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Knowledge and Attitudes of Healthcare Workers Toward the Integration of Environmental Epigenetics into Clinical Practice in Ilorin Metropolis, Kwara State, Nigeria: A Cross-Sectional Study

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ABSTRACT

Environmental epigenetics heritable, potentially reversible changes in gene expression caused by environmental exposures such as pollution, diet, chemicals, and stress, without alteration of the underlying DNA sequence is increasingly recognised as a mechanism linking environmental exposures to disease risk. Healthcare workers are central to translating this evidence into preventive counselling and patient care, yet their readiness to do so, particularly in low-resource settings, is poorly documented. A descriptive cross-sectional study was conducted among healthcare workers in public health facilities across the three Local Government Areas of Ilorin Metropolis, Kwara State, Nigeria, using a multistage sampling technique. Data were collected with a structured, self-administered questionnaire covering socio-demographic characteristics, knowledge, attitudes, perceived barriers, and willingness to train. Of 275 questionnaires distributed, 250 were valid for analysis (90.9% response rate). Data were analysed descriptively and inferentially (chi-square test, Pearson correlation, point-biserial correlation) at $p < 0.05$. Most respondents (69.2%) demonstrated adequate knowledge of environmental epigenetics, while an overwhelming majority (98.4%) held a positive attitude toward its integration into clinical practice. Knowledge was significantly associated with educational qualification ($\chi^2 = 13.856$, $p = 0.001$) and professional cadre ($\chi^2 = 20.225$, $p = 0.003$), and was strongly correlated with attitude ($r = 0.672$, $p < 0.001$). Higher knowledge and more favourable attitude were significantly associated with fewer perceived barriers ($r = -0.318$, $p = 0.002$; $r = -0.285$, $p = 0.004$) and with greater willingness to receive training ($\chi^2 = 8.419$, $p = 0.015$; $r = 0.341$, $p = 0.001$). Only 33.2% had previously received related training, yet 85.2% expressed willingness to attend future training. Healthcare workers in Ilorin Metropolis hold favourable attitudes toward environmental epigenetics that considerably outpace their technical knowledge of the field, and the principal constraints on fuller integration into practice appear to be gaps in training, clinical guidance, and institutional support rather than unwillingness. Structured, cadre-specific training and facility-level clinical guidance are recommended.

KEYWORDS: Environmental epigenetics, healthcare workers, knowledge and attitude, clinical practice, Nigeria, cross-sectional study.

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1. Introduction

Environmental epigenetics examines changes in gene regulation that occur without alteration of the underlying DNA sequence and can be influenced by environmental and lifestyle exposures. Major epigenetic mechanisms include DNA methylation, histone modifications, and non-coding RNA regulation. These mechanisms provide important pathways through which environmental factors can influence biological processes and disease susceptibility across the life course (Baccarelli & Bollati, 2009; Feil & Fraga, 2012). Because some epigenetic changes are potentially reversible, environmental epigenetics has attracted considerable interest in disease prevention and public health, particularly in understanding how modifiable environmental exposures may influence health outcomes (Hou *et al.,* 2012; Feil & Fraga, 2012).

Evidence increasingly demonstrates associations between environmental exposures and epigenetic alterations relevant to human health. Air pollution, including particulate matter and other combustion-related pollutants, has been associated with changes in DNA methylation and other epigenetic processes that may contribute to inflammatory, cardiovascular, respiratory, and cancer-related outcomes (Baccarelli & Bollati, 2009; del Real *et al*., 2021). Environmental chemicals and occupational exposures, including heavy metals, pesticides, and other toxicants, have likewise been investigated for their effects on epigenetic regulation and subsequent biological responses (Baccarelli & Bollati, 2009; Hou *et al*., 2012). Nutritional factors can also influence epigenetic regulation because nutrients involved in one-carbon metabolism contribute to the biochemical processes required for DNA methylation and related regulatory mechanisms (Feil & Fraga, 2012). These findings highlight the importance of considering environmental and lifestyle exposures as potential contributors to biological changes associated with disease susceptibility.

The relevance of environmental epigenetics extends across the life course. Environmental influences during critical periods of development may affect biological programming and contribute to susceptibility to non-communicable diseases later in life (Barouki *et al*., 2012). This life-course perspective is particularly important for public health because environmental exposures are potentially modifiable and may represent opportunities for prevention before disease becomes clinically established. Research on environmental epigenetics therefore provides an important basis for understanding how environmental conditions, individual behaviours, and biological responses may interact to influence health outcomes (Baccarelli & Bollati, 2009; Feil & Fraga, 2012).

Healthcare workers are well positioned to translate environmental health evidence into preventive practice through patient education, risk communication, counselling, and promotion of healthier behaviours. In the context of environmental epigenetics, healthcare workers may contribute to discussions about smoking, nutrition, occupational exposures, and pollution-related risks. However, applying emerging biomedical knowledge in routine practice requires adequate professional education, appropriate guidance, and opportunities for continuing learning. The extent to which healthcare workers understand environmental epigenetics and feel prepared to apply its principles in patient care is therefore an important area for investigation.

In Nigeria, this issue is particularly relevant because healthcare workers operate within a setting where environmental exposures, occupational risks, urbanisation, and other social and environmental conditions may influence population health. Understanding how healthcare workers perceive and understand the relationship between environmental exposures and biological processes could help identify areas where additional education and professional development are required. Such knowledge may also support the development of appropriate health education and preventive counselling strategies within healthcare settings.

Despite the growing scientific literature on environmental epigenetics, empirical evidence concerning healthcare workers' knowledge of the subject remains limited. Much of the existing literature focuses on molecular mechanisms, environmental exposures, and associations between epigenetic alterations and disease outcomes rather than on healthcare workers' preparedness to understand and apply this knowledge in practice (Baccarelli & Bollati, 2009; Feil & Fraga, 2012). Evidence concerning healthcare workers' attitudes towards incorporating environmental epigenetics into routine practice, as well as the barriers and facilitators that may influence such integration, is also limited. This gap is particularly important in low- and middle-income settings, where healthcare training structures, available resources, and environmental health priorities may differ from those in high-income countries.

Addressing this evidence gap could provide useful information for designing context-specific educational interventions for healthcare workers. Assessing their knowledge, attitudes, perceived barriers, and willingness to receive further training may help identify opportunities for strengthening environmental health education and improving the translation of environmental epigenetic knowledge into preventive healthcare practice. Therefore, this study assessed the knowledge and attitudes of healthcare workers regarding environmental epigenetics, examined perceived barriers to its integration into practice, and evaluated their willingness to receive training on the subject.

This study was guided by the Knowledge, Attitude, and Practice (KAP) Model, which conceptualizes knowledge as an antecedent of attitude, which in turn shapes practice behavior. The study assessed the knowledge and attitudes of healthcare workers toward the integration of environmental epigenetics into clinical practice in Ilorin Metropolis, Kwara State, Nigeria. The specific objectives were to: (i) assess healthcare workers' level of knowledge of environmental epigenetics and its relevance to public health; (ii) evaluate their attitudes toward integrating environmental epigenetics into routine clinical and preventive care; (iii) identify socio-demographic and professional characteristics associated with knowledge and attitudes; (iv) identify perceived barriers to integration; and (v) determine healthcare workers' willingness to receive training and retraining in environmental epigenetics.

2. Methodology

2.1 Study Design and Setting

This was a descriptive cross-sectional study conducted among healthcare workers in Ilorin Metropolis, Kwara State, north-central Nigeria. Ilorin Metropolis comprises three Local Government Areas (LGAs) Ilorin West, Ilorin East, and Ilorin South predominantly urban areas characterised by a growing population, expanding healthcare infrastructure, and increasing environmental exposures associated with urbanization, including traffic-related air pollution, waste disposal challenges, and occupational hazards. Across the three LGAs, an estimated 540 healthcare workers were employed in 35 Basic Health Care Provision Fund (BHCPF)-supported primary health centers at the time of the study.

2.2 Study Population, Inclusion and Exclusion Criteria

The study population comprised healthcare workers employed in public (government-owned) health facilities in Ilorin Metropolis, including medical doctors, nurses and midwives, pharmacists, medical laboratory scientists, community health officers and extension workers, health educators, and other allied health professionals. Eligible participants were healthcare workers currently practising in Ilorin Metropolis who had worked in their facility for at least six months and who provided informed consent. Healthcare workers on leave during data collection, and interns or students on short-term clinical postings, were excluded.

2.3 Sample Size and Sampling Technique

The minimum sample size was initially estimated using Cochran's (1977) formula for descriptive cross-sectional studies, (n = Z^2pq/d^2), with Z = 1.96 (95% confidence level), p = 0.5 (assumed prevalence, in the absence of prior local data), q = 0.5, and d = 0.05 margin of error, yielding a calculated minimum sample size of 384. However, due to financial and logistical constraints associated with the conduct of the study, the achievable sample size was reduced to 250 respondents. To account for possible non-response, 275 questionnaires were distributed among eligible healthcare workers across the selected facilities. Of these, 250 questionnaires were retrieved, fully completed, and considered valid for analysis, giving a response rate of 90.9%. The final sample of 250 respondents was therefore used for the analysi

A multistage sampling technique was used. In Stage One, all three LGAs constituting Ilorin Metropolis were included through total population sampling to ensure broad geographic coverage. In Stage Two, wards were selected from each LGA, and in Stage Three, four health facilities were selected from the selected wards in each LGA (Adewole, Pakata, Alanamu, and Oloje Primary Health Centres [PHCs] in Ilorin West; Magaji Are, Okesuna, Okelele, and Ojagboro PHCs in Ilorin East; and Eroomo, Tanke, Kulende, and Olufadi PHCs in Ilorin South). In Stage Four, the final sample of 250 respondents was proportionally allocated to each selected facility according to its number of healthcare workers, using (n_h = (N_h/N) \times n), where (n_h) is the sample allocated to a facility, (N_h) is the number of healthcare workers in that facility, (N) is the total number of healthcare workers across all selected facilities, and (n) is the total achieved sample size (250). In Stage Five, eligible healthcare workers within each selected facility were selected by simple random sampling (balloting, where staff registers were available) or systematic sampling where complete staff lists were unavailable.

2.4 Data Collection Instrument, Validity, and Reliability

Data were collected using a structured, self-administered questionnaire developed following a review of relevant literature. The instrument comprised five sections: (A) socio-demographic and professional characteristics; (B) knowledge of environmental epigenetics; (C) attitudes toward integrating environmental epigenetics into clinical practice; (D) perceived barriers and facilitators to integration; and (E) willingness to receive training and retraining. The questionnaire was written in simple English to enhance clarity and reduce response error. Content and face validity were established through review by experts in public health, environmental health, and research methodology (Taherdoost, 2016). Internal consistency of the knowledge and attitude sections was assessed through a pilot study among healthcare workers in a neighbouring LGA not included in the main study, using Cronbach's alpha, with a value of ≥ 0.70 considered acceptable (Hair *et al.,* 2019).

2.5 Data Collection Procedure

Following ethical approval and permission from relevant health authorities, questionnaires were administered to eligible healthcare workers during working hours after the purpose of the study was explained and informed consent obtained. Participants were given adequate time to complete the questionnaire, which was collected on the same day or at an agreed time.

2.6 Variables and Statistical Analysis

Data were coded, entered, and analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise the socio-demographic characteristics of respondents and the study variables. A composite knowledge score ranging from 0 to 5 was calculated by summing the scores obtained from five core knowledge items. Each correct response was assigned a score of 1, while each incorrect or "don't know" response was assigned a score of 0. Knowledge was subsequently dichotomised as adequate (score ≥3) or inadequate (score <3). A composite attitude score was calculated as the mean of six five-point Likert-scale items. The attitude score was categorised as positive (mean ≥3.50), neutral (mean 2.50–3.49), or negative (mean <2.50). A composite barrier score was similarly calculated as the mean of six Likert-scale items, with higher scores indicating

greater perceived barriers.

Before inferential analyses were performed, the data were assessed for the assumptions relevant to the statistical tests used. The distributions of continuous/composite variables were examined for approximate normality, and the relationships assessed using Pearson's correlation were evaluated for linearity. The categorical variables used in chi-square analyses were checked to ensure that the data were in frequency/count form and that the expected cell frequencies were adequate for the test. Where applicable, the independence of observations was also considered (Field, 2018).

The chi-square test of association was used to examine associations between categorical variables, including associations involving the categorised knowledge and attitude variables and relevant socio-demographic or other categorical variables. Pearson's product-moment correlation was used to assess the strength and direction of linear relationships between continuous composite scores, including knowledge, attitude, and barrier scores where applicable. Point-biserial correlation was used to examine the relationship between a continuous composite score and a dichotomous variable where appropriate. These tests were selected according to the measurement level and distribution of the variables being analysed (Field, 2018). All statistical tests were two-tailed, and statistical significance was set at $p < 0.05$.

2.7 Ethical Considerations

Ethical approval: Ethical approval was obtained from the Ministry of Health Ethical Research Committee, Kwara State Government (ERC/MOH/2026/07/792), dated 15 July 2026.

Confidentiality and anonymity were maintained by excluding personal identifiers from the questionnaire, and collected data were used strictly for research purposes.

3. Results

3.1 Response Rate

Of the 275 questionnaires distributed across the sampled health facilities, 250 were retrieved, fully completed, and valid for analysis, giving a response rate of 90.9% (Table 1). All subsequent analyses are based on these 250 valid responses.

Table 1. Questionnaire Response Rate

Status	Frequency (n)	Percentage (%)
Questionnaires distributed	275	100.0
Retrieved and valid for analysis	250	90.9
Not retrieved / invalid / incomplete	25	9.1

Source: Field Survey, 2026

3.2 Socio-Demographic Characteristics

With regard to age, the largest proportion of respondents (40.8%) were below 25 years, followed by those aged 25–34 years (22.4%); respondents aged 55 years and above formed the smallest proportion (8.8%). Female healthcare workers (66.4%) considerably outnumbered males (33.6%). By professional cadre, Nurses/Midwives (36.8%) and Community Health Officers/Extension Workers (34.8%) together accounted for more than seven in ten respondents, while Medical Doctors (4.0%) and other allied cadres formed smaller proportions. Frequencies (n) for age, sex, and cadre distributions were not stated in the source data; the figures above are the percentages reported.

Table 2 presents marital status, highest educational qualification, and years of professional practice, for which both frequencies and percentages were reported.

Table 2. Marital Status, Educational Qualification, and Years of Practice (n = 250)

Variable	Frequency (n)	Percentage (%)
Age group (years		
<25	102	40.8
25–34	56	22.4
35–44	40	16.0
45–54	30	12.0
≥55	22	8.8
Sex		
Female	166	66.4
Male	84	33.6
Professional cadre		
Nurses/Midwives	92	36.8
Community Health Officers/Extension Workers	87	34.8
Medical Doctors	10	4.0
Other allied cadres	61	24.4
Marital status		
Single	133	53.2
Married	117	46.8
Highest educational qualification		
Diploma	146	58.4
Bachelor's Degree	78	31.2
Master's Degree	26	10.4
Years of professional practice		

<5 years	136	54.4
5–9 years	54	21.6
10–14 years	30	12.0
≥15 years	30	12.0

Source: *Field Survey, 2026*

3.3 Knowledge of Environmental Epigenetics

Slightly less than two-thirds of respondents (64.4%) had previously heard of the term "epigenetics," while 35.6% had not. Table 3 shows that 55.2% of respondents correctly identified environmental epigenetics as changes in gene expression caused by environmental factors without altering the underlying DNA sequence, while 24.0% equated it with disease prevention and health promotion in general, 9.6% associated it with improving patient counselling and preventive care, and 11.2% did not know.

Table 3. Conceptual Understanding and Perceived Relevance of Environmental Epigenetics

Item	Response	n	%
Environmental epigenetics refers to…	Changes in gene expression from environmental factors, no DNA sequence change (correct)	138	55.2
	Disease prevention and health promotion generally	60	24.0
	Improving patient counselling and preventive care	24	9.6
	Don't know	28	11.2
Epigenetic changes are potentially reversible	Yes	134	53.6
	No	41	16.4
	Don't know	75	30.0
Relevant to disease prevention and health promotion	Yes	197	78.8
	No	20	8.0
	Don't know	33	13.2
Can improve patient counselling and preventive care	Yes	192	76.8
	No	18	7.2
	Don't know	40	16.0

Source: Field Survey, 2026

Respondents could select more than one environmental determinant of gene expression from a list of options; percentages are computed on a base of 250 and do not sum to 100% (Table 4). Pollution (36.8%) and smoking (32.8%) were the most frequently identified determinants, while heavy metals (12.8%) and pesticides (9.6%) were the least frequently identified.

Table 4. Perceived Environmental Factors Influencing Gene Expression (multiple response, n = 250)

Environmental Factor	Frequency (n)	Percentage (%)
Pollution	92	36.8
Smoking	82	32.8
Occupational hazards	42	16.8
Diet	50	20.0
Stress	50	0.0
Heavy metals	32	12.8
Pesticides	24	9.6
Don't know	26	10.4

Source: Field Survey, 2026

Regarding perceived disease risk (multiple response, Table 5), cancer was most frequently linked to epigenetic changes (32.8%), followed by cardiovascular disease (29.6%) and asthma (28.0%); 19.2% did not know which diseases could be linked to epigenetic changes.

Table 5. Perceived Disease Risks Associated with Epigenetic Changes (multiple response, n = 250)

Disease/Condition	Frequency (n)	Percentage (%)
Cancer	82	32.8
Cardiovascular diseases	74	29.6
Asthma	70	28.0
Diabetes	56	22.4
Don't know	48	19.2

Source: Field Survey, 2026

A composite knowledge score (0–5) was derived from five core knowledge items. As shown in Table 6, most respondents (69.2%) were classified as having adequate knowledge (score ≥ 3), while 30.8% had inadequate knowledge.

Table 6. Overall Level of Knowledge of Environmental Epigenetics

Knowledge Category	Frequency (n)	Percentage (%)
Adequate knowledge (score ≥ 3)	173	69.2
Inadequate knowledge (score < 3)	77	30.8
Total	250	100.0

Source: Field Survey, 2026

3.4 Attitude Toward Integration of Environmental Epigenetics

Attitude was assessed on a five-point Likert scale (Strongly Agree = 5 to Strongly Disagree = 1); mean scores ≥ 3.50 indicated a favourable attitude. As shown in Table 7, every item recorded a mean score above 4.00; "Healthcare workers should be trained on environmental epigenetics" recorded the highest mean (4.35), and "Integrating environmental epigenetics into practice will improve patient outcomes" recorded the lowest, though still strongly favourable, mean (4.18).

Table 7. Attitude of Healthcare Workers Toward Integration of Environmental Epigenetics (n = 250)

Statement	SA n(%)	A n(%)	U n(%)	D n(%)	SD n(%)	Mean	SD
Relevant to my professional practice	106 (42.4)	125 (50.0)	14 (5.6)	5 (2.0)	0 (0.0)	4.33	0.67
HCWs should be trained on env. Epigenetics	102 (40.8)	137 (54.8)	9 (3.6)	0 (0.0)	2 (0.8)	4.35	0.63
Can improve disease prevention strategies	118 (47.2)	110 (44.0)	14 (5.6)	4 (1.6)	4 (1.6)	4.34	0.79
Will improve patient outcomes	92 (36.8)	118 (47.2)	34 (13.6)	6 (2.4)	0 (0.0)	4.18	0.75
Should be in healthcare training curricula	90 (36.0)	131 (52.4)	27 (10.8)	2 (0.8)	0 (0.0)	4.24	0.67
Willing to apply it in patient care, if trained	86 (34.4)	141 (56.4)	21 (8.4)	2 (0.8)	0 (0.0)	4.24	0.63

Source: Field Survey, 2026

A composite attitude score, categorised as Positive (≥ 3.50), Neutral (2.50–3.49), or Negative (< 2.50), showed that 98.4% of respondents held a positive attitude, 1.6% were neutral, and none were negative (Table 8).

Table 8. Overall Level of Attitude Toward Environmental Epigenetics

Attitude Category	Frequency (n)	Percentage (%)
Positive (mean ≥ 3.50)	246	98.4
Neutral (mean 2.50–3.49)	4	1.6
Negative (mean < 2.50)	0	0.0
Total	250	100.0

Source: Field Survey, 2026

3.5 Perceived Barriers and Facilitators to Integration

Perceived barriers and facilitators were assessed using the same five-point scale (Table 9). "Continuous professional education would enhance my use of environmental epigenetics" recorded the highest mean (4.32), followed by "availability of clinical guidelines" (4.29) and "institutional support" (4.13); "lack of training limits my ability to apply environmental epigenetics" also scored highly (4.04). "Environmental epigenetics is too complex to apply in routine clinical practice" recorded the lowest mean (3.02), with "Disagree" the most frequent single response (36.0%), indicating that perceived intellectual complexity was the least endorsed barrier.

Table 9. Perceived Barriers and Facilitators to Integration of Environmental Epigenetics (n = 250)

Statement	SA n(%)	A n(%)	U n(%)	D n(%)	SD n(%)	Mean	SD
Lack of training limits my ability to apply it	86 (34.4)	116 (46.4)	21 (8.4)	27 (10.8)	0 (0.0)	4.04	0.93
Too complex to apply in routine practice	35 (14.0)	60 (24.0)	48 (19.2)	90 (36.0)	17 (6.8)	3.02	1.20
Time constraints prevent incorporation	84 (33.6)	88 (35.2)	39 (15.6)	39 (15.6)	0 (0.0)	3.87	1.05
Clinical guidelines would encourage integration	96 (38.4)	133 (53.2)	19 (7.6)	2 (0.8)	0 (0.0)	4.29	0.64
Institutional support would improve application	84 (33.6)	121 (48.4)	39 (15.6)	6 (2.4)	0 (0.0)	4.13	0.76
Continuous professional education would enhance use	106 (42.4)	121 (48.4)	19 (7.6)	4 (1.6)	0 (0.0)	4.32	0.68

Source: Field Survey, 2026

3.6 Willingness to Receive Training

Only 33.2% of respondents had previously attended training, seminars, or conferences related to environmental epigenetics; among these, the training was rated Very Useful (63.9%) or Useful (24.1%), with none rating it Not Useful. Among the 167 respondents (66.8%) who had not attended training, the most cited reason was lack of awareness of such training (57.5%), followed by lack of opportunity (25.1%) and lack of time (12.0%). Despite limited prior exposure, 85.2% of respondents expressed willingness to attend future training, 3.6% were unwilling, and 11.2% were unsure; workshops/seminars (39.2%) and online courses/webinars (28.0%) were the most preferred formats (Table 10).

Table 10. Training History and Willingness to Attend Future Training

Item	Response	n	%
Previously attended related training (n=250)	Yes	83	33.2
	No	167	66.8
Usefulness of training (n=83)	Very useful	53	63.9
	Useful	20	24.1
	Neutral	8	9.6
	Not applicable	2	2.4
Reason for non-attendance (n=167)	Lack of awareness of training	96	57.5
	Lack of opportunity	42	25.1
	Lack of time	20	12.0
	Lack of institutional support	12	7.2
	Not relevant to profession	6	3.6
	Not interested	2	1.2
Willing to attend future training (n=250)	Yes	213	85.2
	No	9	3.6
	Not sure	28	11.2

Source: Field Survey, 2026

Relevance to professional practice (51.2%) and availability of funding/sponsorship (45.6%) were the factors most frequently cited as likely to encourage participation in future training (Table 11).

Table 11. Factors That Would Encourage Participation in Future Training (n = 250)

Factor	Frequency (n)	Percentage (%)
Relevance to professional practice	128	51.2
Availability of funding/sponsorship	114	45.6
Certification/recognition	80	32.0
Institutional support	44	17.6
Flexible schedule	32	12.8

Source: Field Survey, 2026

3.7 Tests of Association

Educational qualification ($\chi^2 = 13.856$, df = 2, $p = 0.001$) and professional cadre ($\chi^2 = 20.225$, df = 6, $p = 0.003$) were significantly associated with knowledge category; age, sex, marital status, and years of practice were not (Table 12).

Table 12. Chi-Square Test of Association Between Socio-Demographic Characteristics and Knowledge

Socio-Demographic Variable	χ^2	df	p-value	Decision
Age	2.977	4	0.562	Not significant
Sex	1.608	1	0.205	Not significant
Marital status	3.150	1	0.076	Not significant
Educational qualification	13.856	2	0.001	Significant
Professional cadre	20.225	6	0.003	Significant
Years of professional practice	2.269	3	0.519	Not significant

Source: Field Survey, 2026

A strong, positive, and statistically significant correlation was found between composite knowledge score and composite attitude score ($r = 0.672$, $p < 0.001$; Table 13). This same knowledge–attitude correlation was reported for both Hypothesis Two and Hypothesis Three in the original analysis; this apparent duplication is noted here rather than resolved, since the source data did not provide a distinct test for one of the two hypotheses (see Section 8, item C).

Table 13. Pearson's Correlation Between Knowledge Score and Attitude Score

Variables Correlated	N	r	p-value	Decision
Knowledge score × Attitude score	250	0.672	< 0.001	Significant

Source: Field Survey, 2026

Negative, moderate, and statistically significant correlations were found between knowledge and attitude scores and the composite barrier mean score, indicating that higher knowledge and more favourable attitude were associated with fewer perceived barriers (Table 14).

Table 14. Pearson's Correlation Between Knowledge/Attitude Scores and Barrier Mean Score

Variables Correlated	N	r	p-value	Decision
Knowledge score × Barrier mean score	250	-0.318	0.002	Significant
Attitude score × Barrier mean score	250	-0.285	0.004	Significant

Source: Field Survey, 2026

Knowledge category was significantly associated with willingness to attend future training ($\chi^2 = 8.419$, $df = 2$, $p = 0.015$); 73.7% of respondents with adequate knowledge were willing to train, compared with 26.3% of those with inadequate knowledge (Table 15). A point-biserial correlation likewise showed a positive, significant association between attitude score and willingness to train ($r = 0.341$, $p = 0.001$; Table 16).

Table 15. Chi-Square Test of Association Between Knowledge Category and Willingness to Attend Future Training

Knowledge Category	Yes n(%)	No n(%)	Not Sure n(%)	Total
Adequate knowledge	157 (73.7)	4 (44.4)	12 (42.9)	173
Inadequate knowledge	56 (26.3)	5 (55.6)	16 (57.1)	77
Total	213	9	28	250

$\chi^2 = 8.419$, $df = 2$, $p = 0.015$

Source: Field Survey, 2026

Table 16. Point-Biserial Correlation Between Attitude Score and Willingness to Attend Training

Variables Correlated	N	r	p-value	Decision
Attitude score × Willingness (Yes vs. No/Not Sure)	250	0.341	0.001	Significant

Source: Field Survey, 2026

4. Discussion

The healthcare workforce sampled in this study was predominantly young and female, with Nurses/Midwives and Community Health Officers/Extension Workers constituting the largest professional groups. This composition reflects the important contribution of these cadres to frontline healthcare delivery in primary healthcare settings. The relatively young age distribution may provide an opportunity for the introduction of emerging areas of biomedical knowledge, although age alone should not be interpreted as evidence of greater receptiveness to environmental epigenetics.

Overall, 69.2% of respondents demonstrated adequate knowledge of environmental epigenetics. Pollution and smoking were the environmental determinants most frequently recognised as influencing gene expression, while heavy metals and pesticides were less frequently recognised. Cancer was also the disease outcome most commonly identified as being associated with environmental epigenetic effects. Previous research has established that environmental exposures can influence epigenetic processes and that such alterations may contribute to differences in disease susceptibility (Baccarelli & Bollati, 2009; Feil & Fraga, 2012). The comparatively lower recognition of heavy metals and pesticides may indicate that respondents were less familiar with environmental exposures that are less visible in routine health education or are more technically complex. This suggests that training should extend beyond commonly recognised environmental hazards to include a broader range of chemical and occupational exposures.

The finding that respondents generally recognised the relevance of environmental epigenetics to disease prevention and patient counselling, despite incomplete knowledge of some molecular mechanisms, is important for healthcare practice. Environmental epigenetics provides a framework for understanding how environmental exposures may influence biological regulation and disease susceptibility without altering the underlying DNA sequence (Hou et al., 2012; Feil & Fraga, 2012). Building on respondents' existing recognition of its practical relevance may therefore provide a useful starting point for educational interventions. Such interventions could progressively introduce more technical concepts, including epigenetic mechanisms, exposure pathways, susceptibility, and the potential implications of environmental exposures for disease prevention.

Respondents demonstrated a strongly positive attitude towards integrating environmental epigenetics into healthcare practice, with 98.4% classified as having a positive attitude and all attitude items recording mean scores above 4.00. The substantially higher proportion with a positive attitude than with adequate knowledge suggests that favourable attitudes towards an emerging field may exist even when technical understanding is incomplete. This finding is encouraging from an educational perspective because it indicates that resistance to the introduction of environmental epigenetics may not be the principal challenge among the healthcare workers studied. Instead, the emphasis may need to be placed on converting this favourable attitude into appropriate knowledge and practical competencies.

The major barriers identified by respondents were predominantly structural and organisational, particularly continuous professional education, availability of clinical guidelines, institutional support, and adequate training. Perceived intellectual complexity was the least strongly endorsed barrier, while time constraints also represented an important concern, with a mean score of 3.87. These findings suggest that integration of environmental epigenetics into routine practice may depend not only on individual knowledge but also on the availability of educational opportunities, practical guidance, and institutional support. Evidence from environmental health education among healthcare professionals similarly indicates that relevant competencies require structured training, practical tools, and integration of environmental health content into professional education and practice. Environmental health competency frameworks have emphasised knowledge, clinical application, communication, and systems-level skills as important components of healthcare-worker preparedness (Jagals & Ebi, 2021). This supports the need for continuing professional education and context-specific guidance rather than relying solely on individual interest or self-directed learning.

Educational qualification and professional cadre were significantly associated with knowledge, whereas age, sex, marital status, and years of professional practice were not. This pattern suggests that differences in knowledge may be more closely related to educational background and professional training than to general demographic characteristics or length of professional experience. The finding supports the development of cadre-sensitive educational interventions that take account of differences in professional roles and previous exposure to biomedical and molecular concepts. Rather than assuming that longer professional experience necessarily results in greater familiarity with emerging scientific fields, continuing professional development may be required to provide healthcare workers across cadres with current and relevant knowledge.

The absence of significant socio-demographic associations with attitude should be interpreted

alongside the very high prevalence of positive attitudes in the sample. With 98.4% of respondents classified as having a positive attitude, there was limited variation in attitude scores across participants. This restricted variation may have reduced the ability to detect meaningful differences between demographic groups. Thus, the absence of statistically significant associations should not be interpreted as evidence that demographic characteristics can never influence attitudes towards environmental epigenetics.

Knowledge showed a strong positive correlation with attitude ($r = 0.672$, $p < 0.001$), indicating that respondents with higher knowledge scores tended to report more positive attitudes towards environmental epigenetics. However, because this study used a cross-sectional design, the finding represents an association and does not establish that higher knowledge causes a more positive attitude. Knowledge and attitude were also significantly associated with fewer perceived barriers ($r = -0.318$ and $r = -0.285$, respectively). These relationships suggest that respondents with greater knowledge or more positive attitudes tended to perceive fewer barriers, although the moderate magnitude of the correlations indicates that factors beyond individual knowledge and attitude are likely to influence implementation. Organisational support, access to guidelines, continuing education, and time may therefore remain important determinants of successful integration.

Knowledge and attitude were also associated with willingness to receive training ($\chi^2 = 8.419$, $p = 0.015$; $r = 0.341$, $p = 0.001$). Importantly, 85.2% of respondents expressed willingness to receive training regardless of their current knowledge or attitude level. This finding indicates substantial interest in further education and provides a favourable basis for developing training programmes. Environmental health education literature similarly supports the development of structured competencies among healthcare professionals, including the ability to recognise environmental exposures, communicate risks, and incorporate environmental considerations into patient and community care. Recent evidence also highlights the importance of sustained curricular integration and institutional support for translating environmental health knowledge into routine primary healthcare practice. (PubMed)

From a public-health perspective, strengthening healthcare workers' understanding of environmental epigenetics may be relevant to preventive health practice because environmental exposures can influence biological pathways associated with disease susceptibility (Baccarelli & Bollati, 2009; Barouki et al., 2012). Healthcare workers are well positioned to contribute to environmental risk communication, early recognition of exposure-related risks, and preventive counselling. However, the practical value of this knowledge depends on the availability of appropriate training, clinical guidance, and institutional support. Environmental-health training programmes for healthcare workers have similarly emphasised the need to equip professionals to recognise environmental risks and communicate appropriate preventive information to patients and communities (World Health Organization, 2024).

Taken together, the findings indicate that healthcare workers in the study setting had a generally favourable disposition towards environmental epigenetics but demonstrated knowledge gaps, particularly concerning some environmental exposures and their biological implications. The combination of adequate knowledge among a majority of respondents, a very high prevalence of positive attitudes, substantial willingness to receive training, and the identification of organisational barriers suggests that targeted continuing professional development may be a practical strategy for strengthening environmental epigenetics knowledge. Such training should be supported by accessible guidelines, institutional commitment, and opportunities for continuous learning. Environmental epigenetics should therefore be considered not only as a scientific concept but also as an emerging component of environmental and preventive health education.

These findings should be interpreted in light of the study's cross-sectional design. The observed relationships represent associations and cannot establish causal relationships between socio-demographic characteristics, knowledge, attitude, perceived barriers, and willingness to receive training. In addition, the findings are based on responses from healthcare workers in the sampled facilities and may not be generalisable to all healthcare workers in Nigeria. Nevertheless, the findings provide useful evidence of existing knowledge, attitudes, perceived barriers, and training interest and can inform the development of context-appropriate educational interventions on environmental epigenetics among healthcare workers.

5. Conclusion

Healthcare workers in Ilorin Metropolis possess a reasonably sound, though incomplete, level of knowledge of environmental epigenetics, stronger at the level of applied public health relevance than

of underlying biological mechanism, alongside an overwhelmingly positive attitude toward its integration into clinical and preventive practice that is more uniform and more strongly held than their technical knowledge. Knowledge is significantly associated with educational qualification and professional cadre, and is strongly correlated with attitude; higher knowledge and more favourable attitude are, in turn, associated with fewer perceived barriers and with greater willingness to receive training. Taken together, these findings indicate that the principal constraints on fuller integration of environmental epigenetics into healthcare practice in this setting are gaps in training provision, clinical guidance, and institutional support, rather than a lack of willingness or perceived intellectual difficulty.

6. Recommendations

Based on these findings, it is recommended that:

- Health authorities in Ilorin Metropolis allocate dedicated resources for structured environmental epigenetics training programmes, given that only 33.2% of respondents had previously received such training despite 85.2% expressing willingness to attend future training.
- Relevant health authorities and professional regulatory bodies develop and disseminate standardised clinical guidelines on the practical application of environmental epigenetics in patient counselling and preventive care, given that guideline availability was among the most strongly endorsed facilitators (mean = 4.29).
- Training curricula be differentiated by professional cadre, with particular emphasis on Community Health Officers/Extension Workers and Nurses/Midwives, who constitute the bulk of the frontline workforce but recorded comparatively lower knowledge scores, given the significant association between cadre and knowledge ($\chi^2 = 20.225$, $p = 0.003$).
- Health facility managers institutionalise continuous professional education on environmental epigenetics and provide dedicated time within work schedules for training participation, given that continuous professional education recorded the highest facilitator mean score (4.32) and time constraints were identified as a moderately significant barrier (mean = 3.87).
- Training be delivered through workshops/seminars and online courses/webinars, the two most preferred formats (39.2% and 28.0%, respectively), and be explicitly linked to practice relevance, funding support, and certification, the factors most frequently cited as likely to encourage participation.
- Professional bodies and training institutions incorporate environmental epigenetics competency into pre-service curricula and continuing professional development requirements, so that healthcare workers acquire foundational knowledge of this field as part of formal training rather than informally on the job.

7. Limitations

- The study was conducted within health facilities in Ilorin Metropolis, Kwara State; findings may not be fully representative of healthcare workers in other local government areas, states, or regions of Nigeria with differing exposure to environmental epigenetics education.
- The cross-sectional design captured knowledge, attitudes, and perceived barriers at a single point in time and cannot establish causal relationships or track change over time.
- Data were obtained through a self-reported, self-administered questionnaire, which is susceptible to social desirability bias and may have led to over-reporting of knowledge and positive attitudes.
- Although statistically determined and adequate for the analyses conducted, the sample of 250 valid responses remains relatively modest, which may limit statistical power to detect smaller effect sizes in subgroup analyses.
- Classification of knowledge and attitude into categorical bands, while methodologically necessary for hypothesis testing, relies on predefined cut-off points that are somewhat arbitrary and may not capture nuanced gradations in individual responses.

- The extreme positive skew of the attitude variable (98.4% positive) limited the scope for certain inferential tests, such as chi-square analysis of attitude by socio-demographic factors, and attitude findings should be interpreted with this distributional constraint in mind.
- The study assessed knowledge and attitudes as precursors to practice but did not assess actual clinical practice behaviours regarding environmental epigenetics, and therefore cannot draw conclusions about the translation of knowledge and attitudes into practice.

8. Declarations

Ethical approval

Ethical approval was obtained from the Ministry of Health Ethical Research Committee, Kwara State Government (ERC/MOH/2026/07/792), dated 15 July 2026.

Informed consent

Participation was voluntary, and informed consent was obtained from all participants prior to questionnaire administration. Confidentiality and anonymity were maintained by excluding personal identifiers.

Data availability

The data generated and/or analyzed during this study are not publicly available due to privacy and confidentiality considerations but may be obtained from the corresponding author upon reasonable request, subject to appropriate restrictions.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contributions

Imam-Fulani A.K.Y.: Conceptualization, supervision, and study design; Yinusa Z.: Writing original draft, writing review and editing; Bishir H.: Conceptualization, methodology, and data curation; Abdulrasheed O.Y.: Investigation and data collection; Kamaldeen K.O.: Investigation and writing review and editing; Oladimeji L.: Data collection and investigation; Salaudeen S.F.: Investigation and data collection; Adepoju M.O.: Investigation and data collection; Buhari A.O.: Methodology and investigation; AbdulMumeen I.: Conceptualization and supervision; Hamzat F.O.: Investigation and writing review and editing; Atoyebi A.T.: Methodology, investigation, and writing—review and editing. All authors reviewed and approved the final manuscript.

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