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Original Research Article

Comparative analysis of nasal mucociliary clearance in healthy tobacco smokers and non-smokers in Abuja, Nigeria: implications for respiratory health

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ABSTRACT

Background: Nasal mucociliary clearance (NMC) is a crucial airway defense mechanism. Tobacco smoke, with its noxious components, impairs NMC, predisposing individuals to sinonasal diseases. Limited research exists in sub-Saharan Africa, where environmental and genetic factors may further influence NMC. The primary objective of this study was to investigate the effect of tobacco smoking on nasal mucociliary clearance time (NMCT) in healthy adults in Abuja, Nigeria, comparing smokers to non-smokers.
Methods: A community-based, prospective cross-sectional study was conducted on adults aged 18-45 in Abuja, Nigeria. Participants completed questionnaires on smoking history, medical history and comorbidities. Anterior rhinoscopy was performed, followed by a saccharine transit time test to measure NMCT in minutes.
Results: Three hundred and four (304) participants were recruited, with 152 (50%) smokers (60 smoked both cigarette and shisha, 55 shisha only, 37 cigarette only) and 152 (50%) non-smokers. The mean age was 30.7±6.3 years (smokers: 30.2±6.7; non-smokers: 31.3±5.9). Smokers had a significantly prolonged mean NMCT (14.96±3.75 minutes) compared to non-smokers (8.25±2.02 minutes) ($t=20.197$, $p<0.001$). Significant differences were found between all smoking groups and the non-smoker group (cigarette only: 17.08±2.69 minutes; both: 16.45±2.95 minutes; shisha only: 11.91±2.47 minutes; control: 8.25±2.02 minutes) ($F=246.152$, $p<0.001$). There was no significant difference in NMCT between those smoking both cigarette and shisha and those smoking only cigarettes ($p=0.603$).
Conclusions: Tobacco smoking significantly prolongs Nasal Mucociliary Clearance Time (NMCT), with cigarette-only smokers exhibiting the longest NMCT, followed by combined cigarette and shisha smokers and then shisha-only smokers.

Keywords: Cigarette smoking, Nasal mucociliary clearance, Shisha smoking, Saccharine test

INTRODUCTION

The nasal mucociliary clearance (NMC) is a basic physiological mechanism of the airway, transporting mucus from the nose and paranasal sinuses towards the nasopharynx, serving as the first line of defense against inhaled particles and microorganisms.[1,2] The components are cilia, periciliary and gel mucus layers, which trap inhaled foreign particles that are conveyed by the unidirectional beating of the cilia towards the nasopharynx and subsequently coughed out or swallowed.[1,3-5] Nasal mucociliary clearance is crucial for protecting the respiratory system by removing inhaled particles; however, various factors can disrupt this vital function. Tobacco smoke (cigarettes, shisha, etc.) is a major culprit, damaging cilia and altering mucus quality, leading to impaired NMC.[2-5] Other factors, including medications (topical corticosteroids, sympathomimetics),

environmental factors like dry air, extreme temperatures and medical conditions like septal deviation, nasal trauma, allergies and respiratory infections, can also damage NMC.[2-7] Impairment of NMC can range from chronic inflammation (sinusitis) to life-threatening conditions such as lung cancer.[2,6-9]

Studies show that tobacco use, whether through cigarettes or shisha, negatively impacts both respiratory and cardiovascular systems.[8-10] Harmful effects stem from various toxic substances in tobacco smoke, including carbon monoxide, nicotine, tar, formaldehyde, acrolein and other chemicals. These toxins contribute to oxidative stress, inflammation and damage to the cilia, ultimately impairing mucociliary clearance in the nose and lungs.[2,10,12-16]

Contrary to popular belief, shisha is not a safer alternative to cigarettes. While less extensively studied, research suggests shisha may pose similar or greater risks due to the burning of charcoal, which releases heavy metals like arsenic and lead into the smoke.[10,12] Both active and passive cigarette smoking have been shown to disrupt NMC by reducing the cilia number, cilia length and ciliary beat frequency (CBF).[5,17-19] Cigarette smoke also affects mucus production and its viscoelastic properties.[19] In contrast, limited research is available on the specific effects of shisha smoking on NMC.[2]

Studies consistently show that cigarette smokers have significantly longer NMC times than non-smokers, with some research indicating a correlation between smoking duration and increased NMC time.[5,18-22] Impaired nasal mucociliary clearance is linked to rhino logical diseases, including rhinosinusitis, laryngeal, oesophageal and lung cancers.

While cigarette smoking's effects on NMC are well-studied in developed countries, knowledge gaps exist regarding other forms of tobacco, such as shisha. Research has suggested that these other forms of tobacco use, including shisha and even passive smoking, can also negatively impact NMC.[2,18,20]

There are various methods of measuring NMC, such as rhinoscitigraphy, roentgenography, photoelectron techniques; however, saccharine transit time test (STT test) was used for this study.[17,25] The documented normal NMC time is 7-15 minutes, less than 7 minutes is considered reduced and more than 15 minutes is considered prolonged (impaired).[2,18,25]

This study evaluated nasal mucociliary clearance time (NMCT) in healthy adult non-smokers and active tobacco smokers, particularly in those who smoke cigarettes, shisha or dual smokers. Our aim is to raise awareness about tobacco's harmful effects on nasal mucociliary clearance, inform healthcare workers about the risks associated with shisha and cigarettes and provide a baseline for future studies.

METHODS

This prospective, cross-sectional study was done in Abuja, Nigeria's capital city, a diverse and rapidly growing metropolis. Study period was August 2020-September 2021. Researchers focused on three of Abuja's six area councils, chosen to represent different socioeconomic levels: AMAC (high income), Bwari (middle income) and Gwagwalada (low income).[26] Within each selected council, the busiest motor park was chosen as the study site. Participants included drivers, passengers and other motor park workers.

A sample size of 141 participants was initially calculated using the Leslie Kish formula, based on a 95% confidence interval, 0.05 types 1 error and a 10.3% prevalence of tobacco smokers in North Central Nigeria.[27,28] Accounting for a 10% attrition rate, the target sample size was increased to 155. The study recruited 155 active tobacco smokers and 155 non-smokers (controls). Smokers were further divided into cigarette, shisha and dual users. Using stratified sampling by population, smokers were recruited from motor parks in three area councils: AMAC (55), Bwari (50) and Gwagwalada (50). The control group, matched for age and sex, was recruited from hospital staff and ENT patients with non-nasal symptoms using convenience sampling.

Data obtained was analyzed using IBM-SPSS (Statistical Product and Service Solutions) version 20.

Eligibility criteria

Participants were divided into two groups: tobacco smokers and non-smokers.

Smokers

Had to be healthy, active smokers (cigarette or shisha) aged 18-45 with at least one year of consistent smoking history and no symptoms of sinonasal disease.[2]

Non-smokers

Had to be aged 18-45 and have either never smoked or quit more than five years prior. They also needed to live with non-smokers and avoid environments with significant secondhand smoke exposure.

Both groups were excluded if they had pre-existing respiratory issues (infections, allergies, asthma), were outside the 18-45 age range, previous sinonasal surgery or trauma, had certain systemic diseases (diabetes, kidney disease, etc.), used medications affecting NMC (mucolytics, decongestants, etc.) in the previous two weeks or used other tobacco products like snuff or psychoactive substances. Smokers were also excluded if they had been smoking for less than a year or were passive smokers.

Ethical approval received from the ethical review committee of National Hospital Abuja and Federal Capital Development Authority (NHA/EC/065/2019 and FHREC/2020/01/67/27-07-20 respectively). All participants provided informed written consent and their confidentiality was protected in accordance with the 2013 Declaration of Helsinki. Eligible adult participants were recruited and completed an interviewer-administered questionnaire covering their demographics, medical history and physical examination. Nasal mucociliary clearance was then assessed using Anderson's technique.

Procedure

Participants were recruited at motor parks and, after obtaining informed consent, completed an interviewer-assisted questionnaire about their smoking history. Those meeting inclusion criteria were tested for nasal mucociliary clearance (MCC) in a quiet room after a brief rest. Anterior rhinoscopy was performed to rule out nasal pathologies. One randomly selected nasal cavity was tested per participant due to the persistent sweet taste of saccharine long after the procedure, (which lasted up to two hours in a pilot study, precluding repeat testing).

The saccharine transit time test, a simple and reliable method, was used. A small saccharine (Sodium saccharine E954, ISO9001, USP/BP98, 25kg/bag marketed by FOODING®) measuring approximately 1-2 mm (it was measured using Vernier caliper) at the anterior end of the inferior turbinate approximately 1¬ - 1.5 cm from the nasal vestibule using disposable non tooth forceps under direct vision and participants indicated when they first tasted it.

The time elapsed was recorded as the NMCT using a digital chronometer (KD-6128: Kadio). Participants were instructed to maintain position, not to sniff, sneeze, cough, blow their nose, talk or breathe deeply during the test to avoid dislodging the saccharine granule. If no taste was perceived after 30 minutes, the test was stopped and saccharine taste perception on the tongue was verified. To standardize the study and control for factors like humidity and temperature, all tests were conducted between 4 pm and 7 pm in a controlled environment. The same investigator performed all tests. A nasal MCC time of up to 15 minutes was considered normal, while values greater than 15 minutes were considered prolonged.[2,18,25]

RESULTS

A total of 350 participants were screened during the study period. After applying the inclusion criteria, 31 participants were excluded, leaving a final sample of 304 participants. These were evenly divided into two groups: non-smokers (n=152) and active smokers (n=152). Sociodemographic Characteristics of all Participants are as shown in Table 1.

Nasal mucociliary clearance time

Cigarette-only smokers had the longest mean nasal mucociliary clearance time (NMCT) at 17.08±2.69 minutes, followed by those who smoked both cigarettes and shisha (16.45±2.95 minutes), then shisha-only smokers (11.91±2.47 minutes). Non-smokers had the shortest NMCT (8.25±2.02 minutes). These differences were statistically significant (F=246.152, p<0.001).

Comparison of mean nasal mucociliary clearance time between groups

There were significant differences in mean nasal mucociliary clearance time (NMCT) between non-smokers and each smoking subgroup (cigarette and shisha, shisha only and cigarette only). However, there was no significant difference in mean NMCT between those who smoked both cigarettes and shisha and those who smoked only cigarettes (p=0.603).

Table 1: Sociodemographic characteristics of participants by smoking status (n=304).

Variable	Category	Smokers (n=152) N (%)	Non-smokers (n=152) N (%)	P value
Age group (years)	10-19	3 (2.0)	1 (0.7)	0.770
	20-29	71 (46.7)	69 (45.4)	
	30-39	63 (41.4)	66 (43.4)	
	40-49	15 (9.9)	16 (10.5)	
Gender	Male	93 (61.2)	82 (53.9)	0.202
	Female	59 (38.8)	70 (46.1)	
Education	Primary	0 (0.0)	21 (13.9)	<0.001*
	Secondary	4 (2.6)	75 (49.3)	
	Tertiary	148 (97.4)	56 (36.8)	
Occupation	Professionals	14 (9.2)	90 (59.2)	
	Service/Sales	36 (23.8)	24 (15.8)	
	Technicians/Assoc.	54 (35.5)	34 (22.4)	
	Craft/Trades	23 (15.1)	0 (0.0)	<0.001*
	Elementary	25 (16.4)	4 (2.6)	
Marital status	Single	9 (5.9)	93 (61.2)	<0.001*
	Married	143 (94.1)	59 (38.8)	

*Significant at 95%.

Table 2: Sociodemographic and smoking characteristics of tobacco smokers by type (n=152).

Variable	Category	Cigarette & Shisha (n=60) N (%)	Shisha only (n=55) N (%)	Cigarette only (n=37) N (%)
Age group (in years)	10-19	2 (3.3)	1 (1.8)	0 (0.0)
	20-29	29 (48.3)	32 (58.2)	10 (27.0)
	30-39	24 (40.1)	18 (32.7)	21 (56.8)
	40-49	5 (8.3)	4 (7.3)	6 (16.2)
Gender	Male	53 (88.3)	36 (65.5)	37 (100.0)
	Female	7 (11.7)	19 (34.5)	0 (0.0)
Education	Primary	4 (6.7)	2 (3.6)	8 (21.6)
	Secondary	10 (16.7)	7 (12.7)	19 (51.4)
	Tertiary	46 (76.6)	46 (83.7)	10 (27.0)
Occupation	Professional	4 (6.7)	8 (14.5)	2 (5.4)
	Technicians/Assoc.	21 (35.0)	24 (43.7)	9 (24.4)
	Service/Sales	14 (23.3)	14 (25.5)	8 (21.6)
	Elementary	13 (21.7)	8 (14.5)	4 (10.8)
	Craft/Trades	8 (13.3)	1 (1.8)	14 (37.8)
Marital status	Single	41 (68.3)	38 (69.1)	14 (37.8)
	Married	19 (31.7)	17 (30.9)	23 (62.2)
Exhalation route	Nose	31 (51.7)	21 (38.2)	20 (54.1)
	Other	29 (48.3)	34 (61.8)	17 (45.9)
Smoking duration	1-5 years	21 (35.0)	28 (50.9)	2 (5.4)
	>5 years	39 (65.0)	27 (49.1)	94.6)

Table 3: Nasal mucociliary clearance time (NMCT) of tobacco smokers and non-smokers.

Group	N	Mean±SD (minutes)	Range (minutes)	95% CI (minutes)
Non-smokers (control)	152	8.25±2.02	3.47-14.75	7.93-8.58
Cigarette & shisha smokers	60	16.45±2.95	9.32-25.27	15.70-17.22
Shisha only smokers	55	11.91±2.47	7.13-17.00	11.24-12.58
Cigarette only smokers	37	17.08±2.69	13.00-22.07	16.18-17.98*
Overall comparison				
F-statistic		246.152		
P value		<0.001*		

CI=Confidence Interval, SD=Standard Deviation, *Significant at p<0.05.

Table 4: Comparison of mean nasal mucociliary clearance time (NMCT) between smokers and non-smokers.

Group	Mean±SD (minutes)	t-statistic	P value
Non-smokers	8.25±2.02		<0.001*
Smokers	14.96±3.57	20.197	

*Statistically significant at p<0.05.

Table 5: Pairwise comparison of mean nasal mucociliary clearance time (NMCT) between groups.

Group comparison	Mean time difference (minutes)	P value	95% confidence interval (minutes)
Non-smoker vs. Cigarette and shisha smoker	8.20	<0.001*	7.26-9.15
Non-smoker vs. Shisha only smoker	3.66	<0.001*	2.68-4.63
Non-smoker vs. Cigarette only smoker	8.82	<0.001*	7.69-9.96
Cigarette only smoker vs. Cigarette and shisha smoker	0.67	0.603	-0.62-1.91
Cigarette only smoker vs. Shisha only smoker	5.17	<0.001*	3.86-6.49

*Significant at p<0.05.

DISCUSSION

Tobacco smoking-an act of inhaling and exhaling fumes from burning tobacco leaves, which contains nicotine and other harmful chemicals is an increasing global health problem with WHO estimates of over 1.3 billion smokers in 2023 and 6 million smoking related deaths worldwide.[29] It is reported as a cause of preventable morbidities and mortalities globally.[10] The rate of smoking is increasing in Sub-Saharan Africa and reducing in Western countries probably due to poor smoking regulation policies.[20] Tobacco smoking has been linked to respiratory and cardiovascular diseases.[8,11] It can be used in various forms with cigarette being the commonest, followed by shisha which has an increasing trend globally especially among youths.[11]

This study found a significantly prolonged nasal mucociliary clearance time (NMCT) in smokers (14.96±3.57 minutes) compared to non-smokers (8.25±2.02 minutes), consistent with existing literature. Chethena et al, (16.53 minutes vs. 9.28 minutes, p<0.001), Manu et al, (481.2±29.83 seconds vs. 300.32±17.45 seconds, p<0.001) also reported significantly elevated NMCTs in smokers.[5,30] Studies by Habesoglu et al, Mahmud et al and Ozler et al, similarly found prolonged NMCT in both active and passive cigarette smokers compared to non-smokers, though these focused solely on cigarette smoking.[17,18,20]

While some studies reported even higher NMCTs in smokers Stanley et al, (20.8±9.3 minutes vs. 11.1±3.8 minutes), Utiyama et al, (17.9±10.1 minutes vs. 8.2±3.1 minutes) they also consistently demonstrated significantly higher NMCTs in smokers, possibly due to the inclusion of older participants with potential mucosal atrophy.[6,19] This prolonged duration of NMCT may be due to the ciliotoxic effects of cigarette smoke, reduced number of cilia, changes in composition of mucus and its properties due to smoke.

The prolonged NMCC causes stasis of mucus and subsequent bacterial proliferation, impaired drainage, alterations in the levels of complements, lysozymes and immunoglobulins leading to poor immunological protection and thereby predisposing to upper and lower airway infections. It also leads to reduced local immunity and increases susceptibility to allergies.[2,20,30]

However, studies by Quinlan et al and Nicola et al, reported contrasting results, finding either no significant difference or even faster NMCTs in smokers compared to non-smokers. These discrepancies may be due to methodological differences: Quinlan et al, used the more objective rhinoscintigraphy method, while Nicola et al, studied younger smokers with a smoking history of less than 2.5 years, suggesting a possible temporary increase in mucociliary transport and ciliary beat frequency in early-stage smokers.[23,32]

Our study also compared NMCTs between all groups. Significant mean differences (p<0.001) were found when comparing the control group (non-smokers) to each of the smoking subgroups (cigarette and shisha, shisha only and cigarette only). However, the difference in mean NMCT between those smoking both cigarette and shisha and those smoking only cigarettes was not statistically significant (p=0.603). The reason for this lack of significant difference remains unclear.

Among smokers, those who smoked cigarettes alone had the highest mean NMCT (17.08±2.69 minutes), consistent with previous studies. This was followed by those who smoked both cigarettes and shisha (16.45±2.95 minutes), while shisha-only smokers had the lowest NMCT (11.91±2.47 minutes), similar to Aricigil et al.'s finding of significantly higher NMCC in shisha smokers compared to controls (p<0.001).[2]

While both cigarette and shisha contain harmful substances, this study suggests shisha alone may have a less detrimental effect on NMCT than cigarette-only or combined use. The higher NMCT in cigarette-only smokers could be partially attributed to their smaller sample size (n=37).

The combined exposure from both cigarette and shisha use likely explains the significantly higher NMCT in this group compared to shisha-only smokers. Non-smokers in this study had the lowest NMCT (8.25±2.02 minutes), similar to Mahmud et al's findings (9.17±2.80 minutes) in Northern Nigeria, but significantly different from Olajuyin et al.'s Southern Nigerian study (13.6±4.6 minutes), suggesting a possible influence of geographical location on mucociliary clearance.[20,31]

This study's limitations include the slightly invasive nature of the saccharine test, participants potentially withholding information of other substance use (like snuff and marijuana) and the subjective nature of their responses. Furthermore, it lacked standardization of weather conditions and faced challenges in controlling swallowing time and exhalation recall bias.

CONCLUSION

This study concludes that tobacco smoking significantly prolongs nasal mucociliary clearance time (NMCT) in active smokers compared to non-smokers in Abuja. Among smokers, cigarette-only smokers exhibited the most prolonged NMCT, followed by those who smoked both cigarettes and shisha, with shisha-only smokers showing the least prolonged NMCT.

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