



Short and Long-Term Exposure to Biomass Fuel (Wood Smoke) and Its Effects on Cardiovascular Risk Markers and Lipid Peroxidation of Male Albino Rats

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Authors' contributions

This work was carried out in collaboration among all authors. Authors UT and MSC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DCE, ISN and COD managed the analyses of the study. Authors CJAO and EMU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Prevalence of cardiovascular diseases (CVD) has surged rapidly in recent times. Exposure to particulate matter (PM) has been linked with increased cardiovascular morbidity and mortality. It is considered as one of the leading environmental risk factors of several diseases.

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Biomass smoke exposure has been shown to be associated with inflammation, coagulation, and lipid peroxidation, which are important factors in the development of CVD. Thus the purpose of this study was to evaluate the effect of biomass fuel exposure on cardiovascular risk markers and lipid peroxidation.

Methods: The twenty adult male wistar rats were randomly assigned to two groups of ten animals each designated as groups A and B. Rats in group A served as control (exposed to fresh air) and group B exposed to inhalation of biomass smoke (wood smoke). The exposures were done using whole body exposure chambers 70cm x 60cm x 60cm measurement for six weeks, 6 days per week. . Five millilitres of blood sample were collected and serum extracted at the end of three and six weeks intervals. Serum concentrations of troponin I, CK-MB, hsCRP, myoglobin and MDA were determined using standard methods, while atherogenic indices were calculated using appropriate formula.

Results: The result shows significant increase in troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA at three weeks and six weeks relative to control, and these effects appears to be dependent on exposure duration.

Conclusion: The results suggest that repeated exposure to biomass fuel could potentiate the risk of CVD through elicitation and amplification of oxidative stress and cardio-inflammation, thus acting as significant risk factor for CVD.

Keywords: Biomass fuel; cardiovascular risk markers; lipid peroxidation.

1. INTRODUCTION

Household air pollution from solid fuels is one of the leading risk factors for global disease burden, accounting about 4.3% of global disability-adjusted life-years (DALYs) [1]. Cardiovascular diseases (CVDs) are the leading causes of morbidity and mortality globally, accounting to about 31% of all global deaths [2]. Over 39% of the risk factor and causes of CVDs which have continued to increase in prevalence worldwide are unknown [3,4]. Air pollution exposure particularly particulate matter (PM), has been associated with increased cardiovascular morbidity and mortality [5,6]. Biomass smoke is one of the major source of PM, and contributors of household air pollution worldwide. It is considered as one of the leading environmental risk factors of several diseases, such as chronic obstructive pulmonary disease (COPD), acute lower respiratory disease and cardiovascular outcome, and is thought to cause 4 million deaths annually across the globe [7,8]. It's estimated that over 3 billion people rely on biomass fuels for domestic purposes [9]. Current predictions are that, domestic consumption of biomass fuels will remain substantial for decades to come, particularly in rural areas [10]. In developing countries, women and children have the highest biomass smoke exposure due to cultural practices such as, indoor cooking in housing with very poor air ventilation [11]. The absence of chimneys or pipes prevents the smoke venting outside and as such, particles become trapped and diffuse into the

surroundings [11,12]. Biomass smoke has been shown to consist of over 200 different compounds, which includes, a significant number of toxic compounds. Some of these include, carbon monoxide (CO), varying sizes of PM, mostly PM₁₀; sulphur and nitrogen oxides, polycyclic aromatic hydrocarbons (PAH), aldehydes, free radicals and non-radical oxidising species; and volatile organic compounds [10,11,13]. During the burning of these fuels, people indoors can be exposed with up to 30,000 µg/m³ of PM sized 10 µm or smaller [14], while the stipulated concentration of PM₁₀ exposure according to WHO guideline [15], is 50 µg/m³ for a 24 h period, which is extremely low compared to observed concentrations indoors where biomass fuels are burnt. Biomass smoke exposure has been shown to be associated with inflammation, coagulation, and lipid peroxidation, which are important factors in the development of CVD [13,16]. Gurgueira et al. [17], reported increased reactive oxygen species concentration in the heart and lungs of rats exposed to concentrated ambient particles. Short-term exposures to diluted wood smoke, has been linked with increased arterial stiffness and decreased heart rate variability [18]. More so, exposure to PM from bush fires has been linked with out-of-hospital cardiac arrest [19,20]. Several studies has linked PM from biomass burning to increased oxidative potential which could contribute to cardiovascular mortality [21-23]. However, other studies reported no associations between short-term exposures to wood smoke and cardiac arrhythmia or increase

in biomarkers of systemic inflammation [24,25]. Similarly, Henderson et al. [26], reported no associations between forest fire smoke exposure and physician visits/hospital admissions for cardiovascular outcomes. Weichenthal et al. [27], reported that short-term exposure to ambient PM concentrations from biomass smoke, is associated with increase hospital admissions for myocardial infarction among elderly. In furtherance to that, this study was designed to evaluate the effect of exposure to biomass smoke, on the serum levels of troponin I, creatine kinase-MB (CK-MB), high sensitive C-reactive protein (hsCRP), myoglobin, atherogenic index of plasma (AIP), Cardiac risk ratio (CRR), atherogenic coefficient (AC) and malondialdehyde (MDA) to ascertain possible cardiovascular risk involvement.

2. MATERIALS AND METHODS

2.1 Experimental Animals

Twenty adult male albinos' rats (wistar strain), seven weeks old, that weighed 130 ± 10 g obtained from the Animal Breeding Unit of the Faculty of Veterinary Medicine, University of Nigeria, Nsukka, were used as the experimental animals. The rats were kept in cages for two weeks, allowed to acclimatize to Animal House of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi campus and were allowed free access to food and water *ad libitum*. Thereafter, the animals were randomly (while controlling for weight differences) distributed into two groups of ten animals each based on the exposure.

2.2 Biomass

The biomass Melina wood (*G arborea*) was purchased from commercial wood seller at Nnewi City, Anambra State, Nigeria.

2.3 Design of Exposure Chamber and Wood Combustor

The exposure chamber was fabricated using plywood (China OSB), while the wood combustor was made using iron, with an outlet for the release of the smoke into the chamber and a square oxygen inlet on the lid (10 cm x10 cm). The exposure chamber measures 70cm x 60cm x 60cm as previously described by Uboh et al. [28] and Akintunde et al. [29], was constructed to allow at least 20% ventilation, as stipulated by the Organisation for Economic Co-operation and

Development guidelines for inhalation toxicity. The burning process was initiated first before exposure by igniting 4kg *Gmelina arborea* wood with a lighter in a fabricated combustor. The wood smoke was diverted from the combustor into the exposure chamber using a metal host.

2.4 Experimental Design

The twenty (20) adult male wistar rats obtained from the animal breeding unit of the faculty of Veterinary Medicine, University of Nigeria, Nsukka, after two weeks of acclimatization to the animal house were randomly (while controlling for weight differences) assigned to two groups of ten animals each designated as, groups A and B. Rats in group A served as control (exposed to fresh air) and group B exposed to biomass smoke (wood smoke). The exposures were done using whole body exposure chambers 70cm x 60cm x 60cm measurement. The animals in group B were exposed to biomass smoke by igniting 4kg *Gmelina arborea* wood with a lighter in a fabricated combustor. The wood smoke was diverted from the combustor into the exposure chamber using a metal host. The animals in group B were exposed to $1005 \mu\text{g}/\text{m}^3$ of PM_{10} from wood smoke for 1h/day, 6 day/week for 6 weeks. The PM concentration in the chamber was monitored using a PM_{10} monitor (portable particulate monitor PCE-RCM 10, PCE Deutschland GmbH). At the end of each exposure day, the animals were transferred to biomass smoke free section of the experimental animal house. Body weight of animals and mortality data were routinely monitored. The study lasted for 6 weeks and blood samples were collected at the end 3 weeks and 6 weeks intervals by ocular and cardiac puncture respectively for the biochemical analysis.

2.5 Collection of Blood Sample

The blood samples were collected at three weeks and six weeks intervals. At end of three weeks and six weeks, the animals were fasted overnight, anesthetized with chloroform and blood samples collected by ocular and cardiac puncture respectively, into plain sample tubes. Serum samples were separated 1 h after extraction of blood by centrifugation at 3000 g for 10 mins and stored in at -30°C . Biochemical analyses on the serum samples were done 24 h after sample collection. Biochemical analyses were carried out for the measurement of serum levels of troponin I, creatine kinase MB, high sensitivity C-reactive protein, myoglobin,

atherogenic coefficient, cardiac risk ratio, atherogenic index of plasma and malondialdehyde.

2.6 Biochemical Analysis

The cardiac markers were determined by chemiluminescence immunoassay (CLIA) using Maglumi 600 reagent kits manufactured by Shenzhen New Industries Biomedical Engineering Co., Ltd, 4F, Weames Tech Bldg, Science and Industry Park, Nanshan, Shenzhen, China 518057. Troponin I were determined by the method of Cummins et al. [30], CK-MB by Pierce and Jaffe, [31], hsCRP by McPherson and Pincus, [32] and myoglobin by Mair et al. [33]. Malondialdehyde concentration were determined by method of Jentzsch et al. [34]. The atherogenic indices were calculated from lipid profile as described by Dobiasova [35]:

- Cardiac Risk Ratio (CRR) = TC/HDLC
- Atherogenic Coefficient (AC) = TC-HDLC/HDLC
- Atherogenic Index of Plasma (AIP) = Log(TG/HDL)

2.7 Statistical Analysis

Data collected were subjected to Independent-Samples T-Test, in order to test whether or not significant differences existed between groups. Paired-Samples T-Test were used to compare significant difference between 3 weeks and 6 weeks of exposure. The mean±SD of each parameter were taken for each group. Test probability value of $p < 0.05$ were considered significant. The analyses were carried out on SPSS for Windows version 23.0.

3. RESULTS

Table 2, shows the comparison of values of troponin I, CK-MB, hs CRP, myoglobin, CRR, AC, AIP and MDA after 3 weeks exposure to biomass smoke. The mean troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA level was highest in test group B and lowest in control. The mean troponin I, CK-MB, hsCRP, myoglobin, CRR, AC and MDA value of the test group B compared to control were statistically significantly ($p = .001, .001, .001, .001, .001, .001$ and $.001$ respectively), while the mean AIP value of test group B compared to control were statistically similar ($p = .078$).

Table 3, depicts the comparison of values of troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA after 6 weeks exposure to biomass smoke. The mean troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA level was highest in test group B and lowest in control. The mean troponin I, CK-MB, hsCRP, myoglobin, CRR, AC and MDA value of the test group B compared to control were statistically significantly ($p = .001, .001, .001, .001, .001, .001$ and $.001$ respectively), while the mean AIP value of test group B compared to control were statistically similar ($p = .695$).

Table 4, depicts the comparison of 3 weeks and 6 weeks exposure values of troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA. The mean troponin I, CK-MB, hsCRP, myoglobin, CRR, AC, AIP and MDA level was highest in 6 weeks exposure and lowest in 3 weeks exposure. The mean troponin I, hsCRP, myoglobin, CRR, AC, AIP and MDA value of 6 weeks exposure compared to 3 weeks exposure were statistically significantly ($p = .001, .032, .005, .008, .004, .032, \text{and} .001$ respectively), while the mean CK-MB value of 6 weeks exposure compared to 3 weeks exposure were statistically similar ($p = .102$).

4. DISCUSSION

Wood smoke is one of the major source of particulate matter (PM) and a major contributor of household air pollution worldwide. People living in developing countries, are becoming more vulnerable to the adverse health effect, due to over dependency on woods as alternative source of energy for cooking and heating. There appears to be dearth of information regarding cardiovascular changes in rats and other mammals induced by exposures to environmental toxicants like, biomass smoke. Although exposure to PM has been linked with increased cardiovascular morbidity and mortality [5,6]. Therefore, this study sought to investigate whether short and long-term exposure to wood smoke, affects cardiovascular risk markers and lipid peroxidation. The results showed that, exposure to wood smoke significantly increase serum levels of troponin-I, creatine kinase-MB (CK-MB) and myoglobin, which are indicator of myocardial injury and cardiotoxicity. The myocardium responds to any injury that causes disruption of its sarcolemma membrane by releasing cytoplasmic pool of biomarkers such as, myoglobin, creatine kinase and troponins [36].

Table 1. Summary of exposures

Groups	Exposures
Group A (control)	Exposed to fresh air
Group B (biomass)	Exposed to 1005± 6.3ug/m ³ h-1 Kg-1 of biomass smoke

ug/m³ h-1 Kg-1=micrograms per meter cube, per hour, per kilogram of biomass

Table 2. Comparison of biochemical parameters after 3 weeks of exposure

Parameters	-----Groups-----			
	Group A (Control)	Group B (Biomass)	t-value	p-value
Troponin I (ng/l)	16.11 ±1.04	35.17 ±3.87	-15.012	0.001*
CK-MB (ng/ml)	1.85 ±0.22	3.55 ±0.14	-11.307	0.001*
hsCRP (ng/ml)	195.71 ±34.04	359.19 ±52.15	-8.176	0.001*
Myoglobin (ng/ml)	22.09 ±3.22	42.99 ±3.26	-14.030	0.001*
CRR	1.61 ±0.26	2.21 ±0.25	-5.057	0.001*
AC	0.64 ±0.27	1.20 ±0.24	-4.573	0.001*
AIP	-0.24 ±0.11	-0.13 ±0.12	-1.878	0.078
MDA (µmol/l)	1.37 ±0.07	1.88 ±0.07	-14.854	0.001*

Table 3. Comparison of biochemical parameters after 6 weeks of exposure

Parameters	-----Groups-----		t-value	p-value
	Group A (Control)	Group B (Biomass)		
Troponin I (ng/l)	16.47 ±1.03	41.40 ±3.76	-20.164	0.001*
CK-MB (ng/ml)	2.10 ±0.25	4.07 ±0.53	-10.297	0.001*
hsCRP (ng/ml)	212.69 ±31.24	448.40 ±95.36	-7.385	0.001*
Myoglobin (ng/ml)	23.24 ±3.49	50.96 ±4.50	-14.724	0.001*
CRR	1.77 ±0.25	2.72 ±0.28	-7.49	0.001*
AC	0.80 ±0.24	1.76 ±0.28	-7.659	0.001*
AIP	-0.06 ±0.15	-0.03 ±0.07	-0.399	0.695
MDA (µmol/l)	1.36 ±0.05	2.26 ±0.19	-14.245	0.001*

*= significant at $p < 0.05$, CRR=cardiac risk ratio, AC=atherogenic coefficient, AIP=atherogenic index of plasma, MDA=malondialdehyde, hsCRP=high sensitive C-reactive protein, CK-MB=Creatine kinase-MB

Table 4. Comparison of biochemical parameters between 3 weeks and 6 weeks Exposure

Parameters	Duration of exposure		t-Value	p-value
	3 weeks	6 weeks		
Troponin I	35.17±3.87	41.40±3.76	-5.263	0.001*
CK-MB	3.55±0.41	4.07±0.53	-1.880	0.102
hsCRP	359.19±52.15	448.40±95.36	-2.681	0.032*
Myoglobin	42.99±3.26	50.96±4.50	-4.072	0.005*
CRR	2.21±0.25	2.72±0.28	-3.705	0.008*
AC	1.20±0.24	1.76±0.28	-4.177	0.004*
AIP	-0.13±0.12	-0.03±0.07	-2.666	0.032*
MDA	1.88±0.07	2.26±0.19	-8.706	0.001*

These markers are released, so that the blood levels rise rapidly above its cut off points. This is then followed by a more protracted release of biomarkers from the disintegrating myofilaments that may continue for several days. Troponin-I, is

the biomarker of choice for detection of cardiac injury. Cardiac troponin-I is more sensitive and specific than CK-MB and myoglobin [37]. The cardiac troponin found in blood may not only be due to cell death; but could also result from

reversible myocardial injury [37]. Mechanistic studies have shown that necrosis is not essential for cardiac troponin release, and that, even preload and integrin stimulation both have shown to cause proteolysis and cardiac troponin release [37]. There is sparse literature report on wood smoke induced changes in cardiac marker probably due to strict regulations governing the use of biomass fuel in most countries. The increase in serum levels of troponin I, CK-MB and myoglobin found in this study, is indicative of possible cardiovascular risk involvement of wood smoke exposure. This findings is also dependent on duration of exposure; the higher the exposure duration, the higher the risk of cardiovascular event and vice versa. This result is in agreement with the findings of Abderrahim et al. [38] and Das et al. [39], who both reported significant increases in cardiac markers upon exposure to biomass smoke. Similar findings have also been reported upon exposure to environmental toxicant [40,41]. High sensitivity C-reactive protein (HS-CRP) an acute phase protein has been implicated in various inflammatory conditions. Studies has shown that, increased risks of developing cardiovascular disease (CVD) are associated with elevated high sensitivity C-reactive protein, which is considered as markers of low-grade systemic inflammation [42,43]. There are many evidences to suggest that atherosclerosis is an inflammatory disease [44,45]. The increase in serum levels of hs-CRP found in this study, is indicative of cardiovascular inflammation associated with biomass smoke exposure. This result is in tandem with the findings of Jianmin et al. [46] and Dauchet et al. [47]. Atherogenic indices are strong indicators of the risk of heart disease; the higher the value, the higher the risk of developing cardiovascular disease and vice versa [35,48]. According to Usoro et al. [48], low atherogenic indices are protective against coronary heart disease, while higher atherogenic indices increase the risk. From the result obtained it's apparent that exposure to biomass smoke significantly increased the atherogenic indices; CRR, AC and AIP indicating the likely role in cardiovascular disease. These findings is in tandem with Uboh et al. [49] and Ubani et al. [50], who reported significant increase in atherogenic indices of wistar rats exposed to environmental toxicants. Smoking has been suggested to be one of the factors playing a role in oxidative stress, through its generation of reactive oxygen species [51]. Oxidative stress has been implicated in the pathogenesis of several diseases including, cardiovascular diseases. Increased

malondialdehyde (MDA), is an indicator of lipid peroxidation and thus, oxidative stress [52]. The significant increase in MDA concentration recorded in this study indicates possible increase lipid peroxidation initiated by free radicals generated by the toxic contents of biomass smoke, which could be deleterious to the cells and organs. The significant increase in MDA found in this study agrees with the report of Ujowundu et al. [53]. The exact mechanisms by which biomass smoke induce cardio-toxicity are poorly understood. These effects, could be attributed to inflammation and oxidative stress. Inflammation plays a significant role in the pathophysiology of atherosclerosis. The inflammatory cells types found in atheroma include, monocytes-derived macrophages and lymphocytes. Macrophages present in atherogenous plaque, leads to the release of mediators like, cytokines and chemokines which in turn increase the plasma concentration of hsCRP which amplify inflammatory and procoagulant responses [54]. Among other inflammatory markers studied, for prediction of coronary accidents in healthy adult, hsCRP appears to be the most powerful inflammatory marker of future cardiovascular risk [55-62]. Increased reactive oxygen species concentration has been reported upon exposure to PM [17,63]. The significant increase in level of malondialdehyde found in this study connotes the role of oxidative stress in cardio-toxicity upon exposure to wood smoke.

5. CONCLUSION

In conclusion, the results of this work suggest that, repeated exposure to biomass fuel could potentiate the risk of cardiovascular disease, through elicitation and amplification of oxidative stress and cardio-inflammation, thus, acting as significant risk factor to cardiovascular disease. Hence those occupationally exposed to biomass smoke should ensure appropriate use of personal protective equipment, in addition should have regular medical check-up to ascertain their health condition.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of

knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable

ETHICAL APPROVAL

The study protocol was in line with the guidelines of the National Institute of Health (NIH) (NIH Publication 85-23, 1985) for laboratory animal care and use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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