The Impact of Cigarette Smoking on Oxidative Stress Indices

Saheed Ladipo Kakako [a*], Ibrahim Shuaibu [a], Ibrahim Abdullahi Musa [a], Muhammad Lawal Jidda [a], Sarafadeen Adeniyi Arisegi [b], James Oyeniyi [c], Idris Olawale Tajudeen [a], Zainab Najim [d], Kafilat Taiwo Salvador-Oke [e], Taofeeq Bolarinwa Lawal [f] and Kabiru Bello Aliyu [d]

[a] Department of Chemical Pathology, School of Medical Laboratory Science, Usmanu Danfodiyo University, Sokoto, Nigeria.
[b] National Institute for Cancer Research and Treatment, Wuse 2, FCT, Abuja, Nigeria.
[c] Faculty of Pharmaceutical Science, Usmanu Danfodiyo University, Sokoto, Nigeria.
[d] Department of Medical Microbiology, Usmanu Danfodiyo University Teaching Hospital, Sokoto, Nigeria.
[e] Department of Medical Microbiology, University of Pretoria, South Africa.
[f] Department of Chemical Pathology, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Introduction: Despite the shocking caption 'Smokers are liable to die young', the prevalence of cigarette smokers continues to surge, especially among the youth. Cigarette smoking is a notable health concern globally and is a well-known risk factor for many diseases including cancer and

_____

*Corresponding author: Email: saheed.kakako@udusok.edu.ng;

cardiovascular diseases. Cellular damage due to oxidative stress occurs when there is an imbalance between the body's antioxidant defense mechanism and pro-oxidants (chemicals in cigarettes). This study aimed to assess oxidative stress indices in cigarette smokers.

Methods: A total of 100 cigarette smokers were recruited from various locations in the Sokoto metropolis and 50 apparently healthy nonsmokers as control. Demographic and clinical information were obtained using a standard questionnaire. Using a standard procedure, about 5 ml of blood sample was collected from each participant to analyze serum total antioxidant capacity (TAC) and total plasma peroxide (TPP) using the ferric-reducing ability of plasma and ferric xylenol orange-2 method, respectively.

Results: A total of 54% of the participants were between 20-29 years of age and 63% were school certificate holders while the most frequently smoked cigarette is Bensen. The oxidative stress indices percentage (OSI %) was calculated. The result shows a significant positive correlation between TAC and TPP, and negatively correlated with OSI% ($p<0.05$, $r= 0.261$ and $p<0.05$, $r= -0.332$). Also, TPP shows a significant positive correlation with OSI% ($p<0.05$, $r= 0.316$).

Conclusion: This study indicates that cigarette smoking is well associated with increased free radicals leading to the generation of oxidative stress. This accentuates the harm that has been established with cigarette smoking. We hope this will alert and dissuade nonsmokers from picking up smoking and encourage smoke cessation among chain smokers.

1. INTRODUCTION

Cigarette smoking remains a global health concern with estimated eight million deaths annually (World Health Organization, 2024). Despite various public health measures aimed at reducing the harm associated with smoking, it impacts significantly on health and economic burdens. Efforts to lower tar and nicotine levels in cigarettes have not accounted for the dangers they pose (Cummings et al., 2006). While global smoking rates have slightly declined (Islami et al., 2015), the prevalence remains alarmingly high, with approximately one in five individuals worldwide continuing to smoke (World Health Organization, 2024).

Smoking is one of the most preventable contributors to diseases and premature death. It is substantially linked to conditions such as cardiovascular disease, lung cancer, and chronic respiratory illnesses (De Silva et al., 2024; Kopp, 2022). These effects are largely due to the production of harmful molecules, including free radicals like reactive oxygen species (ROS) which can damage cells and tissues. Cigarette smoking also disproportionately impacts disadvantaged populations by exacerbating poverty and worsening existing health challenges (Varghese & Gharde, 2023). The risk of smoking-related illnesses increases with prolonged exposure, early initiation, and the type of cigarette used. Additionally, exposure to secondhand smoke poses serious health risks to non-smokers, including children, highlighting the far-reaching consequences of tobacco use (Ngobese et al., 2020).

Cigarettes contain thousands of harmful chemicals, contributing to oxidative stress by disrupting the balance between harmful ROS and the body's natural antioxidant defenses (Ozdemir, 2022; Nowak & Pawliczak, 2022). This imbalance damages essential cellular components such as lipids, proteins, and DNA, playing a key role in the onset of various diseases. Smokers often exhibit reduced antioxidant capacity, which makes them more vulnerable to oxidative damage. Excessive ROS production can overwhelm the body's defense mechanisms, increasing the risk of metabolic disorders, cardiovascular conditions, infertility, and other serious health issues (Schieber & Chandel, 2014). Oxidative stress is recognized to activate many intracellular signaling pathways, resulting in apoptosis or excessive cell proliferation, which contributes to organ malfunction (Ogura & Shimosawa, 2014).

Monitoring oxidative stress levels is critical to understanding the health impact of smoking and identifying individuals who may be at heightened risk for related diseases. This study investigates oxidative stress indices among cigarette smokers in the Sokoto metropolis, aiming to provide data that will inform public health interventions to aid in the prevention of smoking-related illnesses, and more importantly, advance advocacy to quit smoking.

2. MATERIALS AND METHODS

2.1 Study Design and Population

This cross-sectional study was conducted amongst one hundred (100) cigarette smokers and fifty (50) healthy nonactive smokers (apparently not smoking) as test and control respectively at various locations within Sokoto Metropolis (Kaoje et al., 2015; Jaykaran et al., 2011). A well-structured interviewer-administered questionnaire was used to obtain clinical and sociodemographic information from participants. All the participants recruited were aged 18 to 60 years. Individuals with any metabolic disorder e.g., diabetes, gouty arthritis, etc., non-cigarette smokers, and those individuals below the age of 18 years were excluded.

2.2 Ethical Clearance/Informed Consent

The ethical approval was obtained from the Sokoto State Ministry of Health (SKHREC/037/019) and verbal and/or written consent was obtained from all participants.

2.3 Blood Sample Collection and Processing

From each of the participants, a total of 5 ml of venous blood sample was collected aseptically through venipuncture into the plain bottle. The serum was harvested into labeled cryovials and stored at 2-6°c in a refrigerator before analysis of total antioxidant capacity (TAC) and total plasma peroxide using ferric reducing ability of plasma (FRAP) and ferrous oxidation on xylenol orange version 2 (FOX-2) assay methods, respectively. The oxidative stress index percentage (OSI%) is calculated as a ratio of TAC and total plasma peroxide (TPP).

$$OSI\% = \frac{TPP}{TAC} \times 100\%$$

ferrous oxidation in xylenol orange version 2 (FOX2) assay.

3. RESULTS

Table 1 shows the analysis of the sociodemographic distribution of 100 cigarette smokers recruited from various locations within the Sokoto metropolis. A total of 54% were within the age of 20-29 while the participants were predominantly Hausa (84%). About 41% of the study participants are traders, while 25% are students

The most frequently smoked cigarette is Bensen and Hedge (Table 2).

Table 3 shows a statistically significant difference in comparing the test and control groups' oxidative stress parameters, TPP, and OSI%.

Table 1. Sociodemographic distribution of the study participants

Variable	Frequency (n=100)
Age Group	**n (%)**
<20	13 (13%)
20-29	54 (54%)
30-39	17 (17%)
40-49	11 (11%)
50>	5(5%)
Ethnicity	
Hausa	84 (84%)
Igbo	7 (7%)
Yoruba	2 (2%)
Others	7 (7%)
Educational Status	
Primary	21 (21%)
Secondary	63 (63%)
Tertiary	11 (11%)
Non-Formal Education	5 (5%)
Occupation	
Farming	11(11%)
Petty Trader	41 (41%)
Civil Service	6 (6%)
Unemployed	17 (17%)
Student	25 (25%)

Table 2. Frequency of brands of cigarette smoke

Variable	Frequency
Types of Cigarette Smoke	
Aspen	22 (22%)
Bensen and Hedge	33(33%)
Sterling	10 (10%)
King Size	11 (11%)
Oris	24 (24%)

Table 3. Comparison of parameters of Oxidative Stress between Test and Control

Parameters	Test	Control	P-value
	Mean± SD	Mean± SD	
	n (100)	n (50)	
TAC (µmol/L)	886.44±1203.4	956.17±666.71	0.648
TPP (µmol/L)	532.9±123.37	116.47±148.5	0.000*
OSI (%)	87.51±53.85	12.69±16.16	0.000*

KEY: mean ± SD. TAC= Total antioxidant capacity, TPP= Total plasma peroxide, OSI%= Oxidative stress indices OSI%, SD= Standard deviation, n= is the number of study participants. P-value ≤ 0.05 is statistically significant.
*Comparison is statistically significant at 0.000

Table 4. Correlation Coefficient (r) of Oxidative Stress parameters among CS Subjects

Variable	r= Value	P= Value
TAC Vs TPP	+0.261**	0.009
TAC Vs OSI%	-0.332**	0.001
TPP Vs OSI%	0.316**	0.001

KEY: **Correlation is significant at the 0.001 level (2-tailed). P ≤ 0.05 is statistically significant.

4. DISCUSSION

Cigarette smoking continues to pose a significant public health challenge that is entirely preventable. However, a substantial number of individuals remain ensnared in this habit, resulting in a range of diseases and, in certain instances, premature mortality. Cigarette smokers are classified as current smokers (those who smoke daily or occasionally), past smokers (individuals who have previously smoked but do not presently smoke), and never smokers (those who have smoked less than 100 cigarettes in their lives) (Ryan et al., 2012).

It has been established that smoking is the sole risk factor common to four principal non-communicable diseases: cardiovascular disease, diabetes, cancer, and chronic respiratory conditions (Sharifi-Rad et al., 2020; Budreviciute et al., 2020). The detrimental impacts of cigarette smoking have been associated with the intricate interactions of the various chemical components found in cigarette smoke and their effects on biological systems (Hecht & Hatsukami, 2022).

In this study, it was observed that most participants who smoke cigarettes are aged between 20 and 29 years. This age range signifies a pivotal transition from adolescence to adulthood, characterized by greater autonomy, freedom, and self-discovery, which typically encourages individuals to lead self-directed lives. The perceived freedom during this phase may expose this demographic to various social vices, including cigarette smoking, often with little consideration for their health and psychological well-being. The customs and lifestyle choices made during this developmental stage can significantly increase their risk of developing chronic illnesses such as hypertension and diabetes which make them vulnerable to cardiovascular diseases as they grow older.

Triggers initiate craving, subsequently result in the act of smoking (Wipfli & Samet, 2012). In Nigeria, ten prevalent cigarette brands serve as triggers for urges before the onset of addiction. Our research indicates that the Benson & Hedges brand is the most smoked, while the Sterling brand ranks the least popular. Despite the prohibition of smoking in public areas, the unrestricted over-the-counter sales of cigarettes at low and accessible prices contribute significantly to the ongoing triggers and the development of nicotine addiction. Furthermore, the premium quality, distinctive packaging, and diverse flavor offerings of the Benson & Hedges brand facilitate increased consumption among smokers.

Additionally, our study revealed a notable disparity in total plasma protein (TPP) levels between individuals who smoke cigarettes and those who do not (controls). The TPP is recognized as a significant indicator of oxidative stress, inflammation, and antioxidant capacity (Monserrat-Mesquida et al., 2021; Kotha et al., 2022), suggesting that its measurement could play a crucial role in the diagnosis, monitoring, and risk assessment of various diseases. This finding aligns with the work of Nsonwu-Anyanwu *et al.*, 2018 who also documented elevated TPP levels among cigarette smokers (Nsonwu-Anyanwu et al., 2018) The increase in TPP observed in smokers may be attributed to the free radicals generated by cigarette smoke, which deplete the body's antioxidant reserves, thereby rendering smokers more vulnerable to oxidative stress and its associated harmful health conditions (Pasupathi et al., 2009; Chauhan et al., 2023; Adunmo et al., 2015)

The test group displays a higher OSI% than the control group, indicating that the body's antioxidant mechanisms are being overwhelmed by the free radicals generated from cigarette smoking. This observation is consistent with the findings of Chandrasekaran et al. (2017) regarding oxidative stress biomarkers (Chandrasekaran et al., 2017). Smokers present with abnormal levels of free radicals, as indicated by the correlations among various oxidative stress parameters, exhibiting positive and negative relationships. Specifically, TAC shows a statistically significant positive correlation with TPP. Additionally, a negative correlation exists between TAC and OSI%, implying that as the concentration of free radicals, which induce oxidative stress, rises, the levels of plasma antioxidants diminish. This finding corroborates the results of Phaniendra et al. (2015). The correlation of TPP and OSI% is positive, this suggest that monitoring of oxidative stress levels may be useful impact of damage caused by cigarette smoking.

5. CONCLUSION

The negative impact of cigarette smoking on health and well-being is indisputable. Consequently, there is a pressing need to strengthen initiatives aimed at preventing adolescents from starting to smoke. The time has

come to prohibit the unrestricted sale of cigarettes to deter young individuals from beginning to smoke and to reduce the overall number of smokers. A renewed emphasis should accompany this initiative on the health risks associated with cigarette use. The pervasive issue of cigarette smoking represents one of the most significant avoidable public health challenges faced globally.

A more effective approach to combat this epidemic would be the promotion of smoking cessation. Quitting smoking is believed to significantly lower the risk of premature mortality and the onset of diseases related to tobacco use, which compromise the body's antioxidant defense mechanism

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Adunmo, G., Adesokan, A., Akanji, M., Biliaminu S., Abdulazeez I., & Adunmo, E. (2015). Lipid peroxide levels, antioxidant status, and protein changes in Nigerian smokers. *International Journal of Science: Basic and Applied Research (IJSBAR),* 21**:**69-77.

Budreviciute, A., Damiati, S., Sabir, D. K., Onder, K., Schuller-Goetzburg, P., Plakys, G., et. al. (2020). Management and Prevention Strategies for Non-Communicable Diseases (Ncds) and Their Risk Factors. *Frontiers in public health,* 8.

Chandrasekaran, A., Idelchik M. D. P. S., Melendez J. A. (2017). Redox control of senescence and age-related disease. *Redox biology,* 11**,** 91-102. https://doi.org/10.1016/j.redox.2016.11.005

Chauhan, P., Reddy, S. S., Chokkanna, V. K., Singh, P. & Majumdar, K. (2023). Oxidant and Antioxidant Status among Tobacco Users: A Cross-Sectional Study. *National Journal of Maxillofacial Surgery,* 14(3), 444-449.

Cummings, K. M., Brown, A., & Douglas, C. E. (2006). Consumer acceptable risk: how cigarette companies have responded to accusations that their products are defective. *Tobacco Control*, 15**,** 84-89. https://doi.org/10.1136/tc.2004.009837

De Silva, R., Silva, D., Piumika, L., Abeysekera, I., Jayathilaka, R., Rajamanthri L., et al. (2024). Impact of global smoking prevalence on mortality: a study across income groups. BioMed Central Public Health, 24(1), 1786. https://doi.org/10.1186/s12889-024-19336-6

Hecht, S. S. & Hatsukami, D. K. (2022). Smokeless Tobacco and Cigarette Smoking: Chemical Mechanisms and Cancer Prevention. *Nature Reviews Cancer,* 22(3), 143-155.

Islami, F., Stoklosa, M., Drope, J., & Jemal A. Global and regional patterns of tobacco smoking and tobacco control policies. *European urology focus,* 2015, 1**,** 3-16. https://doi.org/10.1016/j.euf.2014.10.001

Jaykaran, Saxena D, Yadav P, & Kantharia N. D. (2011). Negative studies published in medical journals of India do not give sufficient information regarding power/sample size calculation and confidence interval. *Journal of Postgraduate Medicine*, 57**:**176-177.

Kaoje, A. U., Sabir, A. A., Yusuf, S., Jimoh, A. O., Raji, M. O., Ango, U. M. et. al. (2015). Tobacco consumption prevalence and pattern among residents of Sokoto metropolis, Northwestern Nigeria. African Journals Online, 12(1), 981-987.

Kopp, W. (2022). Pathogenesis of (Smoking-Related) Non-Communicable Diseases—Evidence for a Common Underlying Pathophysiological Pattern. *Frontiers in physiology,* 13.

Kotha, R. R., Tareq, F. S., Yildiz, E. & Luthria, D. L. (2022). Oxidative Stress and Antioxidants—a Critical Review on in Vitro Antioxidant Assays. *Antioxidants,* 11(12), 2388.

Monserrat-Mesquida, M., Quetglas-Llabrés, M., Bouzas, C., Capó, X., Mateos, D., Ugarriza, L., et. al. (2021). Peripheral Blood Mononuclear Cells Oxidative Stress and Plasma Inflammatory Biomarkers in Adults with Normal Weight, Overweight and Obesity. *Antioxidants,* 10(5), 813.

Ngobese, S. P., Egbe, C. O., Londani, M., & Ayo-Yusuf, O. A. (2020). Non-Smoker's Exposure to Second-Hand Smoke in South

Africa During 2017. *International Journal of Environmental Research Public Health* 2020, 17(21), 8112. https://doi.org/doi.org/10.3390/ijerph17218 112

Nowak, A. & Pawliczak, R. (2022). Cigarette Smoking and Oxidative Stress. *Alergologia Polska-Polish Journal of Allergology,* 9(2), 89-98.

Nsonwu-Anyanwu A., Offor S., John I. (2018). Cigarette Smoke and Oxidative Stress Indices in Male Active Smokers. *Reactive Oxygen Species*, 5(15): 199-208. https://doi.org/https://www.rosj.org/index.php/ros/article/view/127.

Ogura, S. & Shimosawa, T. (2014). Oxidative stress and organ damages. *Current Hypertension Reports*, *16*, 1-5.

Ozdemir, M. (2022). Breaths of Death: How Smoking Leads to Lung Cancer. *Berkeley Scientific Journal*, 27(1). https://doi.org/https://doi.org/10.5070/BS327161286

Pasupathi P., Saravanan G., & Farook J. (2009). Oxidative Stress Bio Markers and Antioxidant Status in Cigarette Smokers Compared to Nonsmokers. *Journal of Pharmaceutical Sciences Research*, 1(3), 55-62.

Phaniendra, A., Jestadi D. B., Periyasamy, L. (2015). Free radicals: properties, sources, targets, and their implication in various diseases. *Indian journal of clinical biochemistry,* 30**,** 11-26.

https://doi.org/10.1007/s12291-014-0446-0.

Ryan, H., Trosclair, A. and Gfroerer, J. (2012). Adult Current Smoking: Differences in Definitions and Prevalence Estimates—Nhis and Nsduh, 2008. *Journal of environmental public health,* 2012(1).

Schieber, M., & Chandel, N. S. (2014). ROS function in redox signaling and oxidative stress. *Current biology.* 24**:** 53-62. http://dx.doi.org/10.1016/j.cub.2014.03.034

Sharifi-Rad M., Anil Kumar N. V., Zucca P., Varoni E. M., Dini L., Panzarini E., et al. (2020). Lifestyle, Oxidative Stress, and Antioxidants: Back and Forth in the Pathophysiology of Chronic Diseases. Frontiers in physiology, 11: 694. https://doi.org/https://doi.org/10.3389/fphys.2020.00694

Varghese, J., & Gharde, P. M. (2023). A Comprehensive Review on the Impacts of Smoking on the Health of an Individual. *Cureus,* 15. DOI: 10.7759/cureus.46532

Wipfli H. L., Samet, J. M. Moving Beyond Global Tobacco Control to Global Disease Control. *Tobacco control.* 2012); 21(2): 269-272. https://doi.org/https://doi.org/10.1136/tobaccocontrol-2011-050322.

World Health Organization. (2024). *WHO global report on trends in prevalence of tobacco use 2000–2030.* World Health Organization.

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/132177