

Relationship between Nasal Mucociliary Clearance and Nasal Index among Adult Volunteers in Kano, Nigeria: Implications for Respiratory Health

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Abstract

Nasal Mucociliary Clearance (NMC) is a vital mechanism that clears foreign particles and pathogens from the nasal cavity, ensuring nasal health and preventing respiratory infections. Although the nasal index, an anthropometric measurement of nose shape, remains unstudied in relation to NMC, exploring this link could provide valuable clinical insights into predicting respiratory conditions and nasal disorders. This study aimed to establish the relationship between nasal mucociliary clearance and nasal index among adult volunteers in Kano. Four hundred and five (405) participants were systematically selected comprising males (233) and females (172) which are all residents of Kano State, Nigeria. The nasal height and width of each participant were measured using a digital Vernier calliper and the nasal index was calculated. Nasal Mucociliary Clearance Time (NMCT) was measured using the saccharine test, as the time taken to experience a sweet taste at the posterior naso-pharynx after the placement of saccharine was recorded as NMC time. The data were analyzed using SPSS (IBM SPSS Statistics 20). The mean age and standard deviation of the study participants were 23 ± 3 years for males and 21 ± 2 years for females. The mean and standard deviation of the nasal index in the males and females were 89 ± 9 and 84 ± 8 , respectively. The mean and standard deviation of NMCT in males was 9 ± 4 min while in females was 8 ± 4 min. This study did not identify a statistically significant correlation between the nasal index and nasal mucociliary clearance ($p \geq 0.05$, $r = 0.46$). However, sexual dimorphism was found in the nasal index, with males having a significantly higher nasal index than females ($p < 0.001$). This study established that no significant correlation exists between the nasal index and NMCT, thus it could be inferred that the shape and size of the nose have no influence on the NMCT.

Keywords: Nasal Mucociliary Clearance NMC, Nasal Index, Nasal Mucociliary Clearance Time (NMCT)

INTRODUCTION

The nasal mucociliary clearance (NMC) is a critical physiological mechanism responsible for clearing foreign particles, allergens, and pathogens from the nasal cavity, providing protection to the respiratory tract (Duran and Ulkü, 2014). Acute or long-term disorders of the upper and lower respiratory tracts might result from ineffective ciliary activity (Koparal *et al.*, 2021). Proper NMC relies on coordinated ciliary beating, mucus secretion, and airway surface liquid, with ciliary beat frequency (CBF) playing a major role in its efficiency (Solak *et al.*, 2018). Various factors such as aging, temperature extremes, and certain drugs can influence NMC duration (Deswal *et al.*, 2017) while active cigarette smoking has been associated with prolonged clearance time (Mahmud *et al.*, 2023). Notably, COVID-19 patients and variant COVID-19 patients have shown higher NMC times compared to healthy controls (Yucedag and Kahraman, 2023).

The nasal index, represents the ratio of nasal width to nasal height multiplied by 100 (Anas and Saleh, 2013). It is used to classify the human nose into three categories: Leptorrhine (nasal index ≤ 69.9), Mesorrhine (nasal index 70.0-84.9), and Platyrrhine (nasal index ≥ 85) (Abraham and Romo, 2006). Although anatomical differences in nasal structure may not significantly impact nasal physiology, they could potentially predispose individuals to varying incidences of nasal diseases (Leong & Eccles, 2009). This prompts further exploration into whether nasal shape and size have clinical relevance beyond aesthetic considerations.

Differences in NMCT have been observed in various populations due to habits, climate, habitat, and facial configurations (Yadav *et al.*, 2005). Some reported mean normal mucociliary clearance times include 11.1 minutes (Caucasian), 11.3 minutes (Chinese), 7.5 minutes (Indian), and 13.3 minutes (Turkish) (HO *et al.*, 2001). The nose plays a crucial role in conditioning inhaled air, warming it to core body temperature and saturating it with water vapor before reaching the lower respiratory tract (Zwicker *et al.*, 2018; Keustermans *et al.*, 2020). This conditioning process maintains the efficacy of the mucociliary apparatus in trapping and removing particles and pathogens from the airways. Computational fluid dynamics (CFD) studies have highlighted the significance of nasal cavity geometry in its respiratory functions and the velocity of inspired air (Naftali *et al.*, 2005; Inthavong *et al.*, 2007). Exploring the correlation between NMC and nasal index holds clinical importance, potentially aiding in predicting susceptibility to respiratory and nasal disorders. Higher nasal indices might be associated with altered NMC, warranting targeted interventions and preventive strategies based on specific nasal characteristics.

MATERIALS AND METHODS

Study Design

The study design was cross-sectional in which 405 participants aged 16 to 35 years were recruited, using systematic random sampling technique of whom 233 were males and 177 were females. All the participants were residents of Kano, a state in northern Nigeria.

Ethical Consideration

Prior to commencing the study, ethical approval was obtained from the Ministry of Health Kano State, Nigeria, Informed consent was obtained from all participants according to standard procedures.

Measurement of Nasal Morphometry

Measurements of nasal morphometry were conducted with the participants seated on a chair or on a bench to ensure consistency, positioning their heads in the Frankfurt plane. The height of the nose (NH) was measured from the nasion (the outer point of intersection between the nasion-sella line and the soft tissue profile) to the subnasale (the junction between the lower end of the nasal septum and the upper lip). Nasal width was measured from one ala to another. The nasal index was calculated using the formula: Nasal index = (Nasal width / Nasal height x 100) (Anas and Saleh, 2013).

Methods of Measurement of Nasal Mucociliary Clearance (NMC)

NMC was assessed using the saccharin test, as described by Andersen. This technique is inexpensive, non-invasive, readily available, and reproducible for evaluating NMC. It has been suggested that this screening test works well for identifying abnormal NMC (Andersen *et al.*, 1971).

During the test, participants were instructed to sit in a chair with their chins elevated 10 degrees and to maintain normal ventilation. They were asked to swallow freely but to avoid deep breaths, talking, coughing, sneezing, sniffing, or moving. A saccharin particle measuring 1mm in diameter was placed under direct vision on the medial surface of the inferior nasal turbinate, just 1mm from its anterior end. A timer was started when the participants returned their chin to the horizontal position. The time was noted and recorded in minutes when the participants reported their first perception of a sweet taste after saccharine deposition. If the participants did not perceive the taste after 60 minutes, the test was stopped, and their ability to taste saccharin directly on the tongue was verified (Nakagawa *et al.*, 2005). Participants were not evaluated for compounders like existing upper respiratory tract infections, allergies, and previous nasal surgeries, amongst others.

Statistical Analyses

After the data was collected, it was entered and filtered using Microsoft Excel and analyzed using Statistical Package for Social Sciences, SPSS version 20.0, Microsoft word and Microsoft Excel [2010] were used for making tables. Quantitative variables were expressed using measures of dispersion (range, minimum, maximum and standard deviation) and measures of central tendency (mean). Categorical variables were also described using absolute numbers and percentages. Sexual dimorphism and comparison of nasal index and nasal mucociliary clearance were analyzed using sample independent t-test. Pearson's correlation was used to determine the relationship between the nasal index and nasal mucociliary clearance and $P < 0.05$ was considered statistically significant.

RESULTS

In Table 1, the socio-demographic characteristics of the participants are presented, including age, sex, ethnicity, smoking, and dietary habits. These demographic factors provide important background information about the study population.

Table 1: Socio-demographic Characteristics of Participants

Variables	Frequency	Percentage (%)
Age(yrs)		
16-20	138	34.0
21-25	225	55.6
26-35	42	10.0
Sex		

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Male	233	57.5
Female	172	42.5
Ethnicity		
Hausa	223	55.0
Fulani	70	17.0
Yoruba	39	9.6
Igbo	8	2.0
Others	65	16.0
Smoking		
Yes	7	1.7
No	398	98.3

Table 2 displays the mean and standard deviation (SD) values of age, nasal height, nasal width, nasal index, and nasal mucociliary clearance for the participants, including both male and female. The mean age was found to be 22.60±2.89 years for males and 20.85±2.44 years for females. The table also includes the minimum and maximum values of nasal parameters and nasal mucociliary clearance.

Table 2: Descriptive Statistics of Anthropometrics Measurements and Nasal Mucociliary Clearance of the Participants (n= 405)

Males (N=233)				Females (N=172)		
Variables	Min	Max	Mean± SD	Min	Max	Mean± SD
Age	17.00	35.00	22.60±2.89	16.00	34.00	20.85±2.44
Nasal height (mm)	34.35	55.14	45.95±3.29	34.15	52.31	43.38±3.16
Nasal width (mm)	30.70	52.44	40.76±3.18	27.80	43.33	36.38±3.04
Nasal index	66.31	128.06	89.15±9.36	63.74	104.17	84.14±7.77
NMCT (minutes)	2.00	33.00	8.81±4.28	2.00	26.00	8.21±3.70

Min; Minimum, Max; Maximum, SD; Standard deviation, NMCT; Nasal mucociliary clearance time

Table 3, shows the distribution of nose types among the participant. The most prevalent nose type was platyrrhine, accounting for 38.52% in males and 20.49% in females. The next most common nose type was mesorrhine, representing 20.74% in males and 20.49% in females. A smaller percentage of individuals had leptorrhine noses, comprising 0.49% in males and 1.23% in females. Overall, the platyrrhine nose type was the most dominant, accounting for 59.01% of both male and female participants.

Table 3: Distribution of the Nose Types of the Participants Base on Shapes

Sex	Leptorrhine	Mesorrhine	Platyrrhine	Total
Male	2 (0.49%)	7 (18.52%)	156 (38.52%)	233 (57.53%)
Female	5 (1.23%)	84 (20.74%)	83 (20.49%)	172 (42.46%)
Total	7(1.72%)	159(39.26%)	239 (59.01%)	405 (100%)

Table 4 presents the analysis of sexual dimorphism in nasal index and nasal mucociliary clearance. The results indicate that the mean value of nasal index was significantly higher in male subjects compared to female subjects (P < 0.001). However, no significant differences were observed in the mean values of nasal mucociliary clearance between males and females (P = 0.14).

Table 4: Sexual Dimorphism on Nasal Index and Nasal Mucociliary Clearance of the Participants

Variables	Males Mean± SD	Females Mean± SD	t Value	p Value
Nasal index	89.15±9.36	84.14±7.77	5.71	<0.001
NMCT (minute)	8.81±4.28	8.21±3.70	1.48	0.14

*P<0.05: Statistically significant, NMCT; Nasal mucociliary clearance time

Table 5 presents Pearson's correlation analysis results for the relationship between nasal index and nasal mucociliary clearance among male and female participants. In the male group, a weak positive correlation was observed between nasal index and nasal mucociliary clearance. Conversely, in the female group, a weak negative correlation was found between nasal index and nasal mucociliary clearance. However, it is important to note that these correlations were not statistically significant ($p > 0.05$) for both male and female students. Additionally, when considering the general population (both male and female combined), no significant correlation was detected between nasal index and nasal mucociliary clearance.

Table 5: Correlation between Nasal Index and Nasal Mucociliary Clearance for Males and Females

Participants	Pearson correlation coefficient (R)	P
Males	0.07	0.29
Females	-0.08	0.30

This suggests that the size and shape of the nose, as measured by the nasal index, do not have a substantial influence on nasal mucociliary clearance in the studied population. The lack of statistical significance in the correlations indicates that other factors may play a more significant role in determining nasal mucociliary clearance, and further research is needed to identify these potential factors and their impact on nasal health.

Overall, the tables provide a comprehensive overview of the nasal morphometric measurements, nasal mucociliary clearance, and socio-demographic characteristics of the participants in the study. The results demonstrate sexual dimorphism in the nasal index but not in nasal mucociliary clearance. The platyrrhine nose type was found to be the most prevalent among both males and females in the study population.

DISCUSSION

Previously, characteristics and differences of the nasal morphometry have been studied in several racial groups for facial identification and reconstructive surgery as well as studying variation in humans (Farkas *et al.*, 1983) and most of the studies on nasal mucociliary clearance time have been carried out based on the comparison between healthy individuals and patients.

In this study, we aimed to establish reference values for nasal index and nasal mucociliary clearance (NMC) among the study population and investigate any potential correlation between these parameters. The nasal morphometric findings showed that the predominant nose type among both males and females was platyrrhine, which falls within the African nasal classification. This is consistent with previous studies on Nigerian populations, where male

and female subjects exhibited nasal indices greater than 85. The results are also in agreement with research conducted on Hausa and Yoruba ethnic groups in Nigeria, which showed a predominance of platyrrhine nose types in the Hausa population (Adelaja, 2016; Mohammed *et al.*, 2018).

Regarding nasal mucociliary clearance, the mean values for NMC were 8.81 ± 4.28 minutes for males and 8.21 ± 3.70 minutes for females. These findings align with previous studies that have reported normal NMC times of up to 20 minutes in healthy individuals, with a cutoff point of 30 minutes distinguishing normal subjects from those with abnormal NMC (Corbo *et al.*, 1989). Similar results were observed in a study investigating the effect of steam inhalation on NMC in normal individuals and those with nasal disease, as well as in a study assessing the impact of passive and active smoking on NMC (Gujrathi *et al.*, 2016; Mahmud *et al.*, 2023).

Sexual dimorphism was evident in the nasal index, with males showing higher nasal index values compared to females, and this difference was statistically significant. This finding is consistent with many previous studies on rhinometry in Nigeria, like study conducted by (Anas and Saleh, 2013) to compare the nasal indices of Hausa and Yoruba ethnic groups among students of Bayero University Kano. However, conflicting results have been reported in other studies, like the study by Oladipo *et al.*, (2009) on the Okrika ethnic group in Rivers state reported that no significant difference exists in the nasal index between males and females, indicating that sexual dimorphism in the nasal index may vary across different populations and could be influenced by factors such as genetics and hormones (Sharma *et al.*, 2014).

Interestingly, no significant sexual dimorphism was observed in nasal mucociliary clearance in the present study. This finding agrees with one study investigating the effect of gender on nasal mucociliary clearance by Tamilselvan *et al.* (2015). However, some other publications (e.g. Armengot *et al.*, 1990; Uzeloto *et al.*, 2018) have reported the existence of sexual dimorphism, with females exhibiting faster NMC compared to male. These discrepancies may be attributed to variations in airway anatomy and sex hormone levels between males and females (Martin *et al.*, 1987; Jain *et al.*, 2012).

Additionally, the study found no significant correlation between nasal index and nasal mucociliary clearance. This indicates that the size and shape of the nose do not influence nasal mucociliary clearance. Similar result have been reported in another study by Leong and Eccles, (2009) suggesting that nasal shape and size do not have a significant impact on nasal physiology, although anatomical differences in nasal structure might predispose individuals to differences in nasal disease incidence. It has also been documented that there is no correlation between nasal index and nasal airway resistance (Doddi and Eccles, 2010).

CONCLUSION

In conclusion, this study establishes reference values for nasal mucociliary clearance and nasal index. Sexual dimorphism was observed in the nasal index but not in the nasal mucociliary clearance. Importantly, there was no significant correlation between nasal index and nasal mucociliary clearance, indicating that the size and shape of the nose do not influence nasal mucociliary clearance. This information can serve as a reference for future studies and provide a benchmark for comparisons. It also helps to refine diagnostic and prognostic approaches, ruling out potential associations and allowing healthcare professionals to focus on other relevant factors in assessing respiratory health.

DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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