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Racial differences in nasal fossa dimensions determined by acoustic rhinometry*†

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SUMMARY *Sixty acoustic rhinographs from subjects of three different ethnic groups (Caucasian [Europeans], Negro, and Oriental) were examined at baseline and after decongestion. The main parameters analysed were minimal cross-sectional area (MCA), the distance at which this occurred (D), nasal volume at 0-4 cm (Vol), mean cross-sectional area at 0-6 cm (MA), and the cross-sectional area at 10 points in the nose (0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, and 6 cm) analysed as a series (A). Values from left and right were combined and mean values used. Analysis was carried out using multiple linear regression and grouped linear regression with analysis of covariance and, for A, multifactorial analysis of variance. For MCA, race was the main determining factor with Orientals and Caucasians significantly lower than Negroes: $p < 0.0001$ (corrected means and 95% confidence intervals [c.i.]: Orientals: 0.63 cm^2, 0.55-0.71 cm^2; Caucasians: 0.69 cm^2, 0.62-0.77 cm^2; Negroes: 0.87 cm^2, 0.79-0.95 cm^2). Height alone correlated with D in the decongested state ($p < 0.0001$); race as well as height in non-decongested noses ($p=0.018$). There were significant racial differences in Vol in both decongested ($p=0.014$), and non decongested noses ($p < 0.0001$). In the non-decongested state MA was significantly different in all racial groups: $p < 0.0001$ (corrected means and c.i.: Orientals: 3.89 cm^2, 3.47-4.31 cm^2; Caucasians: 4.67 cm^2, 4.27-5.09 cm^2; Negroes: 5.13 cm^2, 4.72-5.53 cm^2). In the decongested state there was a significant difference between Negroes and the other two groups ($p=0.015$), and Orientals and Caucasians were a homogenous population. We conclude that race has a significant effect on acoustic rhinometry measurements and this needs to be taken into account.*

Key words: acoustic rhinometry, race, nasal index

INTRODUCTION

It is well recognized that there are differences in the dimensions of the external nose between racial groups, and rhinomanometry has been used to determine if there are corresponding variations in nasal airflow. These studies have produced conflicting results regarding the influence of race over nasal airflow resistance (Babatola, 1990; Calhoun et al., 1990; Ohki et al., 1991).
Acoustic rhinometry was introduced by Hilberg and his co-workers in 1989 to assess the geometry of the nasal cavity. The method, based on the reflection of an acoustic signal introduced into the nasal cavity, can be used to evaluate the cross-sectional area of the nasal cavity as a function of distance from the nostril. The aim of this study was to compare and characterize the nasal cavity geometry of three major racial groups i.e. Caucasians, Negroes and Orientals, by means of the acoustic rhinometer.

MATERIAL AND METHODS

Subjects

Sixty normal adult subjects, with asymptomatic clear noses, aged 21 to 60 years were studied. Subjects were allocated to a particular ethnic group depending on their country of origin and that of their parents and grandparents. Those in the Caucasian sample were of European origin.
Exclusion criteria were gross structural abnormalities, nasal polyposis, previous nasal surgery or trauma, intercurrent upper respiratory tract infection, subjects taking regular nasal medication and those subjects in whom there was doubt about which ethnic group they belonged to.

Methods

The nose of each subject was examined by anterior rhinoscopy

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and rigid nasal endoscopy. External nasal measurements were taken with callipers. The height, weight, age and sex of all subjects was recorded. Acoustic rhinometry was then performed. The instrument used was an ECCOVISION Acoustic Rhinometer (model AR-1003) supplied by HOOD Laboratories (Pembroke, USA).

Silastic nosepieces were used and were selected for each individual according to the size and shape of the nostrils. No particular nosepiece was used for one racial group. Care was taken to establish a good seal and to avoid any distortion of the nostrils. The subjects sat whilst the probe tip was introduced in to the very tip of the nasal aperture. The probe was aligned near the midline and about 45° off vertical, this angle was minimally adjusted to produce a stable trace. No sealant was used. Figure 1 shows one of the nose pieces used. Ten stable measurements were made and the mean and standard deviation were calculated.

Two puffs of 0.1% xylometazoline nasal spray were then introduced into each nostril. After 10 min acoustic rhinometry was repeated as above.

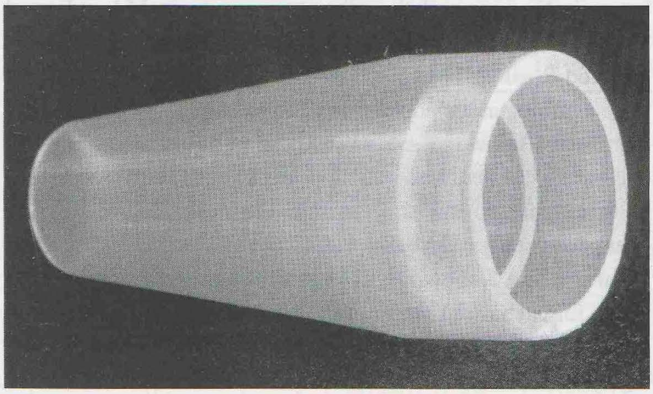

Figure 1. Silastic nosepiece used during acoustic rhinometry.

Statistical analysis

Statistical analysis was performed on a microcomputer using software packages; Statgraphics (Statgraphics Corp., Release 2.6) and Arcus Pro-Stat (Medical Computing, DOS version 3). The main parameters analysed were minimal cross-sectional area (MCA), the distance at which this occurred (D), nasal volume at 0-4 cm (V), mean cross-sectional area at 0-6 cm (MA), and the cross-sectional area at 10 points in the nose (0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, and 6 cm) analysed as a series (A). Mean measurements from left and right nostrils were used, n=20 for each group.

Multiple linear regression with a forward stepwise technique, was used to evaluate the effect of the various population characteristics on each parameter. For A, multifactorial analysis of variance was used with area by distance as the main variable and sex, race and congestion states as factors. Subsequent positive findings were then further examined by Scheffe multiple range testing. Confidence intervals were assessed by grouped linear regression and covariance analysis. Significance at the 5% level was deemed acceptable.

The nasal index data was subjected to a modified t-test (Bonferroni) with significance assessed at the 5% level.

RESULTS

A total of 60 subjects were examined. There were 20 subjects (10 males and 10 females) in each of the three groups. Basic anthropometric details are shown in Table 1.

Using the Kolmogorov-Smirnov test, all four main parameters were found to approximate to the normal distribution. Nasal dimensions derived from the acoustic rhinographs are shown in Table 2a. Weight, age and sex (adjusted for height) had no significant influence on any of the parameters.

For MCA, race was the only significant determinant (Tables 2b–c); with Orientals and Caucasians having a significantly lower MCA than Negroes: adjusted R^2=0.27, F=12.2, and p <0.0001. Height and sex had little influence. Similar relationships occurred when decongested, dMCA.

Table 1. Anthropometric data.

	Oriental	Caucasian	Negro
age (years)			
mean	34	33	34
SD	7.3	10	11
weight (kg)			
mean	56.8	70	68.8
SD	7.3	13	15
height (m)			
mean	1.62	1.70	1.68
SD	0.8	0.1	0.1

Table 2a. Acoustic parameters: sample data.

		Oriental	Caucasian	Negro
MCA	sample mean	0.62	0.71	0.88
	SD	0.19	0.15	0.22
MCA.d	sample mean	0.78	0.77	0.98
	SD	0.16	0.16	0.25
D	sample mean	1.49	1.16	0.98
	SD	0.61	0.69	0.51
D.d	sample mean	0.77	0.99	0.79
	SD	0.52	0.51	0.54
Vol	sample mean	3.86	4.70	5.14
	SD	0.75	0.83	1.09
Vol.d	sample mean	0.25	5.59	6.16
	SD	1.08	0.71	1.28
MA	sample mean	1.21	1.46	1.74
	SD	0.27	0.32	0.41
MA.d	sample mean	1.68	1.77	2.02
	SD	0.37	0.25	0.56

MCA: minimum cross-sectional area (cm^2); D: distance from nostril to MCA (cm); Vol: volume of the segment 0-4 cm (cm^3); MA: mean cross-sectional area 0-6 cm (cm^2); suffix d: values recorded in decongested noses.

Table 2b. Acoustic parameters: adjusted means and population estimates.

		Oriental	Caucasian	Negro
MCA	adjusted mean	0.63	0.69	0.87
	c.i.	0.55–0.71	0.62–0.77	0.79–0.95
MCA.d	adjusted mean	0.81	0.76	0.97
	c.i.	0.72–0.90	0.67–0.85	0.88–1.06
D	adjusted mean	1.61	1.08	0.94
	c.i.	1.35–1.88	0.83–1.34	0.68–1.20
D.d	adjusted mean	0.86	0.93	0.76
	c.i.	0.63–1.08	0.70–1.16	0.53–0.98
Vol	adjusted mean	3.89	4.67	5.13
	c.i.	3.47–4.31	4.27–5.09	4.72–5.53
Vol.d	adjusted mean	5.29	5.56	6.15
	c.i.	4.78–5.80	5.07–6.06	5.65–6.64
MA	adjusted mean	1.21	1.46	1.74
	c.i.	1.05–1.38	1.30–1.63	1.59–1.90
MA.d	adjusted mean	1.69	1.76	2.01
	c.i.	1.49–1.89	1.56–1.95	1.82–2.21

Means adjusted to standard height of 1.67 m; c.i. is 95% confidence interval for estimate of adjusted population mean.

Table 2c. Differences between adjusted means.

		Oriental vs. Negro	Oriental vs. Caucasian	Negro vs. Caucasian
MCA	c.i.	-3.49 to -1.12	-0.18–0.054	0.065–0.28
	p	<0.0001***	0.13	0.0008***
MCA.d	c.i.	-0.20 to -0.12	-0.08–0.18	0.08–0.33
	p	0.006**	0.22	0.005***
D	c.i.	0.29–1.06	0.15–0.92	-0.50–0.22
	p	0.0002***	0.0024**	0.21
D.d	c.i.	-0.23–0.43	-0.42–0.26	-0.50–1.47
	p	0.27	0.32	0.13
Vol	c.i.	-1.74 to -0.74	-1.30 to -0.29	-0.04–0.94
	p	<0.0001***	0.0053**	0.062
Vol.d	c.i.	-1.58 to -0.14	-1.01–0.46	-0.12–1.28
	p	0.008**	0.22	0.06
MA	c.i.	-0.76 to -0.29	-0.49 to -0.0096	0.053–0.51
	p	<0.0001***	0.0164*	0.0065**
MA.d	c.i.	-0.60 to -0.05	-0.34–0.22	0.24–0.29
	p	0.0097**	0.33	0.025*

c.i. is 95% confidence interval for the diference in adjusted population means.

D was smaller in Negroes (p=0.007); height also correlated: coefficient 0.31 and p=0.018; when the model included sex as well: adjusted R^2=0.24, F=5.7, and p=0.0003. Height and race also correlated independently: R^2=0.1, F=6.4, p=0.0032, and adjusted R^2=0.08, F=3.6, p=0.018, respectively. On decongestion height alone remained significant: coefficient 0.41, adjusted R^2=0.15, F=11.7, and p <0.0001.

Values for Vol were greatest in the decongested state (Vol.d). Independently, only race exerted a significant effect on Vol: adjusted R^2 =0.4, F=10.5, and p <0.0001; and the fit was not much changed by adjusting for height and sex: adjusted R^2=0.22, F=5.2, and p=0.0006. For Vol.d, the same relationship existed but explained less of the variation, for race only: adjusted R^2=0.09, F=3.8, and p=0.014; with height and sex: adjusted R^2=0.09, F=2.4, and p=0.047.

In the non-decongested state there was a significant rise in the cross-sectional area 2.5 cm into the nose, and this continued to rise significantly until 6 cm: F=69.9, p <0.0001. There was a significant difference between all three racial groups in MA, (Tables 2b-c). This was not much influenced by accounting for height and sex; for race alone: adjusted R^2=0.27, F=12, and p <0.0001.

In the decongested state there was a similar change in A but it commenced at 2 cm into the nose and continued to 6 cm: F=87.0, and p <0.0001. There was a significant difference between Negroes and the other two groups in MA: adjusted R^2=0.09, F=3.8, and p=0.015; accounting for height and sex: adjusted R^2=0.09, F=2.5, and p=0.04. Orientals and Caucasians were a homogenous population (Tables 2b-c).

Comparing individual points in the non-decongested and the decongested states, A was significantly greater in the decongested state only beyond 2.0 cm into the nose. Before this, no change in area was detected.

Figures 2 and 3 show the average cross-sectional area at each point, for each racial group in the decongested and non-decongested states.

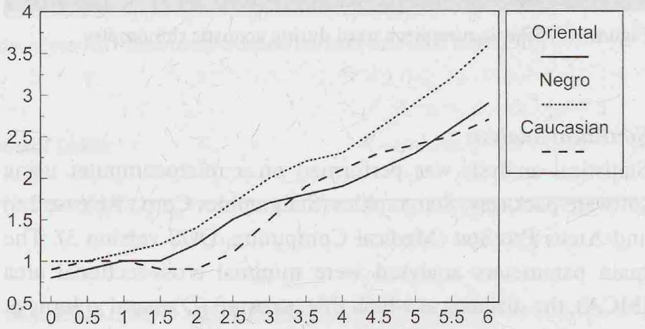

Figure 2. Average cross-sectional area at each point, non-decongested state.

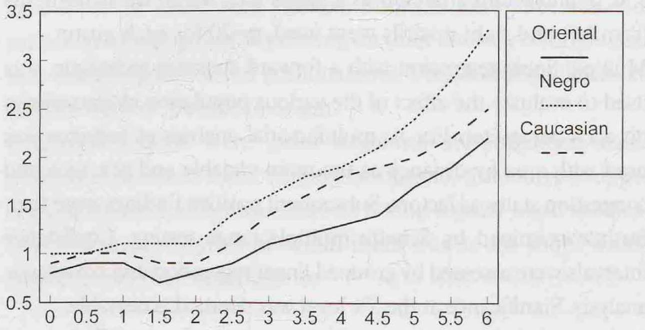

Figure 3. Average cross-sectional area at each point, decongested state.

Racial groups

The cephalometric nasal indices[1] (transverse and anteroposterior) were derived for each individual (Topinard, 1878; Table 3). The data in these samples were not normally distributed, but when Log transformed showed no evidence of non normality. All three groups had significantly different transverse nasal indexes (Table 4).

Table 3. Nasal indices.

	Oriental	Negro	Caucasian
transverse:			
median	0.95	0.97	0.76
interquartile range	0.76–1	0.91–1.1	0.68–0.83
c.i. for population median	0.79–1	0.91–1.1	0.69–0.83
geometric mean	0.91	1.01	0.75
anteroposterior:			
median	2.22	2.23	1.71
interquartile range	2.00–2.56	2.43–2.84	1.50–1.94
c.i. for population median	2.00–2.40	2.91–2.82	1.50–1.90
geometric mean	2.29	2.37	1.68

Table 4. 95% Confidence intervals and p-values for the ratios of the geometric means.

transverse nasal index	c.i.	p
Oriental: Caucasian	1.03–1.13	<0.0007**
Negro: Caucasian	1.09–1.19	<0.0001***
Oriental: Negro	0.37–0.98	0.01*

Bonferroni critical p for 3 comparisons: 0.016.

DISCUSSION

In two previous studies which compared Negroid and Caucasian noses using active anterior rhinomanometry, there were no significant differences in nasal airway resistance between the groups despite differences in external dimensions (Babatola, 1990; Calhoun et al., 1990). In contrast, Ohki et al. (1991) found significant differences in nasal airflow resistance between Caucasian, Oriental and Negro adults using posterior rhinomanometry. In this study we have shown that there are distinct differences in nasal cavity geometry between these three racial groups.

Rhinomanometry is an objective method of assessing nasal patency by expressing characteristics of airflow. Acoustic rhinometry is an objective means of assessing area as a function of distance and hence provides a geographic description of the nasal cavity. Its application in the nose has been actively investigated since its development in 1989 and many studies have been performed to validate the technique (Hilberg et al., 1989; Mayhew et al., 1993). Acoustic rhinometry has been used as both a research tool and as an objective measure of the success of treatment in clinical practice (Grymer et al., 1989; Hilberg et al., 1990; Lenders et al., 1991; Elbrond et al., 1991; Fouke et al., 1992). The issue of standardisation of the technique has been addressed at the 15th Congress of the European Rhinologic Society and XIII ISIAN (Copenhagen, June 19-23, 1994).

In this study we found a similar value for the mean MCA for the Caucasian group as Lenders et al. (1990) and Grymer et al. (1991). We found that Orientals had a similar MCA to Caucasians, but that Negroes had a significantly larger MCA. In addition, Lenders et al. (1990) observed a value for D in a group of normal Caucasian adults (1.3 cm), which was similar to that observed in our study and which approximates to the region of the nasal valve or isthmus nasi.

D was smaller in Negroes and height also correlated, with height the more significant influence. In the decongested state the racial difference disappeared, but the influence of height continued. Height has not been examined as a factor before, but overall growth of the individual appears to influence the geometry of the nose and in particular the distance between the nostril and the narrowest part of the nasal aperture or MCA.

With decongestion, the distance at which there is a significant increase in area moves anteriorly from 2.5 cm to 2.0 cm from the nostril. This suggests that vascular tissue responsive to vasoconstriction begins at 2.0 cm into the nose and would appear to continue for at least 6 cm.

Race appears to have an effect over the total volume of the nasal cavity in the fist 4 cm. In the non-decongested state Orientals have a smaller volume even if height and sex are taken into account (Tables 2c and 5). Similar differences and trends occur in decongested noses.

Table 5. Summary of statistically significant racial differences.

MCA	Negro>Caucasian and Oriental
MCA.d	Negro>Caucasian and Oriental
D	Oriental>Caucasian and Negro (height correlates)
D.d	Height only correlates
Vol	Negro and Caucasian>Oriental
Vol.d	Negro>Oriental
MA	Negro>Caucasian>Oriental
MA.d	Negro>Caucasian=Oriental

When looking at area by distance there was no significant difference between sexes within each racial group, although it was clear that males were responsible for most of the observed increase in A seen in the Negro group. No effect of height was noted. It was therefore considered reasonable to analyse the racial groups as homogenous populations in further analysis.

In the non-decongested nose there was a significant difference in MA between the three racial groups, but after decongestion Orientals and Caucasians became a homogenous population with the value for Negroes remaining significantly higher. This would suggest that much of the difference in MA seen between Orientals and Caucasian was due to an increased amount of vascular tissue in Orientals. The fact that this remained significantly higher in Negroes after decongestion would suggest that they have a larger bony aperture. This contrasts with the work of

[1] *Transverse nasal index*: width/height; *anteroposterior nasal index*: width/projection. *Width* is maximum distance between the lateral rim of the alae. *Height* is the distance on the skin from the nasion to the base of the nasal spine. *Projection* is the distance from the base of the nasal spine to the tip.

Ohki et al. (1991), who measured airflow resistance in the same three racial groups and found no significant difference in the ratio between resistance of untreated and decongested noses between these groups. This could be due to poorer sensitivity of posterior rhinomanometry or it might suggest that other factors are influencing nasal airflow in addition to the degree of mucosal congestion.

In conclusion, race exerts and influence over the internal geometry of the nose and ought to be taken into account when interpreting acoustic rhinographs. In particular, the study demonstrates the need to establish control populations for ethnic groups encountered in other studies. There are implications for the clinical setting. The finding of apparent inferior turbinate hypertrophy on anterior rhinoscopy in Negroes may be the normal state. Further studies on basic anatomy are needed. In particular the extent of vascular tissue compared to the underlying bony skeleton warrants further investigation.

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