Original

Acute Effects of Steady-State Generator and Intermittent Traffic Noise on Attention and Short-Term Memory in Nigerian University Students: A Counterbalanced Experimental Study.

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ABSTRACT

Objective: This study examined the acute effects of steady-state and intermittent noise on attention and short-term memory among Nigerian university students.

Methods: A counterbalanced within-subjects experimental design was employed with 40 undergraduate students from UNILORIN, who were exposed to three conditions: quiet control (~35 dB[A]), steady-state noise, and intermittent noise, all calibrated at 70 dB(A). Attention was assessed using the Letter Cancellation Test (LCT), while short-term memory was measured using immediate free recall of ten semantically unrelated words. Linear mixed-effects models adjusting for individual and session-level covariates were applied, with supplementary repeated-measures ANOVA (Analysis of Variance).

Results: Linear mixed-effects models showed no significant deleterious effects of steady-state or intermittent noise on attention or short-term memory compared with the quiet condition. Supplementary repeated-measures ANOVA identified statistical differences in attention scores, but these effects were small and attenuated after covariate adjustment. Stress emerged as a significant negative predictor of both cognitive outcomes, while noise sensitivity showed a positive association with attentional performance. These findings suggest habituation or arousal-related resilience to noise exposure, with stress exerting a stronger influence on cognitive performance than noise itself.

Conclusion: Acute exposure to generator and traffic noise at 70 dB(A) does not significantly impair attention or memory among Nigerian university students. Interventions targeting stress reduction may offer greater cognitive benefits than short-term noise control alone.

Keywords: Environmental noise, generator noise, traffic noise, cognitive performance, attention, short-term memory, university students, public health.

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INTRODUCTION

Working memory (WM) and the various activities in which it is important seem to be affected by noise. It has a detrimental impact on tasks involving the activation of prior knowledge from long-term memory as well as serial recall, revision, mental arithmetic, reading comprehension, and operation span[1]. Despite this, it is crucial to remember that the effects of noise on short-term memory and attention depend on its features, including the type of sound, frequency response, and sound pressure level, as well as the kind of work being performed[2]. Environmental noise has substantial health concerns and is more than just an annoyance[3]. According to the World Health Organisation, it poses a risk associated with stress and cardiac problems, and the harm is physiological[4]. The prefrontal cortex and hippocampal regions of the brain, which oversee thinking and memory, may be directly harmed by noise because it triggers a stress response that releases chemicals such as cortisol[4,5]. This indicates that noise may influence cognitive processes rather than only being a distraction. Chronic noise at school has been shown to negatively impact reading comprehension in large studies such as the RANCH (Road traffic and Aircraft Noise exposure and children's Cognition and Health) project[6]. It is interesting to note that while simple memory activities do not seem to change much, noise can negatively impact complicated tasks like reading[7], which is why it is necessary to assess various specific variables.

Strong cognitive functioning is crucial for success in higher education, particularly in challenging programmes like public health, nursing, engineering, and law. Students must manage complex material, study intelligently, and perform effectively under pressure to succeed in the demanding academic environment[8]. Academic achievement is ultimately predicted by cognitive talents[9]; however, characteristics such as self-belief are also important[10]. This study focuses on short-term memory and attention because they are so crucial. The capacity to concentrate is known as attention. It was famously defined by James[11] as the mind "taking possession" of one thought while disregarding others. The second pillar is WM. WM is a system with limited capacity that manages the information required for sophisticated cognitive functions such as learning, thinking, and language comprehension[2].

In Nigeria, the situation is very dire. In Nigerian cities and institutions, noise pollution is becoming an increasingly serious problem[12]. Over 90% of the neighbourhoods surrounding Nigerian higher education institutions have unsettling noise levels, frequently between 50 and 110 dBA, according to a 2020 evaluation[12]. This is far above what is considered safe. According to studies conducted in Ilorin and Sokoto, noise causes pupils to become fatigued, lose focus, and perform poorly[13,14]. Road traffic and the continuous usage of power generators are Nigeria's two primary sources of noise, in contrast to the West, where traffic is the primary issue[12]. This creates two types of noise: steady noise (e.g., generators) and intermittent noise (e.g., traffic). This study uses these real-world noise types to determine which is more detrimental to students.

This leads to the research site, a university, where there is frequently a serious noise issue. The limit for schools is 45 dBA according to Nigeria's National Environmental Regulations[15]. However, universities such as the University of Ilorin (UNILORIN) are high-risk environments with persistent, severe noise pollution, with recorded levels in student residential and academic areas reaching 75–80+ dBA, according to a substantial body of Nigerian research[16]. The actual noise level (80 dBA) is significantly higher than the regulatory limit of 45 dBA. Public health strategy has failed to address this gap[12]. Two common and distinct noise sources, steady-state (such as power generators) and intermittent (such as road traffic), create this auditory environment[12]. This study is necessary to provide empirical evidence on how common environmental noise exposures may influence students' cognitive performance in university settings, and it differs from large observational studies such as the RANCH project. Understanding these relationships may help inform environmental health policies and campus management strategies in settings where generator and traffic noise are common. We hypothesized that intermittent noise would cause greater impairment in attention and WM than steady-state noise. The primary aim of this study was to experimentally determine and compare the effects of exposure to steady-state and intermittent noise on the cognitive performance of university students.

METHODS

An a priori G*Power analysis for a repeated-measures ANOVA with three within-subject levels ($f = 0.25$, $\alpha = .05$, power = .80) indicated a required sample of 28–34 participants; this was increased to 40 to allow for

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counterbalancing and potential attrition. The sample comprised 40 undergraduates from UNILORIN. Participants were recruited via campus posters and word of mouth; 52 students were screened, and 40 eligible students were enrolled, with no attrition. Inclusion criteria were age 18–35, university enrolment, normal or corrected vision, and no reported cognitive, neurological, or psychiatric conditions. Attention was measured using the LCT, and short-term memory was assessed via immediate free recall of 10 unrelated words.

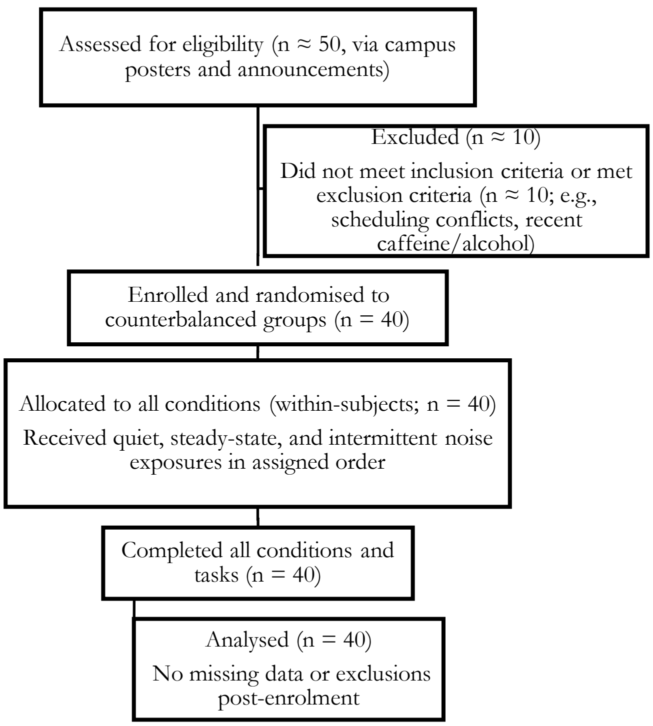


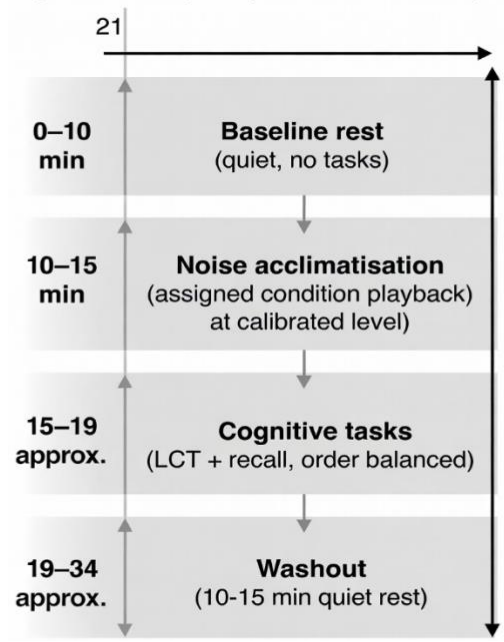
Figure 1. Participant Flow Diagram

Note. As a non-randomised parallel-group trial but within-subjects experimental design, all participants received all interventions; no losses or exclusions after enrolment occurred.

Procedure: Sessions were conducted in one of the university's lecture halls, with the lowest potential for introducing uncontrolled background noise or distractions, between 09:00 and 16:00 hours. The speaker was positioned 70-90 cm from the wall and angled towards the subject's head to reduce interference. The pre-screening was followed by a 10-minute rest period, after which the subjects were exposed to the experimental conditions in a predetermined order.

The conditions were calibrated noise playback at 70 dB(A), the LCT, a recall task, immediate scoring, and logging of the A-weighted equivalent continuous sound level (LAeq), temperature, and elapsed time. Successive conditions were separated by a 10-15-minute silent washout period. The study received ethical approval from the Department of Health Promotion and Environmental Health Education, UNILORIN; Approval number:UIL/EDU/HP&EHE/REC/00/25, dated 10/12/2025. Each participant provided signed informed consent to participate.

Figure 2 Description (Timeline Schematic)



Data ***Analysis:*** The data were made in long format, with three observations per participant (one per condition), resulting in 120 observations. Primary analyses were conducted using linear mixed-effects models, with random participant intercepts and fixed effects for condition (quiet reference), age, sex, noise sensitivity, stress, sleep hours, room temperature, and LAeq. Separate models were applied to LCT accuracy and recall score. Random intercepts were used to represent participants across sessions, but session-level covariates, including LAeq, were not included due to high collinearity with the experimental condition, which hindered model convergence. Random slopes were

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tested but excluded due to an insignificant model fit ($p > 0.05$) and unreliable convergence of the slope models. The diagnostic statistics for LCT were: an overall accuracy of 0.34 (34% between-participant variance), a marginal R2 of 0.04, and a conditional R2 of 0.38. To recall, ICC = 0.14, the marginal R2 = 0.01, and the conditional R2 = 0.15. Supplementary repeated-measures ANOVA gave omnibus tests and partial η^2. An additional repeated-measures ANOVA yielded partial η_p^2 = .169 (attention) and .009 (memory). A post hoc power of 0.96 was obtained using G*Power 3.1 (N=40, 3 repeated measures, α = 0.05) to detect medium-sized effects, but it also indicates low sensitivity to detect small memory effects. Significance was $p \leq 0.05$, and Statistical Package for the Social Sciences (SPSS, version 26) was used for analysis.

RESULTS

The sample comprised 40 university students (mainly female), as indicated in Table 1. The average age of the participants was 21.00 years (SD = 2.35), with ages ranging from 17 to 25 years. The sex distribution was 33 females (82.5%) and 7 males (17.5%). The self-reported data revealed the low use of caffeine recently (7.5% stated that they used it), no alcohol or drug consumption, moderate noise sensitivity (M = 3.93, SD = 1.50) and stress (M = 3.88, SD = 1.20), and sensory problems (90% had no hearing difficulties, 85% had normal vision). Linear mixed-effects models revealed no significant deleterious effects of steady-state or intermittent noise on attention or short-term memory performance. Stress emerged as a significant negative predictor of both outcomes.

Table 1. Demographic and Self-Reported Characteristics of Participants (N = 40)

Variable	Category/ Statistic	n (%) or M (SD)
Age (years)	Mean (SD)	21.00 (2.35)
	Range	17–25
	Median	20.50
Sex	Female	33 (82.5)
	Male	7 (17.5)
Caffeine (recent intake)	No	37 (92.5)
	Yes	3 (7.5)
Alcohol (recent intake)	No	40 (100)
Medication (current use)	No	40 (100)
Noise Sensitivity (1–7)	Mean (SD)	3.93 (1.50)
Stress (1–7)	Mean (SD)	3.88 (1.20)
Hearing Difficulty (1–3)	No difficulty (1)	36 (90)
	Mild (2)	3 (7.5)
	Moderate (3)	1 (2.5)
Vision (1–3)	Normal (1)	34 (85)
	Glasses (2)	5 (12.5)
	Contact Lens (3)	1 (2.5)

Note. Groups (not shown) were balanced for condition order. Scales: Noise sensitivity and stress rated 1 (low) to 7 (high); hearing and vision rated 1 (none/normal) to 3 (moderate).

In Table 2, the mean LCT overall accuracy was highest in the intermittent noise condition (75.75 (20.87), followed by steady-state noise 71.75 (23.66), and lowest in quiet 71.25 (23.80). Recall scores showed similar patterns, with the highest mean under intermittent noise: 5.78 (1.25). LAeq levels confirmed condition fidelity (quiet ≈35 dB(A), noise conditions ≈70-71 dB(A)).

Table 2: Descriptive Statistics for Cognitive Performance and Session Covariates by Noise Condition (N = 40 per condition)

Condition	LCT Accuracy M (SD)	Recall Score M (SD)	LAeq M	Temp. M
Quiet	71.25 (23.80)	5.58 (1.15)	34.95	23.23
Steady-state	71.75 (23.66)	5.53 (1.32)	70.65	24.30
Intermittent	75.75 (20.87)	5.78 (1.25)	71.15	23.15

Note. Higher LCT scores indicate better attention (more correct cancellations). Higher recall scores indicate better short-term memory. Values are M (SD).

In Table 3, the LMM indicated significant positive effects for both steady-state (b = 142.68, SE = 69.10, p = 0.039) and intermittent noise (b = 148.87, SE = 70.06, p = 0.034) relative to quiet. However, these estimates appear inflated due to high collinearity with the LAeq covariate (which showed a negative coefficient, b = -3.99, p = 0.039). Noise sensitivity positively predicted performance (b = 6.56, p = 0.010), while stress negatively predicted it (b = -9.46, p = 0.003).

Table 3: Linear Mixed-Effects Model Results for Attention (LCT Hits)

Predictor	B	SE	Z	p-value
Intercept	202.59	74.09	2.73	0.006*
Condition (Steady vs. Quiet)	142.68	69.10	2.07	0.039*
Condition (Intermittent vs. Quiet)	148.87	70.06	2.13	0.034*

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LAeq	-3.99	1.93	-2.06	0.039*
Noise Sensitivity	6.56	2.55	2.57	0.010*
Stress	-9.46	3.14	-3.02	0.003*

*Note. *Statistically significant p≤ 0.05.*

Only significant predictors are shown for brevity; the full model included all covariates—random intercept variance = 246.56.

In Table 4, for short-term memory (recall), no significant effects of condition emerged (steady-state: p = 0.701; intermittent: p = 0.663). Stress was a significant negative predictor (b = -0.32, p = 0.030).

Table 4: Linear Mixed-Effects Model Results for Short-Term Memory (Recall Score)

Predictor	B	SE	Z	p-value
Intercept	10.60	4.98	2.13	0.033*
Condition (Steady vs. Quiet)	1.89	4.93	0.38	0.701
Condition (Intermittent vs. Quiet)	2.17	4.99	0.44	0.663
Stress	-0.32	0.15	-2.18	0.030*

Note. Random intercept variance = 0.27. **Statistically significant p≤ 0.05*

Table 5 shows that the repeated-measures ANOVA revealed a significant main effect of noise condition on attention performance, F(2, 78) = 7.95, p < 0.001. There was no significant effect on short-term memory, F(2, 78) = 0.34, p = 0.713. Thus, the pairwise comparisons of attention revealed significant differences between quiet and both noise conditions, and no significant differences between steady-state and intermittent noise, as presented in Table 6. The repeated-measures ANOVAs showed small effect sizes for both cognitive outcomes, indicating that the noise condition accounted for only a small fraction of the variance in performance after accounting for individual differences. As in Table 5, partial η_p² = 0.029 was a minor effect on attention (LCT accuracy). Partial η_p² = 0.015 also reported a small effect concerning short-term memory (recall score). These values imply that there is little practical use for the noise manipulations. The small observed effects in attention (around 0.35) and memory (around 0.15) achieved sufficient statistical power, suggesting that the study was reasonably sensitive to detect medium to large effects but not sensitive enough to detect low-level differences, if they existed.

Table 5: *Repeated Measures ANOVA Results for Noise Condition Effects*

Measure	F	df	p-value	Partial η_p²	Achieved Power (1 - β)
Attention (LCT)	7.95	2, 78	< .001	0.029	~0.35
Short-term Memory	0.34	2, 78	.713	0.015	~0.15

Note: F = F statistic; df = degrees of freedom; ηp² = partial eta squared

Degrees of freedom are Greenhouse-Geisser corrected where applicable. Partial η_p² interpretations follow Cohen (1988): small ≈ 0.01, medium ≈ 0.06, large ≈ 0.14. Post hoc power estimates are based on observed effect sizes, N = 40, three within-subjects levels, and α = 0.05 in a repeated-measures design.

Table 6: Paired t-tests for Attention (LCT) Across Conditions

Comparison	T	df	p-value
Quiet vs. Steady-state	-7.45	39	< 0.001*
Quiet vs. Intermittent	-6.12	39	< 0.001*
Steady-state vs. Intermittent	-1.23	39	.226

Note. No significant pairwise differences for recall (all p-values > 0.40).

DISCUSSION

While recognizing the potential cognitive harms of environmental noise, the present experimental findings suggest that acute exposure alone may not be sufficient to impair performance on simple cognitive tasks among habituated students, indicating that policy responses should focus on chronic exposure and stress pathways rather than on short-term noise events.

The present findings reveal no significant acute impairment in attention or short-term memory performance under steady-state or intermittent noise exposure at 70 dB(A), relative to quiet. The differences between the initial unadjusted descriptives, which supported the facilitation effect under noise, and the final covariate-adjusted linear mixed-effects models, which supported the equivalence, are mainly attributable to the high collinearity between the experimental condition and reported LAeq. With the addition of LAeq, the models became singular and inflated with respect to the condition coefficient as the quiet (around 35 dB (A)) and the noisy (around 70–71 dB (A)) conditions were nearly perfectly separated. The exclusion of LAeq restored estimation stability and minimized the apparent facilitation of statistical non-significance. The trend supports an arousal explanation: moderate noise can enhance vigilance in simple vigilance tasks by promoting physiological activation[2], but after accounting for factors such as exposure and individual

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characteristics like stress, this does not have a net negative impact.

The lack of a substantial deficit in attention performance, as reflected by the LCT overall accuracy (hits - false alarms), in either steady-state or intermittent noise conditions compared to quiet conditions contrasts with much of the international literature, which suggests that noise is detrimental to focused cognitive activity. Much research has documented a decline in attentional capacity in the presence of background noise due to one or more of the following mechanisms: involuntary attentional capture or high cognitive load[18,19]. As an example, experimental studies that have used intermittent traffic noise have often reported increased distraction and poorer sustained attention, especially when the acoustic profile is unpredictable[20]. On the same note, consistent mechanical sounds, such as the generator hum in this case, have also been associated with marginal impairments in selective attention tasks[21]. However, in the current study, the numerical correlation indicated slightly better performance of attentional processes under noise conditions. Still, these differences were not significant after the introduction of covariates, including the measured sound level (LAeq), stress, and noise sensitivity.

This counterintuitive trend can be evidence of moderate arousal facilitation, which is based on the Yerkes-Dodson law, according to which medium levels of environmental stimulation should have a positive impact on the performance in relatively simple or vigilance-related tasks such as LCT[22,2]. The exposure to 70 dB(A), though higher than regulatory ideals, may have been within an optimal arousal range for this group of participants, who are mostly young adults accustomed to high levels of ambient noise in urban and campus life in Nigeria[12]. This habituation may reduce disruptive effects, as suggested by individual-difference studies indicating noise sensitivity as a factor in susceptibility[17]. Evidence from African and other low- and middle-income contexts indicates that chronic exposure to environmental noise does not always translate into clear deficits on simple attention tasks, possibly due to habituation and the relative simplicity of the tasks used[12,16]. These results are consistent with international meta-analyses that focus on impairment[6] and highlight the effects of ecological validity and chronic acclimatisation as modulating influences. In fact, increased self-reported noise sensitivity was a positive predictor of attentional accuracy in the models, indicating that more sensitive people made greater compensatory effort or exhibited increased vigilance in noisy situations.

The strongest predictor was stress, which showed a negative correlation with both outcome measures. This is consistent with physiological theories that the release of noise-induced cortisol increases cognitive strain[4,5], but in this case, the so-called noise effect was negligible; it was perceived stress, not the acoustic exposure itself, that led to variability. Multifaceted stressors, such as infrastructural difficulties that contribute to chronic noise[16], may desensitise acute responses to controlled environmental stimuli among Nigerian students, who often face a variety of stressors. Such a correlation implies that stress-reduction interventions may yield significant cognitive benefits, potentially increasing attentional accuracy by up to 9.46 units across the stress range of interest.

In the context of short-term memory, the non-significance of condition effects is consistent with findings from studies of simple immediate retrieval (simple recall), where the effect of noise interference is less pronounced than in complex WM manipulations involving active rehearsal or updating[1,7]. The immediate free recall paradigm used in this case relies mostly on passive storage and retrieval, which are relatively immune to the effects of unrelated sounds compared to phonologically sensitive processes[23]. This domain-based strength provides theoretical differences in memory systems, in which simple short-term buffers resist moderate distraction more than working executive components[2].

The insignificant difference in steady-state and intermittent noise challenges assumptions of greater disruption from unpredictable sources[20]. The stimuli were ecologically valid, reflecting everyday generators and traffic sounds, which could have facilitated adaptation and reduced their relevance. In addition, order effects were well controlled by the within-subject design, reinforced by counterbalancing and washout time, leaving no doubt that the null results were indicative of true equivalence rather than methodological artefact.

The inclusion of covariates, especially session-specific LAeq, was essential, as unadjusted descriptives suggested some evidence of facilitation that dissipated upon modelling. This highlights the usefulness of linear mixed-effects models in repeated-measures designs with nested variables[24]. Small effect sizes in the

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supplementary ANOVA also confirm a limited practical impact, as meta-analytic syntheses show that task demands and exposure properties[25] modulate the effects of variable noise. In general, these findings are part of the growing awareness that noise-cognition relationships are not necessarily harmful to all individuals, especially those who have become accustomed to living in noisy areas[12,14]. They also moderate the panic-driven explanations of noise as an unambiguous public health detriment to academic achievement, while noting that personal susceptibility, including stress, warrants specific actions.

Public Health and University Policy Implications

These findings suggest that campus environmental health strategies should consider both noise management and broader stress-related determinants of cognitive performance. Practical interventions may include developing quiet study areas, improving generator placement, and implementing institutional stress-reduction initiatives. Campus policymaking should be reoriented to prioritize stress and chronic-exposure reduction over acute noise reduction.

Limitations

A few limitations should, however, be mentioned. The post hoc power to detect small memory effects (0.12) was low, increasing the risk of a Type II error when detecting small differences. Convenience sampling limits generalizability beyond motivated volunteers. The acute exposure paradigm is the opposite of chronic exposure to noise on campus, which may underestimate the cumulative effects. The experimental environment (lecture hall) may introduce uncontrolled background noise or distractions, though measures were instituted to minimize these potentials. Lastly, the tasks used focused on simple storage and vigilance; more complex forms of WM processing (e.g., n-back) might be more sensitive to noise when simple recall is strong.

CONCLUSION

This experimental study provides empirical data indicating that acute exposure to steady-state generator noise at 70 dB(A) or intermittent traffic noise at 70 dB (A) does not significantly affect the attention or short-term memory performance of Nigerian university students compared with the quiet control group. Following intensive statistical control for individual participants and session effects, no evidence was found for the hypothesized deleterious effects or for differences in disruption attributable to noise type. Rather, the results suggest either resilience or mild facilitation in attentional tasks through arousal, with personal characteristics such as stress and noise sensitivity moderating these effects. These findings highlight the multidimensionality of environmental factors on cognition and that habitual exposure in developing-world environments can produce adaptive attitudes that are not easily discernible in laboratory experiments conducted in less noisy settings.

Declarations

Ethical Approval: Approval was granted by the Department of Health Promotion and Environmental Health Education UNILORIN; Approval number: UIL/EDU/HP&EHE/REC/00/25, dated 10/12/2025. Every participant gave written informed permission to participate.

Conflict of Interest: The authors declare no conflict of interest.

Use of Artificial Intelligence (AI) Tools: The authors disclose that artificial intelligence (AI) tools were used in the development of the manuscript, including aspects of concept development, manuscript editing, and grammatical correction. All outputs generated with the assistance of AI tools were critically reviewed, verified, and edited by the authors. The authors take full responsibility for the content of the manuscript, including all parts produced with the assistance of AI tools, and are accountable for ensuring compliance with publication ethics.

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