MAXIMUM INSPIRATORY NASAL FLOW

AND

NASAL INDICES IN MAN

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by

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I would like to thank all those who volunteered to be subjects for this study.

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

CHAPTER I

Introduction

The purpose of this study was to analyse the relationship between the maximum inspiratory nasal flow (MINF), nasal resistance, and the anthropometric characteristics of the nose in healthy individuals.

Thomson and Buxton (1923) found that there was a tendency for populations with a high Nasal Index ($\frac{\text{nasal breadth}}{\text{nasal height}} \times 100$) to be found in hot, moist climates, whereas a low Nasal Index tend~~s~~ed to be associated with cold or dry climates. They proposed that selection favored an open passage to facilitate loss of excess body heat in hot climates and a narrow passage to condition incoming air in cold or dry climates. They postulated that temperature was a more important selective factor than relative humidity in influencing nasal shape.

Weiner (1954) reworked the data collected by Thomson and Buxton (1923) using wet bulb temperature and the vapor pressure of the air as additional climatic variables that may be correlated with Nasal Index. In 146 groups studied Weiner (1954) found nasal index to be most highly correlated with the vapor pressure of the air ($r = 0.82$) and he postulate~~s~~d that the functional basis underlying the Nasal Index - climate relationship is the humidification of the inspired air.

However, Hoyme (1965), using skull measurements, found nasal height, not breadth, to vary with climate. This, she relates to the size of the upper face; she found a smaller upper facial height and a smaller nasal height in warmer climates. She argues that if nasal height is highly correlated with the height of the upper face then a physiological explanation of the variation of nasal index with climate, involving respiratory function, may not be appropriate.

At this point it seems important to examine the accepted physiological respiratory function of the nose, which is to warm and moisten inspired air (Cottle, 1955; Davies, 1932; Fenn and Rahn, 1964; Harrison et al, 1964; Negus, 1958; Proctor, 1964).

Normal airway function can be divided into extrathoracic and intrathoracic moieties. In the extrathoracic airways (nose, mouth, pharynx, larynx, and extrathoracic trachea) the flow of the air is determined by the pressure drop between the atmosphere and a point in the airway where it enters the chest and the caliber, shape and length of the airway. Most of the anatomical features of the extrathoracic airway are fixed. However two principal mechanisms, dynamic compression of the nose and glottal aperture are variable. Glottal aperture is an important variable during mouth breathing and dynamic compression is the prime variable during inspiration in nose breathing (DeGraff & Bouhuys, 1973).

Cottle (1955) in discussing the structure and function of the external nose noted that the upper lateral cartilages act as a valve. They usually make an angle of 10 degrees with the septum just under the septum roof and move to and from the septum with the respiratory air currents.

In a "white" adult the posterior wall of the vestibule inferiorly is not usually continuous with the floor of the nasal chamber proper, but instead is encroached upon by the inferior portion of the pyriform crest.

Generally, Caucasian nostrils are almost vertical in their longest diameter when seen from below, whereas the Negroid nostril is horizontal or transverse. The Caucasian nostril is more or less narrow and elliptical, the Negroid is wide and round. The shape of the Caucasian nostril is associated with a high projecting narrow bony - cartilaginous pyramid. The shape of the Negroid nostril is associated with a flat, broad, low-lying nose. The Negroid nose usually has less markedly developed baffles, and the floor of the pyriform aperture is not prominent, a true crest is usually absent. Thus, it offers fewer obstacles to the passage of air from the posterior portion of the nasal chamber, as does the Caucasian nose (Cottle, 1955).

Butler (1960) found that one-third of the heat and water that conditioned inspired air was recovered in expiration.

Although in our study we are concerned with nasal shape and nasal inspiration, Butler's (1960) observation suggests further functional significance of human variation in nasal structure, since the increased baffles and resistance of the 'Caucasian' (long and narrow) nose may well act as a more efficient (in terms of total body energy) recovery agent for heat and moisture during expiration. Butler's (1960) study however, used only 10 subjects and did not make note of any metric nasal characteristics.

Cottle (1955) noted that in the adult Negroid nose the streams of air passing through the horizontally placed nostrils would be guided downward into the inferior portion of the nasal chamber, where they are received (in the flat nose) by the large, moist inferior turbinates "so well able to modify temperature and humidity of very warm air." The nasal space anterior to the turbinates plays a lesser role in humidification in the Negroid nose than in the typical adult white Nordic nose.

In the typical adult white Nordic nose the vestibule receives air which it helps shunt not into the inferior meatus and around the inferior turbinate, but into the much larger external nasal pyramid and thence into the middle meatus and around the middle turbinate. Air in the posterior portion of the vestibule frequently encounters the barrier of the well defined floor of the pyriform aperture and consequently is directed above the level of the inferior turbinate upward in the external nasal pyramid toward the middle turbinate.

Caucasian noses seem to have more baffles which seem to slow down air currents, impart to them warmth, and direct them upward into the external nasal pyramid space. This observation is based on anatomical rather than direct flow measurements.

These anatomical entities described are also important in creating resistance to air currents on expiration as well as inspiration (Cottle, 1955). The Caucasian baffles, on expiration, may act to retrieve some of the warmth and humidity and therefore minimize total energy loss.

Cottle (1955) speculates that the Caucasian nose is a more efficient mechanism for making inspired air warmer, while the Negroid nose probably is more efficient for making the inspired air cooler when necessary, though each type of nose can do both.

Earlier work by Dishoveck (1942) agrees with Cottle's (1955) basic conclusions. Dishoveck (1942) found that inspiratory resistance in a wide nose is controlled by the ostium internum and the alae nasi. In a narrow nose, on the contrary, the resistance of the conchaie plays a greater role.

The inn er nostril (ostium internum) functions to direct the air stream, and control resistance to air flow. The resistance to air flow is altered in grossly deformed nostrils, at an extremely high rate of flow, and when the nostrils are voluntarily dilated during rapid breathing ('flaring'). A more complex passage increases resistance to air flow. (Proctor, 1964)

Bridger and Proctor (1970) found that during maximum voluntarily nasal inspiration the nasal "valve" compresses as negative pressure increases until a stable point is reached where a further increase in pressure cannot increase flow. The nose has a collapsible or flow limiting segment (FLS) that acts like a starling resistor.

On inspiration a pressure difference is established between atmospheric pressure and the nasopharynx producing an air flow related to nasal resistance.

According to Bridger and Proctor (1970) the flow limiting segment (FLS) in most normal subjects was situated at the proximal portion of the nasal "valve" where the upper lateral cartilages are attached to the pyriform margin of the maxilla. This area is 0.5 to 1.0 cm deeper in the nose than the ostium internum which is the narrowest part of the nasal passage at the distal margin of the upper lateral cartilages. There are important ethnic differences in the anatomic structure of this region which have been described by Cottle (1955).

Dynamic compression of the nose occurs during forceful inspiration. With rapid inspiration the pressure inside the nares becomes sufficiently negative to overcome the elastic recoil of the alae nasi and the cartilaginous portions of the external nose cave in, due to the resistance within the external nose. When inspiratory effort is increased the maximum inspiratory nasal flow (MINF) becomes constant, limited by the dynamic compression of the nose. (DeGraff and Bouhuys, 1973; Bridger and Proctor, 1970)

Considered separately, increased inspiratory force always results in increased flow; however, the dynamic compression of the nares decreases flow. Together increased inspiratory force and dynamic compression result in a constant rate of flow independent of inspiratory force once a maximum flow has been reached. (MINF)

Among the subjects tested, the most negative ptm ((the critial transmural pressure at which the FLS (flow limiting segment) becomes active, i.e. the ptm at which collapse occurs)) values were found in several Negro subjects. This result can be interpreted as a case where the FLS resists collapse and there is a low nasal resistance. (Bridger and Proctor, 1970)

This lower nasal resistance does not necessarily mean that there is a higher MINF in broad flat noses. However we tried to test this hypothesis in our study.

In our study we measured the nasal resistance and maximum inspiratory flow rates to see if indeed there was a correlation with these factors and the size and shape of the nose.

CHAPTER II

MATERIAL & METHODS

(a) Subjects

Volunteers were drawn from the University community and were largely students. It was found to be impractical to classify them on racial grounds but most were of a broadly "white" background with some originating from various parts of Asia, the Caribbean, Middle East, and Japan. Overall the ethnic makeup of the sample was fairly representative of the McMaster University student population. There were few "blacks" as the category is used in the United States.

In all fifty males and twenty-seven females were tested. All subjects whose data are presented here were tested during the winter months.

It should be noted that with regard to the range of Nasal Index the sample is not entirely satisfactory, as the long and narrow type of nose is over-represented with a deficiency of broad and short (Table I).

Volunteers were interviewed and a short medical history was taken. All volunteers were between the ages of 15-40 and had not had any upper respiratory illness within four weeks prior to testing. Volunteers who had had any upper respiratory difficulties (chronic or acute bronchitis,

TABLE I

CHARACTERISTICS OF THE SAMPLE

		MALES	FEMALES	COMBINED SAMPLE
Number of Volunteers		50	27	77
NASAL INDEX	69 or less	15	16	31
	70 - 79	21	10	31
	80 - 89	11	1	12
	90 - 100	3	0	3

MEAN VALUES ± sd (n)	MALES	FEMALES	COMBINED SAMPLE
Nasal Height (cm)	5.1 ± 0.3 (50)	4.9 ± 0.4 (27)	5.1 ± 0.6 (77)
Nasal Breadth (cm)	3.8 ± 0.4 (50)	3.3 ± 0.4 (27)	3.7 ± 0.4 (77)
Nasal Projection (cm)	3.1 ± 0.3 (50)	2.8 ± 0.2 (27)	3.0 ± 0.4 (77)
Nasal Index $-\frac{B}{H}100$	75.2 ± 9.2 (50)	68.7 ± 7.6 (27)	72.9 ± 9.2 (77)
MINF (ℓ/min)	122 ± 33 (50)	103 ± 24 (27)	115 ± 32 (77)

asthma, sinusitis, respiratory allergies) within the past year were not included in the sample group. It was noted if the volunteer was a smoker or non-smoker.

(b) Measurements

The age, stature, weight, and sex of the volunteer were recorded. Using a sliding caliper, measurements were taken of the nasal height [(nasion to subnasale, (Comas, 1960; Oliver, 1969)] , and nasal breadth [maximum external separation between the alae nasi, (Oliver, 1969)] . The nasal projection (depth) [the distance between the summit (pronasal) point of the nose and the most posterior point of the insertion of the alae nasi on the face, (Oliver, 1969)] , was measured with a metric ruler, the measurement being taken in projection, not obliquely. The maximum and minimum diameters of the nares were measured with a metric ruler.

(c) Data Processing

From these measurements were calculated several indices:

(a) the nasal index: $\frac{\text{nasal breadth}}{\text{nasal height}} \times 100$,

(b) the index of nasal projection: $\frac{\text{nasal depth}}{\text{nasal breadth}} \times 100$,

(c) the nasal depth index: $\frac{\text{nasal depth}}{\text{nasal height}} \times 100$.

The estimated nasal volume was calculated using the mathematical formula for ½ the volume of a right circular cone.

est. nasal volume = ½ volume of right circular cone

$$= \tfrac{1}{2}\left[1/3 \text{ (area base) (height)}\right]$$

$$= 1/6\, \pi r^2 h$$

The radius, r, was calculated as follows from nasal breadth and nasal depth.

$$r = \sqrt{\frac{\left(\frac{\text{nasal breadth}}{2}\right)^2 + (\text{nasal depth})^2}{2}}$$

$$r^2 = \frac{\left(\frac{\text{nasal breadth}}{2}\right)^2 + (\text{nasal depth})^2}{2}$$

$$h = \text{nasal height}$$

Therefore the formula used was:

$$\text{estimated nasal volume} = \frac{\pi}{6} \cdot h\left[\frac{\left(\frac{b}{2}\right)^2 + d^2}{2}\right]$$

The estimated area of the nasal surface was calculated using the mathematical formula for ½ the surface area of a right circular cone.

estimated nasal surface = ½ surface area of a right circular cone

$$= \frac{\pi r \sqrt{h^2 + r^2}}{2}$$

$$\text{estimated surface area} = \pi \cdot \sqrt{\frac{\left(\frac{b}{2}\right)^2 + d^2}{2}} \cdot \sqrt{h^2 + \frac{\left(\frac{b}{2}\right)^2 + d^2}{2}}$$

where:

$$r^2 = \frac{\left(\frac{b}{2}\right)^2 + (d)^2}{2}$$

$$r = \sqrt{\frac{\left(\frac{b}{2}\right)^2 + (d)^2}{2}}$$

h = nasal height

In addition, the area of the nostril was estimated using the formula:

estimated area of nostril =

$$\frac{\text{(greatest width)} \quad \text{(smallest width)}}{2}$$

A general index of nostril shape was calculated using the formula:

$$\frac{\text{greatest width}}{\text{smallest width}} = \text{general index of nostril shape}$$

(d) Techniques and Equipment

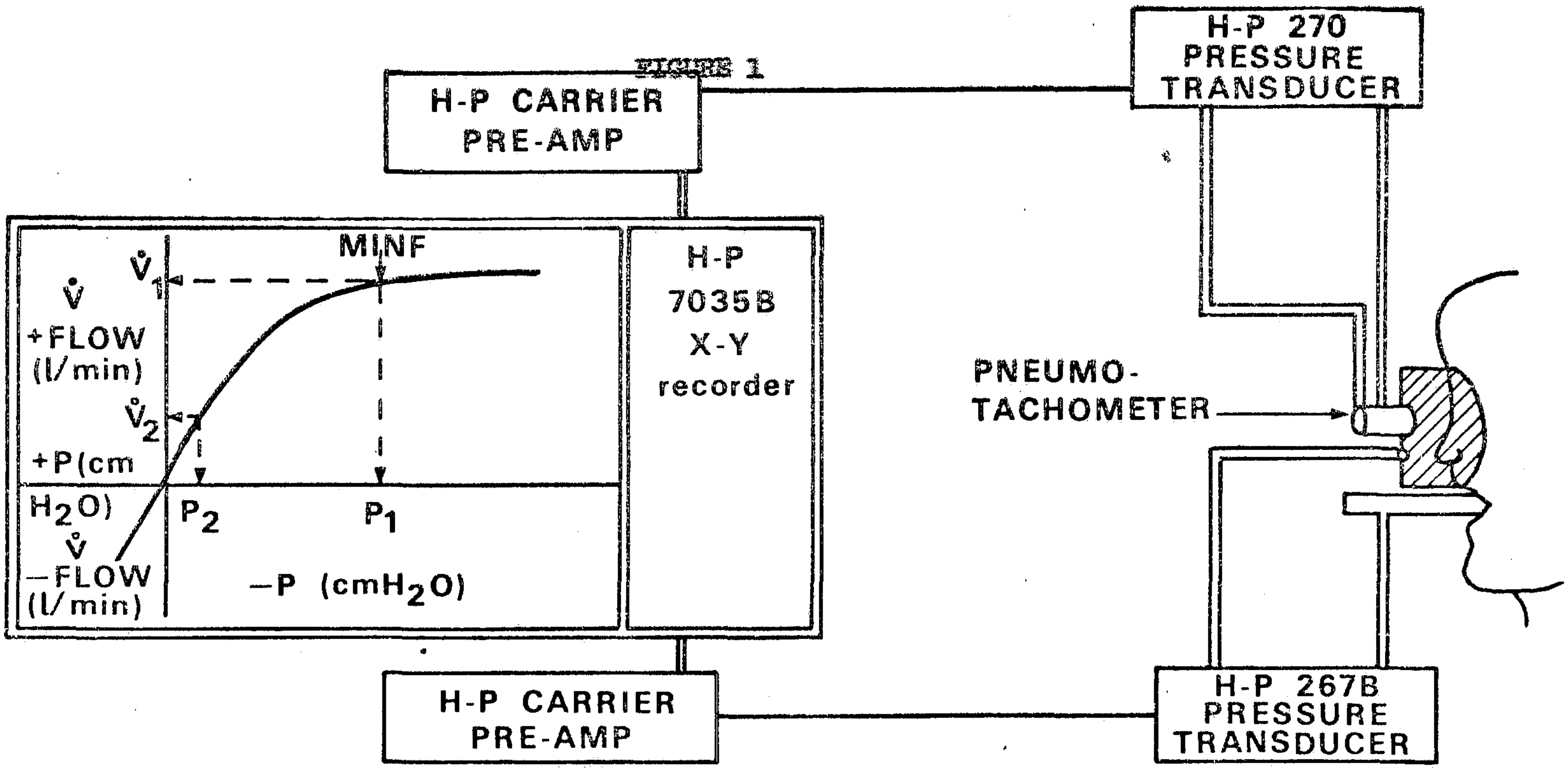
The rate of flow and transmural pressure on nasal inspiration during quiet breathing and during a maximum voluntary inspiration were recorded with the subject seated at rest, using the equipment described below.

Measurements of the nasal flow resistance and maximum inspiratory nasal flow (MINF) were obtained using a self-contained system. [see figure (1)] . A Fleisch #2 pneumotachometer was fitted into a 1/4" Plexiglas panel which replaced the faceplate of an underwater diving mask. A pressure sampling port was also fitted to this plate. A simple tube of the size to accept disposable mouthpieces was fitted with a pressure measuring port, and was occluded at its distal end. A Hewlett-Packard 270 pressure transducer was coupled to the pneumotachometer to measure flow, and a Hewlett-Packard 267B pressure transducer measured the difference in pressure between the mouth and the mask interior (estimated transmural pressure). Hewlett-Packard signal conditioning was used, and data were displayed on a Hewlett-Packard 7035B XY recorder.

A characteristic display of the results of this measurement is shown in figure (2). Note that in this subject there appear to be two "maxima". This reflects the alteration in the dynamic characteristic of the nose brought about when the subject voluntarily "flares" his nostrils. Consistent response in the same subject is reflected by the results of this test in most subjects. The maximum inspiratory nasal flow (MINF) was considered to be the value obtained without voluntary nasal flaring.

It can be seen from figures 1 and 2 that $\dot{V}_1$ (MINF), $\dot{V}_2$ (1/3 $\dot{V}_1$), and P_1 and P_2 could be calculated directly from the record. The nasal resistance was calculated to be $\frac{P2}{\dot{V}_2}$. ($\dot{V}_2$ = 1/3 MINF) P_1 was the lowest negative transmural pressure at which MINF occurred. P_2 was the negative transmural pressure at 1/3 MINF.

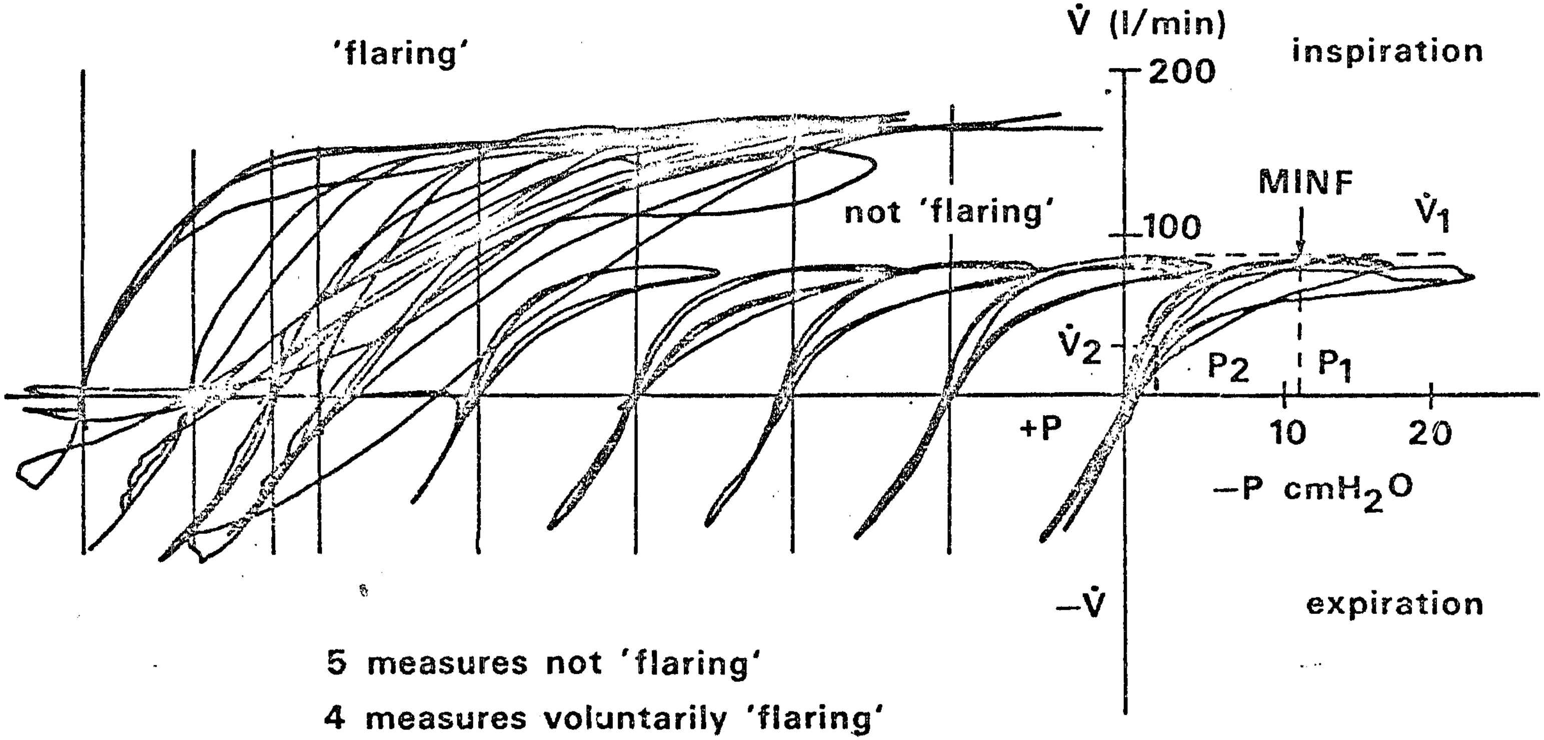
FIGURE 1



Schematic Diagram of the System Used
to Evaluate the Flow Limiting Characteristics
of the Human Nose During Inspiration

FIGURE 2

A Characteristic Display of the Recorder Printout on a Subject (L.D.P. ♂ 1/15/74)



CHAPTER III

RESULTS

Test data were analysed using a Hewlett-Packard 9810A programable calculator and a Hewlett-Packard 9862A Plotter.

The possible effect of sex was examined using a point bi-serial correlation[1] with MINF as the continuous variable and sex as the dichotomous variable. It was found that females throughout the group had significantly lower MINF values than the males throughout the group.

The data collected from the males and females in the sample group were analyzed independently. However, the observed correlations between MINF and Nasal Index did not reach a statistical level of significance. The absence of statistical significance in the correlation between MINF and Nasal Index in the female group could be accounted for by the narrow range of nasal index in that group and the small sample size (27).

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(1) $rpb = \dfrac{\bar{Y}_1 - \bar{Y}_0}{sy} \cdot \sqrt{\dfrac{N_1 N_0}{N\ (N-1)}}$

$rpb = 0.2956$

$t = rpb \sqrt{\dfrac{N-2}{1-(rpb)^2}}$

$df = 75$

$t = 2.6797$

$p < 0.01$

$\bar{Y}_1$ = mean MINF of ♂'s

$\bar{Y}_0$ = mean MINF of ♀'s

N_1 = # of males

N_0 = # of females

sy = s.d. of entire group

$N = N_1 + N_0$

In the case of the male group there was a broader range of variation in Nasal Index and the sample size was larger (50). In this case the value of r approached statistical significance. $r=0.2381$, $P<0.10$.

All the following data are the combined values for the male and female groups.

The results of analysing the grouped data for seventy-seven subjects are summarized in Tables II + III. The plots in Figures 3 to 8 illustrate the scatter of points and indicate the calculated linear regression of best fit.

No significant correlation was found to exist between MINF and nasal height, nasal depth, nasal projection index, P_1 (transmural pressure at which MINF is measured), nasal resistance, area of the nostril, nostril shape index, stature, and weight. (TableII)

There was found to be a statistically significant positive correlation between MINF and estimated nasal volume (Figure 3), estimated nasal surface area (Figure 4), P_2 (transmural pressure at 1/3 MINF) (Figure 5), nasal breadth (Figure 6), nasal depth index (Figure 7), and nasal index (Figure 8). (Table II)

The association of MINF with Nasal Index is emphasized by the finding that when the sample group (n=77) was divided into two groups on the basis of nasal index those with the lower Nasal Index (NI = below 76) had a significantly lower MINF than the group with a Nasal Index of 76 or above. (Table III)

Figures 3-8 illustrate the scatter of points and the calculated linear regression of best fit with MINF as the dependent variable and nasal volume, nasal surface area, P_2 (negative transmural pressure at 1/3 MINF), nasal breadth, nasal depth index, and nasal index, respectively, as the independent variables. It is fairly clear that MINF is a function of nasal volume, nasal surface area, nasal breadth, nasal depth index, and nasal index and not the other way around, since these other variables are the anatomically fixed independent variables.

P_2 (the negative transmural pressure at 1/3 MINF) has been used as an indicator of nasal resistance. The slope of the curve at that point, P_2/1/3 MINF, (which we have defined as nasal resistance) was not found to be correlated with MINF and was difficult to interpret in relation to the other variables because it was not a repeatable measure in the same individual.

An additional analysis of the relationship between P_2 (negative transmural pressure at 1/3 MINF) and the six other variables was performed. When P_2 was designated as the dependent variable and a correlation and linear regression were done using MINF, nasal volume, nasal surface area, nasal breadth, nasal depth index, and nasal index, respectively, as the independent variables, it was found that P_2 was significantly positively correlated with MINF, nasal breadth, and nasal index. (See Table IV)

TABLE II: PROPERTIES OF THE SAMPLE (COMBINED DATA FOR BOTH SEXES)

Measurement	Number of Subjects	Mean	S.D.	Range	Correlation with MINF Pearsons "r"
MINF $\overset{o}{V}_1$ (ℓ/min)	77	115.3	31.5	60-80	
Nasal Height H (cm)	77	5.1	0.6	4.4-5.7	r=0.0750 NS
Nasal Depth, D (cm)	77	3.0	0.4	2.1-3.8	r=0.2278 NS
Nasal Projection Index (D/B 100)	77	82.9	13.6	60-117	r=0.000 NS
P_1 (cmH_2O) Transmural Pressure at MINF	55	10.8	3.8	2.5-19.0	r=0.1881 NS
Nasal Resistance P_2/1/3 MINF	43	0.0633	0.0949	0.02-0.51	r=0.000 NS
Area Nostril D_1 D_2/2 (cm^2)	77	0.47	0.14	0.02-1.0	r=0.0000 NS
Shape Nostril Index D_1/D_2	77	2.29	0.62	1.2-3.7	r=0.0000 NS
Stature (inches)	77	68.0	3.0	62-75	r=0.2200 NS
Weight (lbs)	76	145	25	92-205	r=0.1400 NS
Nasal Volume (cm^3)	77	16.6	3.4	8.5-22.0	r=0.2608 $P<0.05$
Nasal Surface Area (cm)	76	22.3	2.8	15.4-27.0	r=0.3500 $P<0.01$
P_2 (cm H_2O) Transmural Pressure at 1/3 MINF	43	1.57	1.27	0.4-8.0	r=0.4826 $P<0.01$
Nasal Breadth, B (cm)	77	3.7	0.4	2.8-5.0	r=0.2722 $P<0.05$
Nasal Depth Index D/H 100	77	60.2	7.2	44-78	r=0.2375 $P<0.05$
Nasal Index B/H 100	77	72.9	9.2	56-100	r=0.2676 $P<0.05$

TABLE III

MEAN MINF IN SUBJECTS WITH LOW AND HIGH NASAL INDICES

		Nasal Index NI = < 76	Nasal Index NI = 76 or above
MINF:	mean	109.3	127.2
(ℓ/min)	sd	26.6	37.2
	n	51	26

The difference is significant at the $P < 0.02$ level

NASAL INDEX

		<69	70 - 79	80 - 89	90 - 100
MINF TOTAL (ℓ/min)	mean	109.1	108.6	143.6	136.7
	sd	26.6	29.8	32.4	35.1
	n	31	31	12	3
MINF MALES	mean	117.0	111.5	145.7	136.7
	sd	26.0	32.4	33.1	35.1
	n	15	21	11	3
MINF FEMALES	mean	101.6	102.4	120	--
	sd	25.6	23.7	--	--
	n	16	10	1	0

TABLE IV

Correlations Using MINF and P_2 as Dependent Variables

Subjects	MINF $\dot{V}$ (ℓ/min)	NASAL Volume (cm^3)	NASAL Surface Area (cm^2)	P_2 (cmH_2O) (pressure at 1/3 MINF)	NASAL Breadth (cm) B	NASAL Depth Index D/H(100)	NASAL Index B/H(100)
mean	115.3	16.6	22.3	1.57	3.7	60.2	72.9
s.d.	31.5	3.4	2.8	1.27	0.4	7.2	9.2
number	77	77	76	43	77	77	77
range	60–180	8.5–22.0	15.4–27.0	0.4–8.0	2.8–5.0	44–78	56–100
correlation with MINF (r)		r = 0.2608 $P<0.05$ n=77	r = 0.3500 $P<0.01$ n=76	r = 0.4826 $P<0.01$ n=43	r = 0.2722 $P<0.05$ n=77	r = 0.2375 $P<0.05$ n=77	r = 0.2676 $P<0.05$ n=77
correlation with P_2	r = 0.4826 $P<0.01$ n=43	N.S.	N.S.		r = 0.4076 $P<0.01$ n=43	N.S.	r = 0.4027 $P<0.01$ n=43

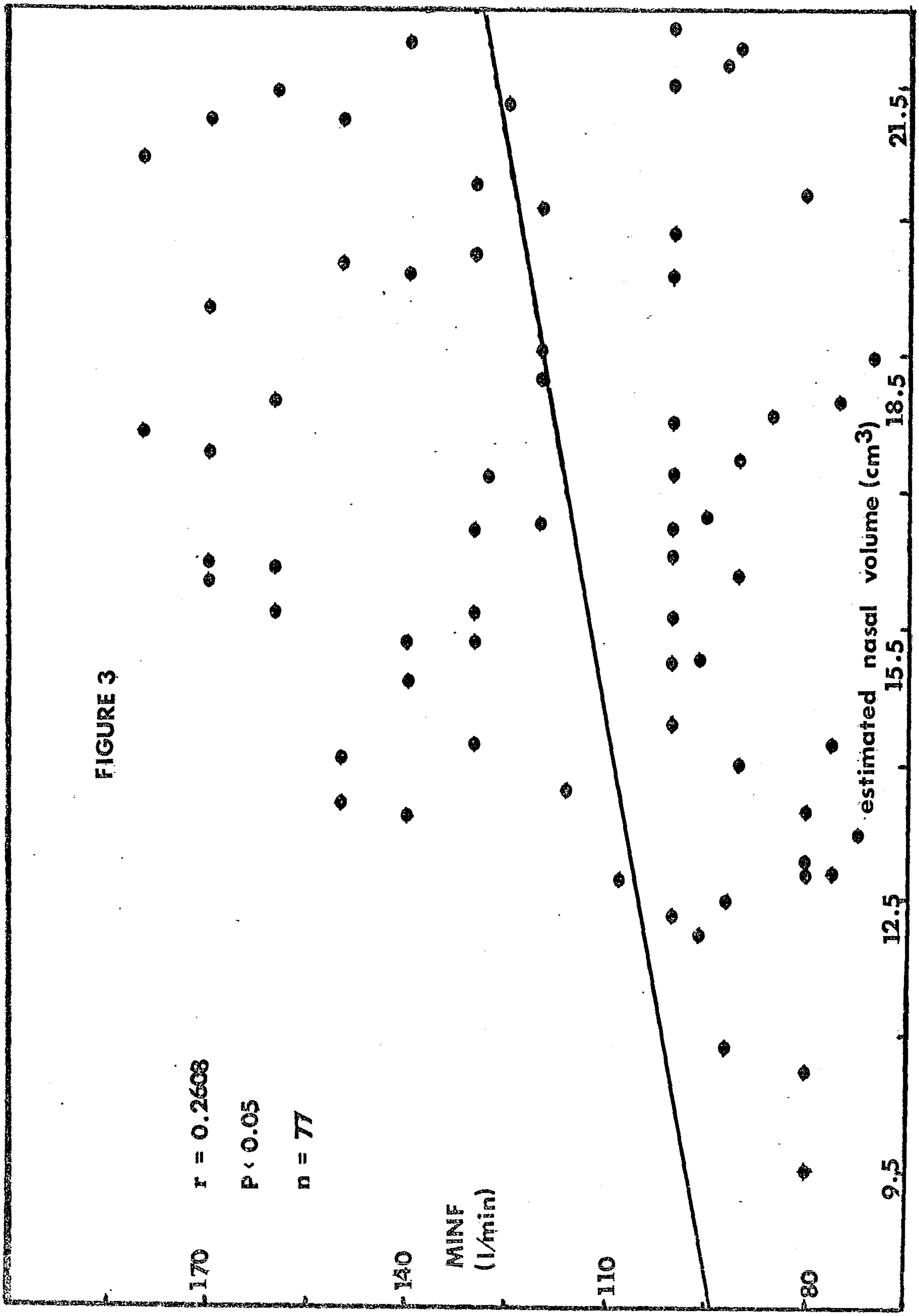


FIGURE 3
r = 0.2608
P < 0.05
n = 77
MINF
(l/min)
170
140
110
80
9.5
12.5
15.5
18.5
21.5
estimated nasal volume (cm3)

FIGURE 4

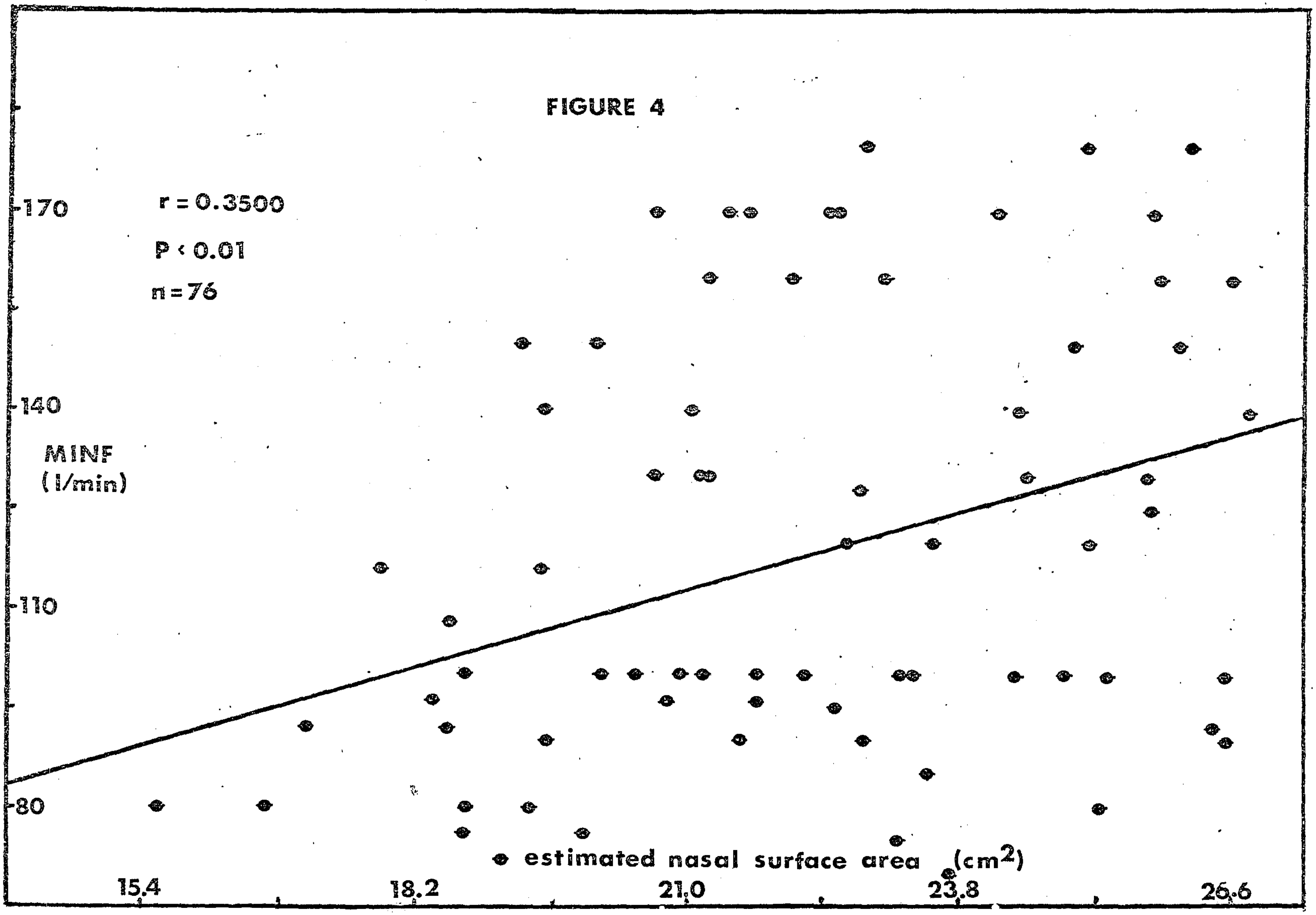

r = 0.3500
P < 0.01
n = 76
MINF
(l/min)
170
140
110
80
estimated nasal surface area (cm2)
15.4
18.2
21.0
23.8
26.6

FIGURE 5

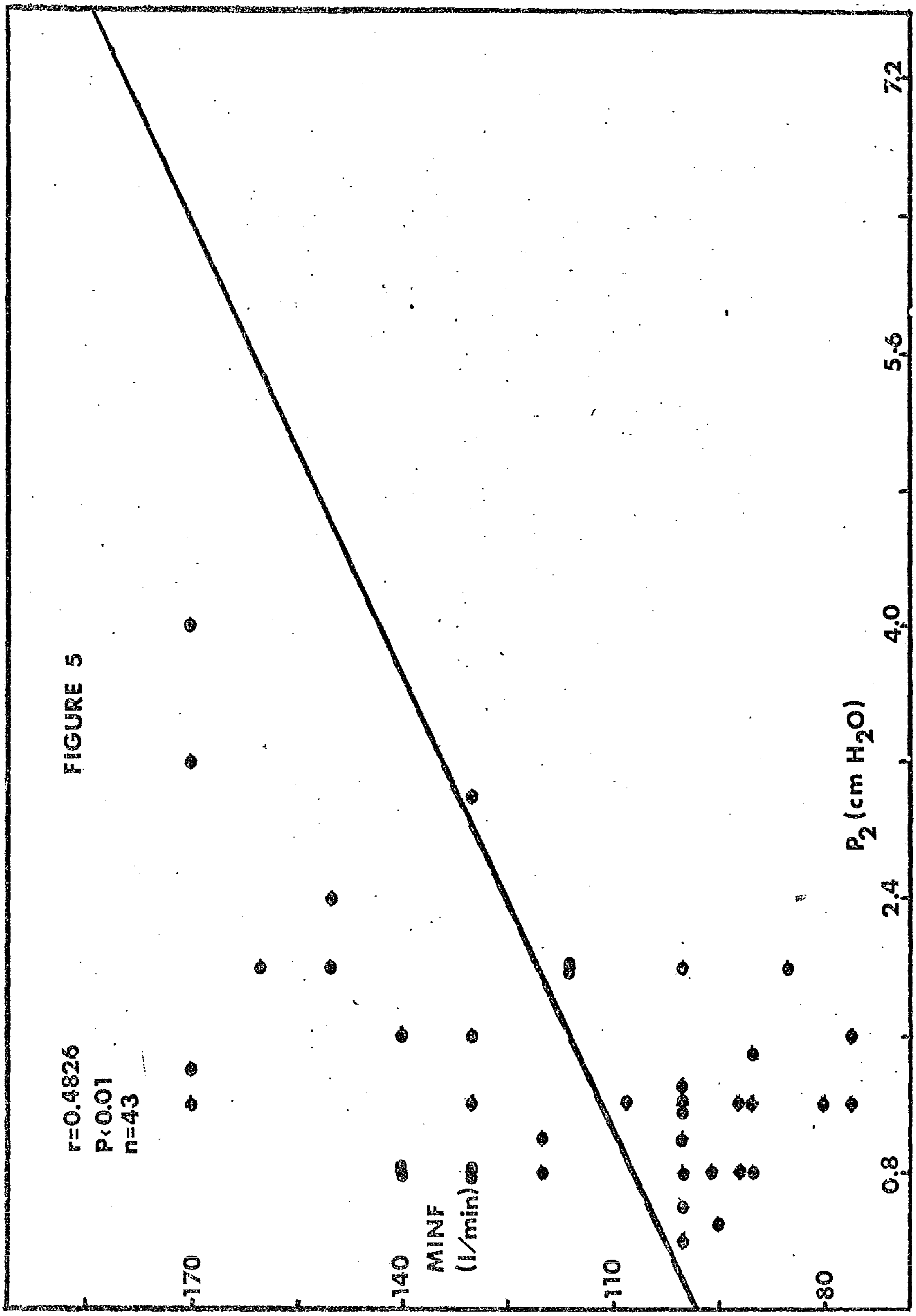
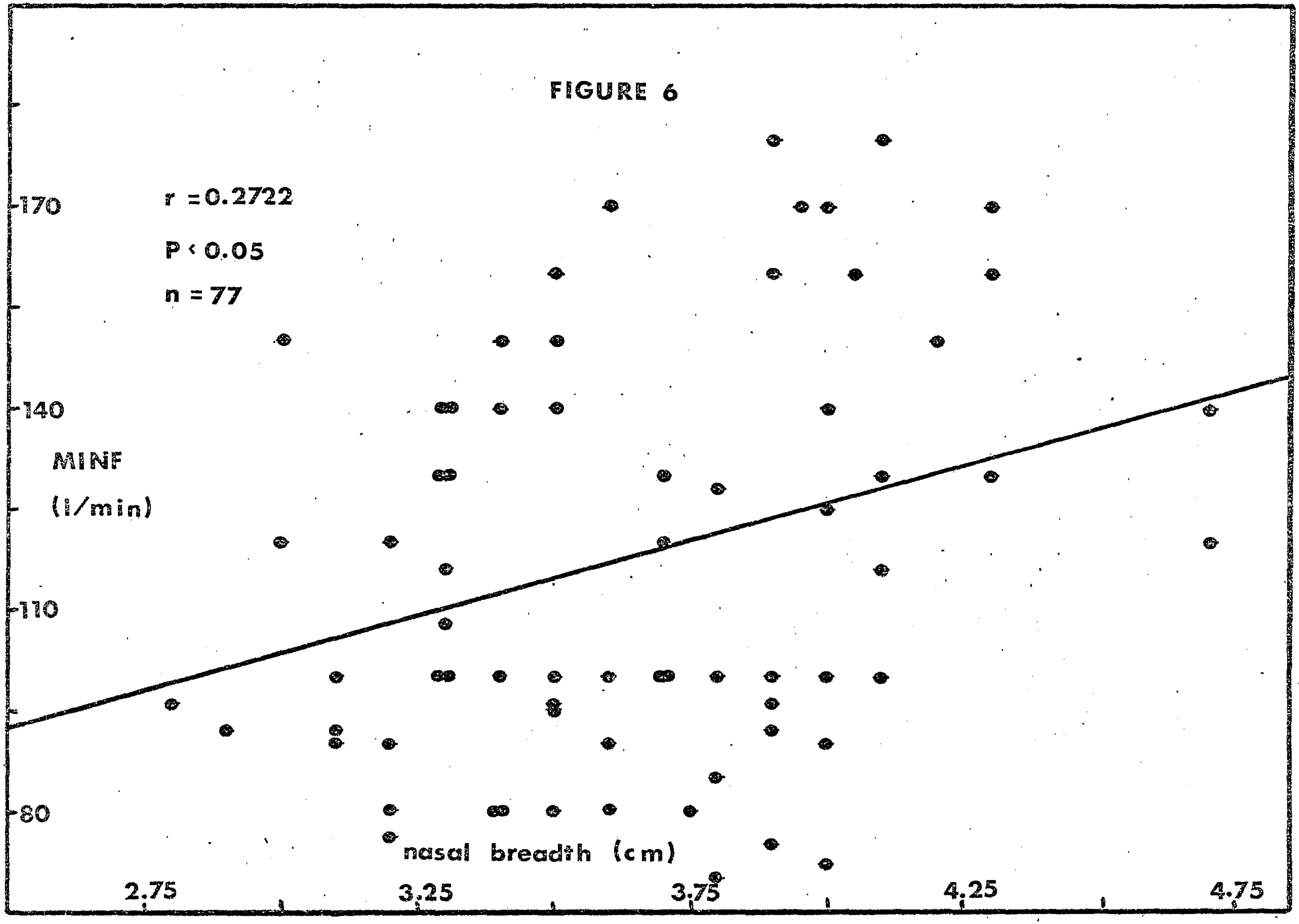


FIGURE 6


r = 0.2722
P < 0.05
n = 77
MINF
(l/min)
170
140
110
80
nasal breadth (cm)
2.75
3.25
3.75
4.25
4.75

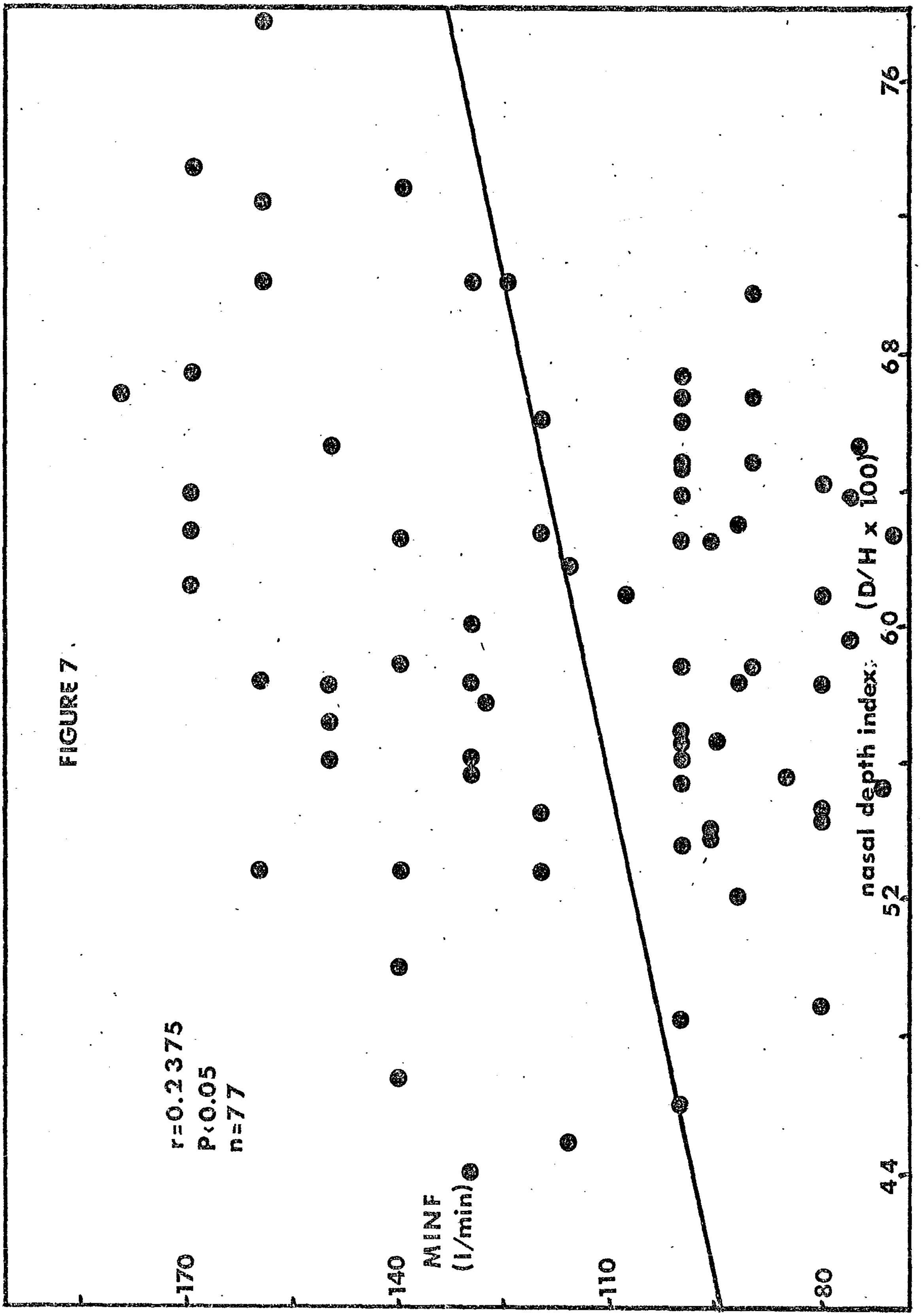
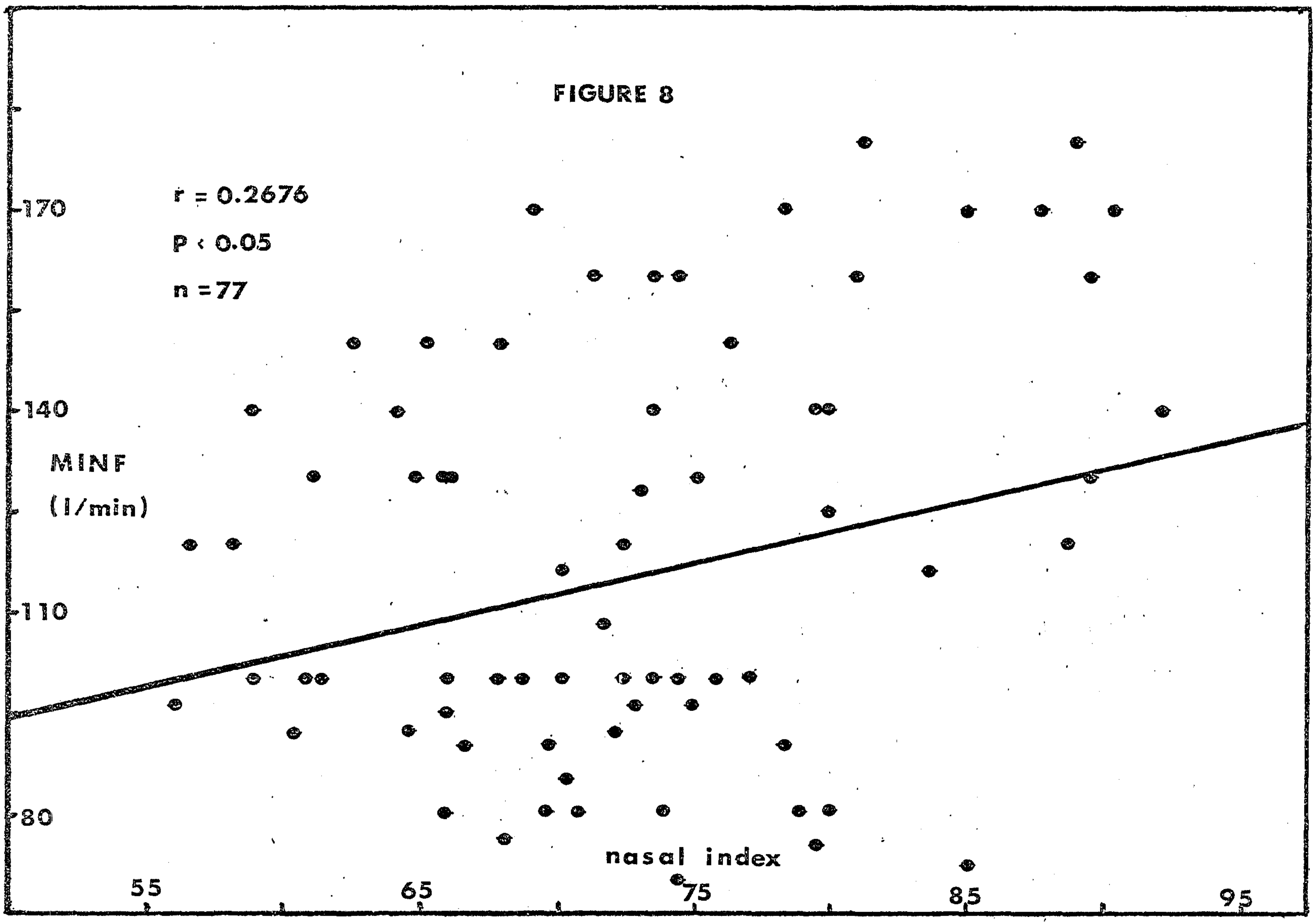

r=0.2375
P<0.05
n=77
MINF
(l/min)
170
140
110
80
4.4
5.2
6.0
6.8
7.6
nasal depth index; (D/H x 100)

FIGURE 7

FIGURE 8


r = 0.2676
P < 0.05
n = 77
MINF
(l/min)
170
140
110
80
nasal index
55
65
75
85
95

CHAPTER IV

DISCUSSION

Inspiratory nasal resistance is the largest single component of flow resistance of the respiratory system, accounting for nearly sixty-six percent of the total airway resistance during nose breathing (Ferris, Mead, and Opie, 1964).

In contrast with the study we undertook (to measure MINF) Salman, Proctor, Swift and Evering (1971) endeavored to measure the relationship between nasal resistance (the area of the recording we designated as $P_2/1/3$ MINF) and changes in temperature and humidity of air. Using nasal resistance as a <u>major</u> parameter may not be the most accurate way of conducting this sort of experiment. MINF is a repeatable measure; nasal resistance, even in the same subject, has a large variation. They used 36 subjects (18 male and 18 female) with an age range of 6-44 years. They found no correlation between nasal resistance and race; however, they do not indicate the sample size or the metric measurements of the nose, nor do they define "race" (Salman, Proctor, Swift and Evering, 1971).

In our study the maximum inspiratory nasal flow (MINF) was found to be significantly positively correlated with nasal volume, nasal surface area, and nasal breadth. These variables are anatomically fixed and it would be expected that they would be significant determinants of MINF.

The significant positive correlation between MINF and nasal depth index and the anthropological nasal index is possibly an interesting functional interpretation of the variation of nasal index with climate. A high nasal index (broad flat nose) tends to be found in hot moist climates. A high nasal index is correlated with a high MINF and a high P_2 (a possible indicator of a low nasal resistance) value. Therefore it is possible that this type of nose offers less resistance to air flow on inspiration, and allows a higher air flow per unit time to occur.

Weiner (1954) hypothesized that the primary function of the nose (in relation to climate) on inspiration may be humidification of inspired air; if this is true then what we have found would not contradict his hypothesis. A nose with a high flow per unit time and a low resistance would be adaptive in a climate where the air is virtually saturated.

Conversly, a nose with a low nasal index (high narrow nose) tends to be found in cool dry climates. A low nasal index is correlated with a low MINF and a low P_2 (a possible indicator of a high nasal resistance) value. It is possible that this type of nose offers greater resistance to air flow on inspiration, and allows a lower air flow per unit time to occur. A nose with a high resistance and a low flow per unit time may be more efficient in a climate where the air is very dry and greater work must be done to humidify the inspired air.

In addition, it would be of some significance to measure the expiratory resistance of noses with varying nasal indices. A nose with a low nasal index (high narrow nose), low maximum inspiratory nasal flow and high inspiratory nasal resistance may also have a higher expiratory resistance. This may be another adaptation to dry climates. A nose with a high expiratory resistance may act to retrieve some of the moisture lost during inspiratory humidification and therefore minimize the total body moisture loss.

With regard to the flow limiting characteristics of the nose, in subjects with a high MINF the nasal mechanics are such that a higher pressure can be developed in the non-flow limiting range. This in turn allows for a higher flow to be sustained. Consequently, it may be predicted that individuals with a high MINF may switch from nose breathing to mouth breathing later than those with a low MINF under conditions of work stress.

BIBLIOGRAPHY

Bridger, G.P., and D.F. Proctor (1970) "Maximum Nasal Inspiratory Flow and Nasal Resistance", Annals of Otolaryngology, 79:481-488.

Butler, J. (1960) "The Work of Breathing Through the Nose", Clinical Science, 19:55-62.

Comas, Juan (1960) Manual of Physical Anthropology. Springfield Illinois: Charles C. Thomas Publishers.

Cottle, M.H. (1955) "The Structure and Function of the Nasal Vestibule", Archives of Otolaryngology, 62:173-181.

Davies, A. (1932) "A Re-survey of the Morphology of the Nose in Relation to Climate", Journal of the Royal Anthropological Institute of Great Britain and Ireland, 62:337-359.

DeGraff, A.C. and A. Bouhuys (1973) "Mechanics of Air Flow in Airway Obstruction", Annual Review of Medicine, 24:111-134.

Dishoeck, H.A.E. van (1942) "Inspiratory Nasal Resistance", Acta Oto-Laryngology, 30:431-439.

Fenn, Wallace O. and Hermann Rahn (1964) Handbook of Physiology Section 3: Respiration Volume I. Washington, D.C.: American Physiological Society.

Ferris, B.G., J. Mead and L.H. Opie (1964) "Partitioning of Respiratory Flow Resistance in Man", Journal of Applied Physiology, 19:653-658.

Harrison, G.A., J.S. Weiner, J.M. Tanner and N.A. Barnicott (1964) Human Biology. Oxford: Oxford University Press.

Hoyme, L.E. (1965) "The Nasal Index and Climate: A Spurious Case of Natural Selection in Man", American Journal of Physical Anthropology, 23:336-337.

Negus, Victor E. (1958) The Comparative Anatomy and Physiology of the Nose and Paranasal Sinuses. Edinburgh: Livingstone Ltd.

Olivier, Georges (1969) Practical Anthropology. Springfield Illinois: Charles C. Thomas Publishers.

Salman, S.D., D.F. Proctor, D.L. Swift, and S.A. Evering (1971) "Nasal Resistance: Description of a Method and Effect of Temperature and Humidity Changes", Annals of Otolaryngology, 80:736-743.

Proctor, D.F. (1964) "Physiology of the Upper Airway", in Handbook of Physiology Section 3: Respiration Volume I edited by W. O. Fenn and H. Rahn Washington, D.C.: American Physiological Society. pp.309-345.

Thomson, A. and L.H. Buxton (1923) "Man's Nasal Index in Relation to Certain Climatic Conditions", Journal of the Royal Anthropological Institute of Great Britain and Ireland, 53:92-133.

Weiner, J.S. (1954) "Nose Shape and Climate", American Journal of Physical Anthropology, n.s. 12:615-618.