The Journal of Phytopharmacology 2026; 15(4):218-224
Online at: www.phytopharmajournal.com

Research Article

ISSN 2320-480X
JPHYTO 2026; 15(4): 218-224
July- August
Received: 19-05-2026
Accepted: 20-07-2026
Published: 31-07-2026

doi: 10.31254/phyto.2026.15404

Joel Ayodele Adewole
Department of Physiology, College of Medical Sciences, University of Benin, Benin City, Nigeria

Magdalene Imuwaihen Omigie
Department of Physiology, College of Medical Sciences, University of Benin, Benin City, Nigeria

Caroline D. Ekpruke
Department of Physiology, College of Medical Sciences, University of Benin, Benin City, Nigeria

Correspondence:
Dr. Magdalene Imuwaihen Omigie
Department of Physiology, College of Medical Sciences, University of Benin, Benin City, Nigeria
Email: magdalene.omigie@uniben.edu

Vitamin C attenuates mosquito repellent-induced aortic histopathological changes and elevated high-sensitivity C-reactive protein in Wistar rats

Joel Ayodele Adewole, Magdalene Imuwaihen Omigie, Caroline D. Ekpruke

ABSTRACT

Background: The prevalence of malaria parasite-carrying mosquitoes necessitates the use of mosquito repellents in households; however, these chemical agents have been associated with adverse health effects. The aorta, being the largest elastic artery, is susceptible to inflammatory and degenerative changes. High-sensitivity C-reactive protein (hs-CRP) is an acute-phase inflammatory marker synthetized primarily by the liver. Although pyrethroid insecticides are widely used, limited data exist on their specific effects on aortic histology and the potential protective role of antioxidant and lifestyle interventions. **Objective:** The study was designed to investigate the effect of mosquito repellent (Raid®) exposure on aortic histopathology and serum hs-CRP level in Wistar rats, and to evaluate the potential protective effects of vitamin C supplementation and daily exercise against these changes. **Materials and Methods**: Thirty (30) Wistar rats (average body weight of 146.1 ± 8.75g) were randomly assigned to six (6) groups (n = 5 each). Group A served as the control; Group B was directly exposed to insecticide overnight; Group C was indirectly exposed to insecticide; Group D received direct exposure plus liquid vitamin C *ad libitum*; Group E underwent direct exposure plus daily exercise; and Group F received vitamin C supplementation plus daily exercise without insecticide exposure. After 28 days, rats were sacrificed under chloroform anesthesia. Blood samples were collected by cardiac puncture for serum hs-CRP estimation, and aortic tissues were harvested for histopathological examination. **Results:** Serum hs-CRP levels were significant elevated in Groups B and C (direct and indirect insecticide exposure) compared to the control (p <0.05). However, no significant differences were observed in Groups D, E, and F compared to controls. Histopathological examination revealed necrosis, inflammatory infiltrates and reduced connective tissue in the adventitia of the aorta in Groups B and C, while these alterations were absent in the vitamin C-supplemented and exercise groups. **Conclusion:** Exposure to mosquito repellent induced aortic necrosis and inflammation, as evidenced by significant elevation of serum hs-CRP levels. These findings suggest that pyrethroid insecticide may contribute to vascular injury through inflammatory pathways, and that vitamin C supplementation and exercise may offer protective effects.

Keywords: Mosquito repellents, High-sensitivity C-reactive protein, Aorta, Inflammation, Vitamin C, Exercise.

INTRODUCTION

The primary route of insecticide exposure among the general Nigerian population occurs within domestic settings; however, epidemiological data on the prevalence of household pesticide use in Nigeria remain scarce [1]. The persistent burden of malaria, transmitted by *Anopheles* mosquitoes, has necessitated the widespread insecticide use in homes, as individuals typically spend more time in indoors than outdoors [2]. Insecticides have been associated with a range of adverse health effects, including reproductive impairment, congenital anomalies, neurological deficits, and other systemic toxicities [1].

Mosquito repellents are chemical substances designed to deter mosquitoes and other hematophagous insects [3]. The active ingredients in most commercial mosquito repellents are synthetic pyrethroids including allethrin and deltamethrin [4]. Pyrethroids exert their insecticidal effects primarily by targeting voltage-gated sodium channels, prolonging their opening and causing sustained neuronal depolarization, repetitive firing, and ultimately hyperexcitation [5-8]. These neurotoxic effects are not limited to insects;

mammalian exposure can also lead to symptoms such as tremors, involuntary movements, and salivation [5]. Raid®, a commonly used household insecticide, contains synthetic pyrethroids and is known to be toxic to non-target organisms, including fish and mammals [9].

Pyrethroid insecticides, while effective against disease vectors, have been increasingly recognized for their potential cardiovascular toxicity. The aorta, the largest elastic artery in the body, is composed of three distinct layers: the tunica intima (innermost endothelial layer), the tunica media (thickest layer containing smooth muscle cells and elastic fibers), and the tunica adventitia (outermost connective tissue layer containing collagen fibers, fibroblasts, and vasa vasorum) [10,11]. Vascular damage can result from oxidative stress, chronic low-grade inflammation, and endothelial dysfunction, all of which may be induced by xenobiotic exposure [12].

High-sensitivity C-reactive protein (hs-CRP) is an acute-phase inflammatory protein synthesized primarily by the liver in response to interleukin-6 (IL-6) and other pro-inflammatory cytokines. Initially discovered by Tillet and Francis in 1930 as a protein that reacts with the C-polysaccharide of *Streptococcus pneumoniae* [13], CRP has since been established as a sensitive marker of systemic inflammation and a predictor of cardiovascular events. The Centers for Disease Control and Prevention (CDC) and the American Heart Association (AHA) recommend hs-CRP measurement for cardiovascular risk stratification in intermediate-risk individuals [14].

The vascular endothelium and arterial wall are particularly susceptible to injury from circulating toxins and inflammatory mediators. Several studies have reported that pyrethroid insecticides induce oxidative stress, inflammation, and endothelial dysfunction in various experimental models [15,16]. Vitamin C, a potent antioxidant, has demonstrated protective effects against xenobiotic-induced oxidative damage by scavenging reactive oxygen species (ROS) and modulating inflammatory responses [17]. Similarly, regular exercise training has been associated with reduced circulating inflammatory markers, including CRP, through mechanisms involving improved metabolic profile and reduced adiposity [18].

Despite the widespread use of pyrethroid-based mosquito repellents in Nigerian households, limited research has focused on their specific effects on aortic histology and systemic inflammation. Furthermore, the potential synergistic protective effects of vitamin C and exercise against insecticide-induced vascular injury remain poorly characterized. Therefore, this study was designed to investigate the effects of exposure to a commonly used mosquito repellent (Raid®) on aortic histopathology and serum hs-CRP levels in Wistar rats, and to evaluate the potential protective roles of vitamin C supplementation and daily exercise.

MATERIAL AND METHODS

Ethical Approval

All experimental procedures were conducted in accordance with the National Institutes of Health (NIH) Guidelines for the Care and Use of Laboratory Animals (NIH Publication No. 85-23, revised 1985). Ethical approval for this study was obtained from the Institutional Animal Ethics Committee of the University of Benin (Approval Number: CMS/REC2024/318).

Experimental Animals

Thirty (30) Wistar rats of both sexes, weighing between 113.7 g and 196 g, were purchased from the animal facility of the Department of Anatomy, College of Medical Sciences, University of Benin, Benin City, Nigeria. The rats were housed in six ventilated cages under standard laboratory conditions: room temperature (25 ± 2 °C), relative humidity (50–60%), and a 12-h light/12-h dark cycle. They were provided with commercial *Grower Mash* feed and water *ad libitum*. The animals were allowed to acclimatize for two weeks prior to the commencement of the experiment.

Experimental Design

The rats were randomly assigned to six groups of five animals each:

- Group A (Control): Rats received standard feed and water *ad libitum*.
- Group B (Direct Exposure): Rats were directly exposed to insecticide overnight, with feed and water provided *ad libitum*.
- Group C (Indirect Exposure): Rats were placed in cages adjacent to Group B, allowing indirect exposure to insecticide vapors, with feed and water provided *ad libitum*.
- Group D (Direct Exposure + Vitamin C): Rats were directly exposed to insecticide and supplemented with liquid vitamin C *ad libitum*.
- Group E (Direct Exposure + Exercise): Rats were directly exposed to insecticide and subjected to daily exercise (20 minutes/day on a Rat's Wheel).
- Group F (Vitamin C + Exercise): Rats received vitamin C supplementation and daily exercise without insecticide exposure.

Insecticide Exposure Protocol

The insecticide used was Raid® Multipurpose Insect Killer, purchased from Thelver Pharmacy and Superstores, Benin City, Nigeria. The exposure protocol was adapted from previous studies [1,9]. Briefly, cotton wool was sprayed with the insecticide until saturated and placed inside the cages of the exposed groups (Groups B, D, and E) overnight (approximately 12 h) for 28 consecutive days. The cotton wool was removed each morning. The concentration of insecticide used was approximately 0.5 mL per 100 cm^2 of cotton wool surface area, based on a single spray application. The cages were maintained under standard ventilation conditions, and no additional measures were taken to confine the insecticide vapors.

Vitamin C Supplementation

Liquid vitamin C (Ray Vita® Bio-vitamin Plus, Animal Store House, Benin City) was supplemented *ad libitum* at a concentration of 2.5 mL of concentrated solution diluted in 1 L of drinking water (0.25% v/v). The supplement was provided daily throughout the 28-day experimental period. The composition of the vitamin C supplement included vitamin C (ascorbic acid) in addition to other vitamins, minerals, amino acids, and electrolytes; however, the concentration of vitamin C in the product was not specified by the manufacturer.

Exercise Protocol

Rats in Groups E and F were subjected to daily exercise for 20 min using a Rat's Wheel apparatus. The exercise session was performed at the same time each day (between 8:00 AM and 10:00 AM) to minimize diurnal variations. The rats were allowed to run voluntarily on the wheel, and the duration was standardized across all sessions.

Body Weight Monitoring

Body weights of all rats were recorded weekly using a digital weighing scale throughout the 28-day experimental period.

Blood Collection

At the end of the 28-day experimental period, rats were anaesthetized using chloroform ($CHCl_3$) inhalation. Blood samples (approximately 4 mL) were collected by cardiac puncture using 5 mL plain tubes without anticoagulant. The blood samples were allowed to clot at room temperature for 30 min and then centrifuged at 4000 rpm for 15 min. Serum was separated and stored at -20 °C until analysis.

High-Sensitivity C-Reactive Protein (hs-CRP) Assay

Serum hs-CRP levels were measured using a commercially available enzyme-linked immunosorbent assay (ELISA) kit (Elabscience Biotechnology Inc., Wuhan, China; Catalog No. E-EL-R0506) following the manufacturer's instructions. The assay sensitivity was 0.094 ng/mL, with a detection range of 0.156–10 ng/mL. The intra-assay and inter-assay coefficients of variation were < 8% and < 10%, respectively. Absorbance was measured at 450 nm using a microplate reader (Thermo Fisher Scientific, Waltham, MA, USA).

Histopathological Examination

Following euthanasia, aortic tissues were carefully dissected and fixed in 10% neutral buffered formalin. Tissue processing was performed using an automatic tissue processor (Leica TP2010) through the following steps: fixation, dehydration using ascending grades of isopropyl alcohol, clearing in xylene, and infiltration with molten paraffin wax. Tissues were then embedded in paraffin wax, sectioned at 5 µm thickness using a semi-automated rotary microtome (Thermo Scientific), and stained with hematoxylin and eosin (H&E) to demonstrate general tissue architecture [19-21]. Stained slides were mounted in DPX mounting medium and examined under a light microscope (Olympus BX43) at ×10 and ×40 magnifications. Photomicrographs were captured using a digital camera. Histological changes were evaluated qualitatively for the presence of necrosis, inflammatory infiltrates, and alterations in connective tissue architecture. All histopathological examination was done at the Department of Histopathology, University of Benin Teaching Hospital (UBTH), Edo State, Nigeria.

Statistical Analysis

Data were expressed as mean ± standard error of the mean (SEM). Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by Dunnett's *post hoc* test for multiple comparisons against the control group. Statistical analyses were conducted using GraphPad Prism version 8.0 (GraphPad Software, Inc., San Diego, CA, USA). A p-value of less than 0.05 ($p < 0.05$) was considered statistically significant.

RESULTS

Serum High-Sensitivity C-Reactive Protein (hs-CRP) Levels

The serum hs-CRP levels of the experimental groups are presented in Figure 1. Rats in Group B (direct exposure) and Group C (indirect exposure) showed significantly elevated serum hs-CRP levels compared to the control group ($p < 0.05$). In contrast, rats in Group D (insecticide + vitamin C), Group E (insecticide + exercise), and Group F (vitamin C + exercise) did not show statistically significant differences in hs-CRP levels compared to the control group ($p > 0.05$).

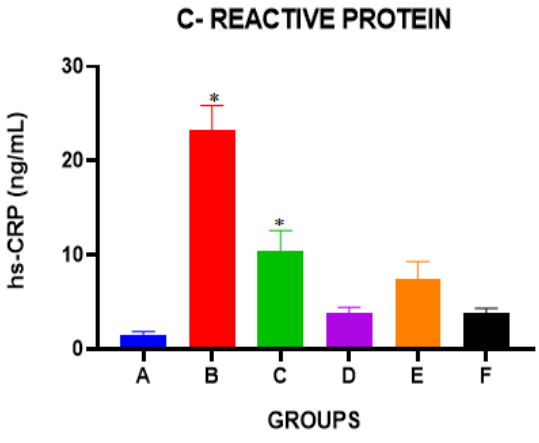

Figure 1: Serum hs-CRP Levels in Experimental Groups

Group	Description	hs-CRP (ng/mL)
A	Control	1.540 ± 0.3019
B	Direct Exposure	23.23 ± 2.6460*
C	Indirect Exposure	10.36 ± 2.2370*
D	Direct Exposure + Vitamin C	3.858 ± 0.6076
E	Direct Exposure + Exercise	7.382 ± 1.9280
F	Vitamin C + Exercise	3.792 ± 0.5344

Data are presented as mean ± SEM for each group, n = 5/group, p < 0.05 vs. control group

Histopathological Findings

The histopathological examination of aortic tissues is presented in Figures 2–7.

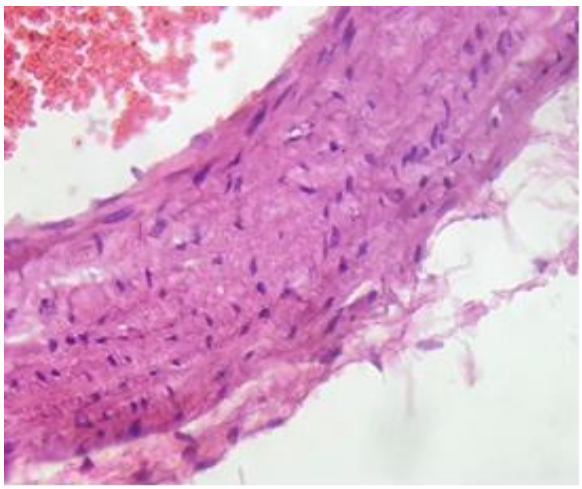

Figure 2 (Control Group): Normal aortic architecture showing intact tunica intima (short arrow), tunica media with smooth muscle bundles and occasional mononuclear cells (medium arrow), and tunica adventitia comprising connective tissue (long arrow). (H&E, x400 magnification)

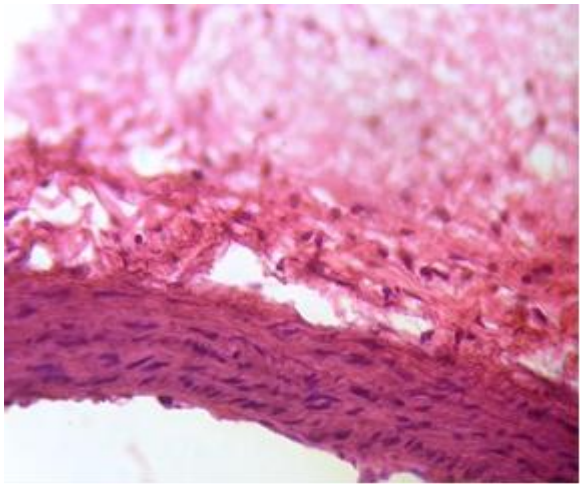

Figure 3 (Group B: Direct Exposure): Aortic section showing evident necrosis of the tunica intima (short arrow), reduced connective tissue in the adventitia and prominent inflammatory cell infiltrates in tunica media with visible mononuclear (long arrow). (H&E, x400 magnification)

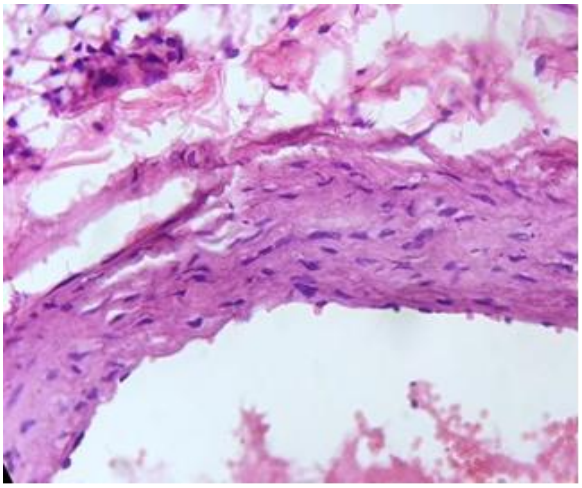

Figure 4 (Group C: Indirect Exposure): Aortic section showing necrosis (short arrow), reduced connective tissue in the adventitia and focal mononuclear inflammatory cell infiltrates (long arrow). (H&E, x400)

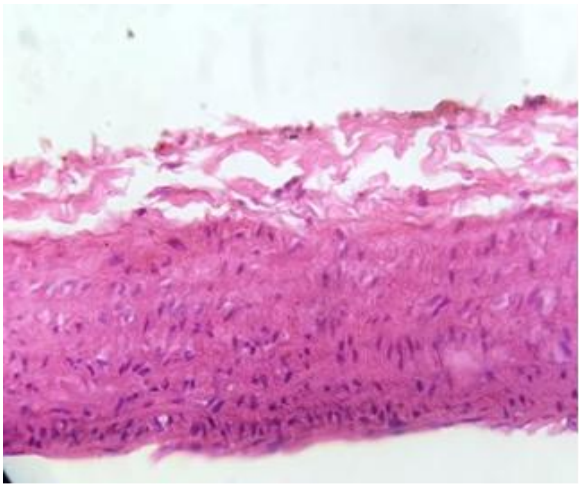

Figure 5 (Group D: Direct Exposure + Vitamin C): Aortic section showing necrosis (short arrow), but the presence of inflammatory infiltrates in the media appears reduced compared to Groups B and C (long arrow), (H&E, x400)

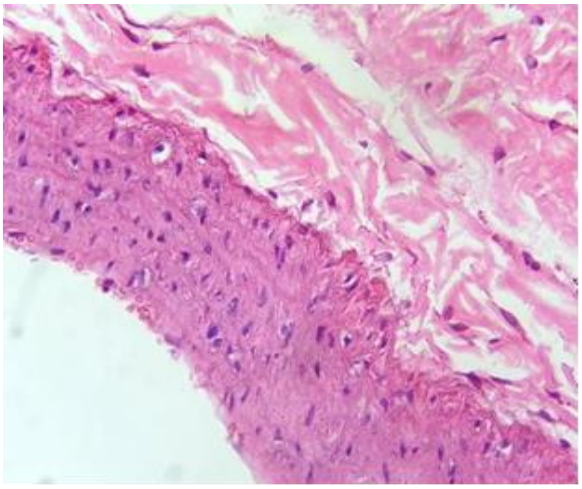

Figure 6 (Group E: Direct Exposure + Exercise): Aortic section showing intact tunica intima (short arrow), tunica media with minimal inflammatory infiltrates (medium arrow), and adventitia with connective tissue (long arrow). No necrosis observed. (H&E, x400)

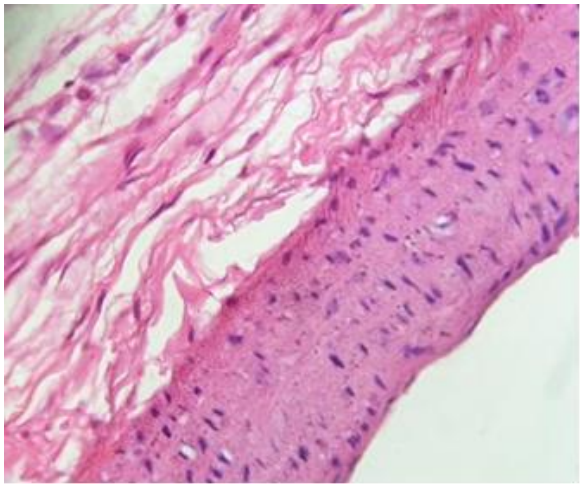

Figure 7 (Group F: Vitamin C + Exercise): Aortic section showing normal architecture with intact tunica intima (short arrow), tunica media (medium arrow), and adventitia (long arrow). No pathological changes observed. (H&E, x400)

Summary of Histopathological Findings:

Group	Necrosis	Inflammatory infiltrates	Connective Tissue Changes
A (Control)	Absent	Minimal (physiological)	Normal
B (Direct Exposure)	Present	Marked	Reduced
C (Indirect Exposure)	Present	Marked	Reduced
D (Direct Exposure + Vit C)	Present	Reduced	Slightly reduced
E (Direct Exposure + Exercise)	Absent	Minimal	Normal
F (Vitamin C + Exercise)	Absent	Minimal	Normal

DISCUSSION

Pyrethroid insecticides are among the most widely used pesticides globally, accounting for approximately 25% of the world's insecticide market [22]. Their extensive use in domestic settings for mosquito control has raised concerns about potential adverse health effects in humans, particularly through inhalation exposure [23]. While the neurotoxic effects of pyrethroids are well-documented, their cardiovascular toxicity, particularly on the aortic wall, remains less well characterized.

In the present study, direct and indirect exposure to Raid® (a pyrethroid-based insecticide) resulted in significant histopathological alterations in the aorta, including necrosis of the tunica intima, inflammatory cell infiltration in the tunica media, and reduced connective tissue in the tunica adventitia. These findings are consistent with previous studies demonstrating that pyrethroid insecticides can induce vascular inflammation and extracellular matrix remodeling. Feriani *et al* [15] reported that permethrin treatment aggravated inflammatory responses in both plasma and aortic tissues through the production of pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α), interleukin-2 (IL-2), and interleukin-6 (IL-6). The authors also observed increased mRNA expression of collagen types I and III, indicating dysfunction of the aortic extracellular matrix.

The vascular injury observed in this study may be attributed to multiple mechanisms. Pyrethroid insecticides have been shown to affect cholinergic pathways in the brainstem that mediate pressor responses, leading to increased total peripheral resistance and hypertension [24-26]. Hemodynamic changes, mechanical forces, and immune reactions contribute to endothelial cell injury and subsequent vascular remodeling [26]. Additionally, Tuna *et al* [16] demonstrated

that organophosphate insecticides alter the mechanical properties of the rat aorta, affecting vascular compliance and elasticity. Vascular smooth muscle cells can produce numerous cytokines and chemokines in response to diverse systemic and cellular stresses, including genotoxic stress, endoplasmic reticulum (ER) stress, and hypoxia [27].

The present study demonstrated that exposure to mosquito repellent significantly elevated serum hs-CRP levels in both directly and indirectly exposed rats. CRP is an acute-phase protein synthesized primarily by the liver in response to IL-6 and other pro-inflammatory cytokines [28]. CRP levels increase dramatically within hours of tissue injury, infection, or inflammation, making it a sensitive marker of systemic inflammatory responses [29]. The observed elevation in hs-CRP is consistent with the histological findings of aortic inflammation and necrosis, suggesting that insecticide exposure induces systemic inflammation that is reflected in both circulating biomarkers and tissue pathology.

The synthesis of CRP is regulated at the transcriptional level by IL-6, with synergistic effects from IL-1 and glucocorticoids [30]. As a pattern recognition molecule, CRP binds to specific molecular configurations exposed during cell death or on pathogen surfaces, contributing to the innate immune response [31]. The significant elevation of hs-CRP in the present study indicates that pyrethroid insecticide exposure triggers an acute-phase response, likely secondary to tissue injury and inflammation in the aorta and potentially other organs.

Rats exposed to insecticide and simultaneously supplemented with vitamin C (Group D) showed reduced inflammatory infiltrates and necrosis compared to insecticide-only groups, although some necrosis persisted. This finding is consistent with the well-established role of vitamin C as a potent antioxidant that can scavenge reactive oxygen species (ROS) and modulate inflammatory responses. Block *et al* [17] demonstrated that vitamin C supplementation was associated with reduced CRP levels, supporting a reverse relationship between antioxidant status and systemic inflammation. Vitamin C likely exerts its protective effects by neutralizing free radicals generated during pyrethroid metabolism, thereby attenuating oxidative stress and subsequent inflammatory signaling.

Interestingly, rats in Group E (insecticide + exercise) showed no aortic necrosis and minimal inflammatory infiltrates, with hs-CRP levels comparable to the control group. This finding suggests that daily exercise provides significant protection against insecticide-induced vascular injury. Regular exercise training has been associated with reduced circulating CRP levels, with effects appearing to be driven by decreased basal metabolic rate and percentage of body fat [18]. Exercise may also enhance antioxidant defense mechanisms, improve endothelial function, and reduce sympathetic nervous system activation, thereby counteracting the pressor and inflammatory effects of pyrethroid exposure.

The combination of vitamin C and exercise (Group F) also showed protective effects, with no pathological alterations observed in the aorta and hs-CRP levels similar to controls. However, the experimental design did not include groups receiving vitamin C or exercise alone without insecticide exposure, which would have allowed for the assessment of the independent effects of these interventions. Furthermore, the vitamin C supplement used contained multiple vitamins and minerals in addition to ascorbic acid, making it difficult to attribute the observed effects solely to vitamin C. The presence of other bioactive compounds in the supplement (including B-complex vitamins, minerals, amino acids, and electrolytes) may have contributed to the protective effects.

The observed aortic injury and elevated hs-CRP levels following insecticide exposure are likely mediated through multiple interconnected pathways. Pyrethroid insecticides induce oxidative stress by generating reactive oxygen species (ROS) and depleting endogenous antioxidant systems [5]. Oxidative stress, in turn, activates redox-sensitive transcription factors, including nuclear factor-kappa B (NF-κB), which upregulates pro-inflammatory cytokine expression (TNF-α, IL-6, IL-1β) [15]. These cytokines promote hepatic CRP synthesis and recruit inflammatory cells to the vascular wall, leading to endothelial dysfunction, smooth muscle proliferation, and extracellular matrix remodeling.

It is important to note that while the present study provides evidence of vascular injury and systemic inflammation following insecticide exposure, the absence of direct measurements of oxidative stress biomarkers (e.g., malondialdehyde, superoxide dismutase, and catalase) and pro-inflammatory cytokines limits the ability to definitively establish these mechanistic pathways. The conclusions regarding oxidative stress and inflammation were therefore interpreted as biologically plausible explanations based on existing literature rather than confirmed mechanisms in this study.

Study Limitations

Several limitations of this study are acknowledged. First, the sample size was relatively small (n = 5 per group), which may limit the statistical power to detect small but clinically meaningful differences. Second, the hs-CRP assay method was not fully described in terms of sensitivity, detection limits, and manufacturer details, which should be clarified in future reports. Third, the histopathological evaluation was qualitative rather than quantitative; the use of a semi-quantitative lesion scoring system or histomorphometric analysis would have strengthened the findings. Fourth, no direct measurements of oxidative stress biomarkers (e.g., MDA, SOD, CAT) or pro-inflammatory cytokines (TNF-α, IL-6) were performed, limiting the ability to confirm the proposed mechanistic pathways. Fifth, the experimental design lacked groups receiving vitamin C alone or exercise alone without insecticide exposure, which would have allowed for the assessment of the independent effects of these interventions. Sixth, the exposure concentration of insecticide was not precisely quantified, making it difficult to assess dose-response relationships. Seventh, the vitamin C supplement used was a multi-ingredient product, making it difficult to attribute the observed effects solely to vitamin C. Finally, the study was conducted in a laboratory animal model, and the findings may not directly translate to human exposure scenarios.

Clinical and Public Health Implications

The findings of this study have important implications for public health, particularly in developing countries where indoor insecticide use is widespread for malaria control. The observed vascular injury and systemic inflammation following insecticide exposure suggest that chronic, low-level pyrethroid inhalation may contribute to cardiovascular risk, potentially through inflammatory mechanisms. The protective effects of vitamin C and exercise highlight the potential for lifestyle interventions to mitigate the adverse health effects of environmental toxicant exposure.

However, the limitations of this study must be carefully considered before translating these findings to human populations. The exposure regimen (overnight, 28 days) may not accurately reflect real-world human exposure patterns, which typically involve intermittent, lower-dose exposures over many years. Furthermore, the use of a multi-ingredient vitamin supplement makes it difficult to isolate the specific protective effects of vitamin C. Future studies should employ controlled exposure paradigms, quantitative exposure monitoring, and the use of purified vitamin C to better characterize the protective effects of these interventions.

Future Research Directions

Future studies should address the limitations of the present investigation by: (1) employing larger sample sizes to improve statistical power; (2) incorporating quantitative histomorphometric analysis and semi-quantitative lesion scoring; (3) measuring oxidative

stress biomarkers (MDA, SOD, CAT, GSH) and pro-inflammatory cytokines (TNF-α, IL-6, IL-1β) to confirm mechanistic pathways; (4) including experimental groups receiving vitamin C alone and exercise alone to assess independent effects; (5) performing dose-response studies to characterize the relationship between insecticide concentration and vascular injury; (6) using purified vitamin C to isolate the specific protective effects of ascorbic acid; (7) evaluating longer exposure durations to assess cumulative effects; and (8) investigating potential molecular mechanisms, such as NF-κB activation and inflammatory gene expression.

CONCLUSION

This study demonstrates that exposure to a pyrethroid-based mosquito repellent (Raid®) induces aortic histopathological changes, characterized by necrosis, inflammatory infiltrates, and reduced connective tissue, which are accompanied by significantly elevated serum hs-CRP levels. These findings suggest that pyrethroid insecticide exposure may contribute to vascular injury through inflammatory pathways. Vitamin C supplementation and daily exercise appear to offer protective effects against insecticide-induced vascular damage, potentially through antioxidant and anti-inflammatory mechanisms. However, given the study's limitations, including the small sample size, qualitative histological assessment, absence of oxidative stress and cytokine biomarkers, and the use of a multi-ingredient vitamin supplement, these findings should be interpreted with caution. Further well-controlled studies incorporating quantitative measures of vascular injury, oxidative stress, and inflammation are warranted to confirm these observations and elucidate the underlying mechanisms.

Author Contributions

CDE and AJA was involved in concept, design, literature review and execution of research work; MIO and AJA conceptualized the manuscript; AJA was involved in statistical analysis and in the data acquisition; AO was involved in histopathology and examination of histological findings; BOU was involved in hematological examination. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data that support the findings of this study are available and will be made available upon request.

Use of AI in Drafting of Manuscript

The authors declare that they have not used any generative AI/AI-assisted technologies in the writing of this manuscript.

Conflict of interest

The authors declared no conflict of interest.

Financial Support

None declared.

ORCID ID

Joel A. Adewole: https://orcid.org/0009-0009-3239-3420

Magdalene I. Omigie: https://orcid.org/0009-0009-0390-6776

REFERENCES

1. Achudume AC, Nwoha PU, Ibe JN. Effects of dietary exposure to insecticide Raid® on the survival, growth and inhibition of metabolic processes in Wistar rats. *J Environ Chem Ecotoxicol*. 2010;2(8):120-5.
2. Eddleston M. Patterns and problems of deliberate self-poisoning in the developing world. *J Med*. 2000;93:715-31.
3. Bencsits F. Insect repellent. US Patent 5589181. 1996. https://patents.google.com/patent/US5589181A/en Accessed on May 20, 2026.
4. Okine LKN, Njarkoi AK, Armah GE, Awumbila B, Owusu K, Set-Sofia S, *et al*. Adverse effect of mosquito coil smoke on lung, liver and certain drug metabolizing enzymes in male Wistar albino rats. *Ghana Med J*. 2004;38:1-13.
5. Hénault-Ethier L. Health and environmental impacts of pyrethroid insecticides: What we know, what we don't know and what we should do about it - Executive summary and Scientific Literature Review. 2016. Available at: https://doi.org/10.13140/RG.2.1.2304.8721
6. Narahashi T, Frey JA, Ginsburg KS, Roy ML. Sodium and GABA-activated channels as the targets of pyrethroids and cyclodienes. *Toxicol Lett*. 1992;64-65:429-32.
7. Soderlund DM, Bloomquist JR. Neurotoxic actions of pyrethroid insecticides. *Annu Rev Entomol*. 1989;34:77-96.
8. Vijverberg HPM, van den Bercken J. Action of pyrethroid insecticides on the vertebrate nervous system. *Neuropathol Appl Neurobiol*. 1982;8:421-40.
9. Ansari RA, Kaur M, Ahmad F, Rahman S, Rashid H, Islam F, *et al*. Genotoxic and oxidative stress-inducing effects of deltamethrin in the erythrocytes of a freshwater biomarker fish species, Channa punctata Bloch. *Environ Toxicol*. 2009;24(5):429-36.
10. Gasser TC. Aorta. In: Biomechanics of Living Organisms. *Cham: Springer; 2017*. p. 169-90.
11. Komutrattananont P, Mahakkanukrauh P, Das S. Morphology of the human aorta and age-related changes: anatomical facts. *Anat Cell Biol*. 2019;52:109-114.
12. Ungvari Z, Kaley G, de Cabo R, Sonntag WE, Csiszar A. Mechanisms of vascular aging: new perspectives. *J Gerontol A Biol Sci Med Sci*. 2010;65:1028-41.
13. Tillet WS, Francis T. Serological reactions in pneumonia with a nonprotein somatic fraction of pneumococcus. *J Exp Med*. 1930;52(4):561-71.
14. Black S, Kushner I, Samols D. C-reactive protein. *J Biol Chem*. 2004;279(47):48487-90.
15. Feriani A, Tir M, Hachani R, Allagui MS, Tlili N, Nahdi S, *et al*. Permethrin-induced arterial retention of native and oxidized LDL in rats by promoting inflammation, oxidative stress and affecting LDL receptors and collagen genes. Ecotoxicol Environ Saf. 2021;207:111269.
16. Tuna BG, Ozturk N, Comelekoglu U, Yilmaz BC. Effects of organophosphate insecticides on mechanical properties of rat aorta. *Physiol Res*. 2011;60:39-46.
17. Block G, Jensen CD, Dalvi TB, Norkus EP, Hudes M, Crawford PB, *et al*. Vitamin C treatment reduces elevated C-reactive protein. *Free Radic Biol Med*. 2009;46:70-7.
18. Fedewa MV, Hathaway ED, Ward-Ritacco CL. Effect of exercise training on C-reactive protein: a systematic review and meta-analysis of randomized and non-randomized controlled trials. *Br J Sports Med*. 2017;51(8):670-6.
19. Avwioro G. Histochemical uses of haematoxylin: *a review*. *JPCS*. 2011;1:24-34.
20. Kiernan JA. Histological and Histochemical Methods: Theory and Practice. 4th ed. Bloxham (UK): *Scion Publishing Ltd*; 2008.
21. Baker JR. Experiments on the action of mordants: aluminium-haematein. *Q J Microsc Sci*. 1962;103:493-517.
22. Kakko I, Toimela T, Tähti H. The synaptosomal membrane-bound ATPase as a target for the neurotoxic effects of the pyrethroids permethrin and cypermethrin. *Chemosphere*. 2003;51:475-80.
23. Cardoso EJBN, Vasconcellos RLF, Bini D, Miyauchi MYH, dos Santos CA, Alves PRL, et al. Soil Health: Looking for Suitable Indicators. What Should Be Considered to Assess

the Effects of Use and Management on Soil Health? Scientia Agricola. 2013;70:274-89.
24. Buckley NA, Dawson AH, Whyte IM. Organophosphate poisoning: peripheral vascular resistance- a measure of adequate atropinization. *J Toxicol Clin Toxicol*. 1994;32:61-8.
25. Gordon CJ, Padnos BK. Prolonged elevation in blood pressure in the unrestrained rat exposed to chlorpyrifos. *Toxicology*. 2000;146:1-13.
26. Smith EG, Padnos BK, Gordon CJ. Peripheral versus central muscarinic effects on blood pressure, cardiac contractility, heart rate, and body temperature in the rat monitored by radiotelemetry. *Pharmacol Toxicol*. 2001;89:35-42.
27. Zarins CK, Glagov S. Artery wall pathology in atherosclerosis. In: Rutherford RB, editor. Vascular Surgery. *Philadelphia (PA): WB Saunders*; 1989. p. 203-21.
28. Tellides G, Pober JS. Inflammatory and immune responses in the arterial media. Circ Res. 2015;116:312-22.
29. Sproston NR, Ashworth JJ. Role of C-reactive protein at sites of inflammation and infection. *Front Immunol*. 2018;9:754.
30. Kingsley A, Jones V. Diagnosing wound infection: the use of C-reactive protein. *Wounds UK*. 2008;4(4):32-46.
31. Du Clos TW. Function of C-reactive protein. *Ann Med*. 2000;32(4):274-8.

HOW TO CITE THIS ARTICLE
Adewole JA, Omigie MI, Ekpruke CD Vitamin C attenuates mosquito repellent-induced aortic histopathological changes and elevated high-sensitivity C-reactive protein in Wistar rats. J Phytopharmacol 2026; 15(4):218-224. doi: 10.31254/phyto.2026.15404