0.6	1.5	0.1	0.7	1.3	0.6	0.4	0.4	1.0	0.5	0.8	1.4	0.4	0.8	1.2
The mucosal position after submax. physical exercise																
n	11	12	12	13	10	12	6	10	12	6	9	11	6	12	14	19
mean (mm)	2.4	0.4	4.0	0.5	1.5	2.7	0.2	3.2	1.6	1.1	3.3	3.1	0.9	2.3	1.0	1.3
range (mm)	2.1–	0.2–	2.7–	0.2–	0.2–	2.0–	0.0–	2.5–	1.2–	0.8–	2.9–	2.8–	0.8–	2.0–	0.5–	0.6–
	2.8	0.8	6.0	1.5	3.0	4.4	0.4	5.0	2.2	1.4	3.7	4.4	1.2	2.8	1.5	3.1
SD (mm)	0.2	0.2	0.9	0.3	0.9	0.7	0.1	0.8	0.3	0.3	0.2	0.4	0.2	0.3	0.3	0.6
The mucosal position after oximetalozinechloride spray																
n	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
mean (mm)	2.1	0.5	2.6	0.2	0.8	2.2	0.3	2.5	0.7	1.3	2.8	3.5	1.0	2.3	0.7	0.7
range (mm)	1.9–	0.4–	2.5–	0.2–	0.6–	2.2–	0.2–	2.5–	0.6–	0.8–	2.7–	3.3–	0.6–	2.2–	0.6–	0.3–
	2.2	0.5	2.8	0.2	1.1	2.3	0.4	2.5	0.7	1.7	2.9	3.6	1.5	2.3	0.9	1.0

Table 2. The distance between the mucosal surface on the medial side of the right inferior concha and the optical axis during rest, after maximal physical exercise and after oximetazolinechloride applied to the mucosal surface by a soaked piece of cottonwool.
n denotes the number of tests and SD the standard deviation.

	volunteer no.							
	11	15	16	17	18	19	20	21
The mucosal position during rest								
n	4	5	4	4	5	5	6	8
mean (mm)	4.9	2.3	3.9	5.3	1.2	3.4	4.6	3.5
range (mm)	4.8–4.9	1.8–2.6	3.6–4.3	4.9–5.5	0.8–1.5	2.8–4.2	4.2–5.1	3.0–5.3
The mucosal position after maximal physical exercise								
n	2	2	2	2	2	2	2	3
mean (mm)	2.7	0.5	0.3	3.0	0.3	0.8	2.8	2.3
range (mm)	2.6–2.8	0.4–0.6	0.2–0.3	2.9–3.2	0.3–0.3	0.6–0.9	2.8–2.8	0.0–4.2
heart rate, range	188–189	190–192	174–176	188–188	182–190	186–192	181–182	
The mucosal position after oximetazolinechloride applied by a soaked cottonwool								
n	7	9	7	7	7	7	7	7
mean (mm)	2.7	0.1	0.3	2.9	0.4	1.0	2.8	2.5
range (mm)	2.6–2.9	0.0–0.4	0.0–0.5	2.5–3.0	0.1–0.5	0.7–1.2	2.7–2.8	1.7–3.3
SD	0.12	0.16	0.16	0.18	0.14	0.16	0.07	0.52

the other seven subjects in the two tests at 1–3 month intervals was the same in respect of the limits of accuracy of the method used (Table 2). Volunteer no. 21 was three times examined at maximal effort. In two of the three tests, the mucosal decongestion continued during increasing effort level to 50–75% of the maximal effort level of the volunteer. In both tests, the mucosa then began to congest during increasing effort up to maximal effort. During the third test there was a continuous mucosal decongestion until maximal effort level was reached.

Oximetazolinechloride tests

In 16 volunteers, oximetazolinechloride was sprayed into the right nostril in repeated tests. The results show that in 5 of 16 volunteers the maximal mucosa decongestion attained within 10–15 minutes was greater than that caused by submaximal physical exercise (Table 1). In 13 of 16 volunteers, the final position of the mucosal surface was the same in all tests when taking into account the accuracy limit of the method.

In 8 volunteers, repeated tests were performed with a piece of cottonwool saturated with oximetazolinechloride placed between the concha inferior and the septum for 15 minutes. In all subjects, except for no. 21, the final position of the mucosal surface was the same when taking into account the accuracy limit of the

method. The mucosal surface positions were the same as those after maximal physical exercise in all but two subjects (nos. 15 and 21) (Table 2).
Regarding volunteer no. 15, it was found that the mucosal positions in the oximetazolinechloride tests were the same as in the maximal physical exercise tests when performed during the same month. However in the tests performed during the winter, half a year later, a greater decongestion, 0.4 mm in average, was observed as compared to in the physical exercise tests.

DISCUSSION

As the nasal cavity is mucosa lined, no structures in the nose can be used as fixed points for topographic measurements. This problem is overcome in rhinostereometry by relating the mucosal surface in the plane of focus to the optical axis of the microscope used to visualize the interior of the nose. The exact and reproducible fixation of the test subject to the apparatus means that the position of the mucosal surface in different tests can be compared (Juto et al., 1982). However, as there are individual variations in nasal anatomy, the localization and direction of the optical axis will vary slightly between the test subjects. Consequently, the distance between the optical axis and the mucosal surface determined in different test subjects cannot be directly compared.
Earlier studies have shown that physical exercise causes decongestion of the nasal mucosa as determined by rhinomanometry (Aschan et al., 1958; Broms, 1980; Hasegawa et al., 1978). These observations were confirmed by rhinostereometry in the present study. The extent of decongestion caused by physical exercise to pulse rate of 150/minute was mostly not constant in the test subject and varied between the tests. To some extent, this can be explained by the fact that the position of the mucosal surface prior to the test varied. However, neither were the final positions of the mucosal surface constant from test to test. When oximetazolinechloride was sprayed into the nose, decongestion was observed but again the final mucosal surface positions were not constant. These results imply that neither physical exercise to pulse rate 150/minute nor nasal oximetazolinechloride spray are stimuli strong enough to produce maximal decongestion of the nasal mucosa. Consequently these methods cannot be used for standardization in studies concerning congestion, respectively decongestion, in the nasal mucosa.
The present results show that physical exercise to maximal effort level causes a considerable mucosal decongestion and in repeated tests shows a constant final position of the mucosal surface. The same position was found in repeated tests when the oximetazolinechloride solution was applied in constant contact with the mucosa for 15 minutes on a piece of cottonwool. These results imply that the mucosal position established either by maximal physical exercise or by an oximetazolinechloride saturated piece of cottonwool can be regarded as the position

of the mucosal surface in the state of maximal decongestion. Thus, these two methods can be used for standardization in studies of the congestion and decongestion of the nasal mucosa. In practice the position of the mucosal surface in the state of maximal decongestion is determined and taken as zero level. The state of congestion and decongestion can then be expressed as the distance between the actual position of the mucosal surface and the zero level. Subsequently these figures can also be used for interindividual comparison.

Furthermore, the present results establish that in scientific studies the nasal mucosal reaction of the test subject cannot be predicted but has to be determined at the start of the investigation. Moreover, when possible all tests should be performed within a reasonable time span, 1–2 months. This is illustrated in subject no. 15 where the nasal decongestion differed in the tests performed at a half year interval. The reason for this change in reactivity of the mucosa is obscure, but could be due to a variation in the amount of interstitial tissue fluid in the mucosa on the test occasions. If this should be so, it suggests a possible approach to the study of the effect of anti-inflammatory treatment. The varying mucosal reactivity in subject no. 21 also illustrates the need for close controls. The congestion of the mucosa seen after an initial phase of decongestion as this subject approached his maximal physical effort level is as yet not possible to explain. The reaction may be equivalent to that of effort asthma and this emphasizes the need for further nasal mucosal studies.

ZUSAMMENFASSUNG

Es ist bekannt, dass bei Körperanstrengung der Atemwiderstand in der Nase sinkt. Mit der Rhinostereometrie, einer optischen Messmethode, wurde der Einfluss von Körperanstrengung auf die Schwellung der Nasenschleimhaut getestet. Bei 16 Versuchspersonen wurde nach submaximaler körperlicher Anstrengung oder Einsprühen einer Oximetazolinechlorid-Lösung eine Abschwellung der Nasenschleimhaut beobachtet, doch waren die Stimuli nicht stark genug, um immer eine maximale Abschwellung der Mucosa zu bewirken. Nach maximaler Körperanstrengung oder mit einem in die Nase geführten mit Oximetazolinechlorid getränkten Wattebausch konnte eine deutliche Abschwellung (0,5 mm–4 mm) beobachtet werden. Auch bei wiederholten Messungen von den acht Versuchspersonen war die Endposition der Schleimhautoberfläche konstant. Daraus kan geschlossen werden, dass die Position der Schleimhautoberfläche als Zustand der maximalen Abschwellung definiert werden und in physiologischen und pharmakologischen Versuchen als Ausgangsposition verwendet werden kann.

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