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Effectiveness of a structured ECG training program among medical students and early-career doctors in Nigeria: A pre-post quasi-experimental study

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Abstract

Background:

Electrocardiogram (ECG) interpretation is a fundamental clinical skill required for the timely diagnosis and management of cardiovascular conditions. However, multiple studies have shown that medical students and early-career doctors often demonstrate inadequate ECG knowledge and low confidence in interpretation. The aim of our study was to assess the effectiveness of a structured ECG workshop on improving the knowledge and self-reported confidence of ECG interpretation among medical students and early-career doctors in Nigeria.

Methods:

A one-group pretest–posttest quasi-experimental design was conducted to evaluate the effectiveness of a structured online electrocardiography (ECG) training workshop. The study population comprised medical students and early-career doctors who attended at least 75% of the training sessions. Data were collected using validated, self-administered online questionnaires that assessed participants' ECG knowledge and self-reported confidence before and immediately after the intervention. Pre- and post-intervention scores were compared using appropriate non-parametric statistical tests, and associations between outcome measures and selected sociodemographic variables were further explored.

Results:

Of 424 enrolled participants, 188 completed both assessments (attrition rate 55.7%). The mean knowledge score increased from 42.6% to 67.9% (25.3% improvement; $p < .001$), while mean confidence scores increased from 39.2% to 72.6% (33.5% improvement; $p < .001$), both with large effect sizes. Participants without prior ECG training and medical students demonstrated significantly greater improvements. Overall satisfaction with the training was high (mean score 4.3 ± 0.8).

Conclusion:

This study demonstrates that structured online ECG training significantly improved ECG interpretation knowledge and confidence among medical students and early-career doctors in Nigeria. By addressing gaps in undergraduate and early postgraduate medical training through scalable, interactive ECG workshops can equip trainees to make informed clinical decisions on ECG interpretation and strengthen healthcare delivery in resource-limited settings.

Background

The electrocardiogram (ECG) is a vital non-invasive diagnostic tool in clinical medicine, essential for evaluating cardiac rhythm disturbances, myocardial ischemia, and structural abnormalities. The increasing prevalence of cardiovascular disease (CVDs) and the need for accurate diagnosis and treatment has highlighted the significance of understanding ECG knowledge and application within the

medical community. ECG is essential in the diagnosis of CVDs such as coronary artery disease (CAD), arrhythmias, inflammatory heart diseases and certain electrolyte imbalances. Proper ECG interpretation is vital in the management of cardiac diseases and emergencies.[1] ECG misinterpretation can result in erroneous clinical decisions with harmful outcomes.[2]

Despite the widespread clinical use of ECG, several studies have shown that performance in ECG interpretation is poor among both undergraduate and postgraduate students of medicine, cardiologists included.[3] Furthermore, studies showed that the majority of medical students felt a low level of self-confidence regarding their competence in ECG interpretation.[4] In low-resource settings like Nigeria, additional barriers include a lack of up-to-date knowledge about ECGs and infrequent use of this skill in practice.[5] Hence, this necessitates an effective way to improve the knowledge of ECG interpretation among medical students and doctors.

In response to this issue, a variety of learning and teaching methods have been developed to enhance ECG competence, including courses and workshops. Such modalities recorded significant improvements in the knowledge and confidence of ECG interpretations of the participants, especially when compared with classroom lectures.[6] Blended learning, which combines face-to-face lectures with e-learning, has proven effective in increasing confidence in ECG analysis and interpretation, as well as enhancing diagnostic accuracy.[2] E-learning provides a convenient and asynchronous learning experience and facilitates immediate online feedback. Self-directed learning (SDL) is beneficial in that it allows for repetitive practice and focused revision of learning material, thereby increasing the time spent on learning.[2] Focused teaching program (FTP) was found to be more effective than self-directed learning.[4] Other interventions include ECG workshops with the use of HEARTS approach,[7] “reverse classroom” method - an interaction-based learning[8] - which was found to be more effective than conventional lecture-based teaching and courses like Foundations of Emergency Medicine (FoEM) ECG 1 course, among many others.[6]

Therefore, a combination of conventional and electronic methods is more effective than either one alone for improving ECG learning and competence among medical and postgraduate trainees.[9] Studies has shown a positive impact of medium- and long-term educational workshops on ECG knowledge and interpretation; however, more studies are needed to further understand the nature of this impact.[10] The primary aim of our study is to assess the effectiveness of a structured ECG workshop on improving the knowledge and self-reported confidence of ECG interpretation among medical students and early-career doctors in Nigeria. The findings from this study are intended to inform the development and standardization of effective, scalable ECG training workshops across Nigeria medical institutions, ultimately contributing to improved clinical competency and patient care.

Methods

Study setting and design

The training workshop was conducted online to accommodate Nigerian medical students and early-career doctors across different states in Nigeria. The study was a one-group pretest-posttest survey using a quasi-experimental design to evaluate the impact of a structured ECG training workshop on ECG interpretation knowledge and self-reported confidence among medical students and early career doctors in Nigeria.

Intervention

Overview of IMGN

The Internal Medicine Interest Group of Nigeria (IMGN) is a non-profit independent organization dedicated to promoting interest and excellence in Internal Medicine among medical students and early career medical doctors in Nigeria.

Program description

The IMGN ECG training workshop was a structured online webinar program open to all medical students and early-career doctors in Nigeria and Africa at large. The training sessions delivered in English covered the following key areas: Core ECG Foundations, Rhythm Disorders & Interpretation, Ischemia & Infarction Patterns, Electrolytes and Drugs, with the overall aim being to boost understanding and confidence in ECG interpretation and to ensure standard ECG application in clinical practices in Nigeria. The training was delivered over three weekends via the virtual conferencing platform “Zoom”. All participants registered for the study beforehand. All communications for the program were conducted via a dedicated WhatsApp group.

Study population

This study was carried out among undergraduate medical students, house officers and early-career medical doctors across Nigeria who registered for the IMGN ECG training workshop and gave informed consent to be included in the study. However, only participants who attended at least 75% of the training sessions were included in the study. Sample size was based on the number of eligible participants that enrolled, provided informed consent and attended at least 75% of the training sessions. No sample size calculation was required due to convenience-based recruitment.

Data collection and management

Data collection involved pre- and post-test structured questionnaires which were pretested and self-administered online using a web-based survey administration software, “KoboToolbox”. The questionnaire was developed based on the course outline of the training webinar, with consultation and approval from the cardiologists involved in the course. The link to the questionnaire was distributed to all

participants via the dedicated WhatsApp group at two points: At baseline (pretest) which assessed demographics, knowledge, and confidence and immediately after the training workshop (post test) which assessed knowledge, confidence and satisfaction with the training. Each participant received a unique anonymized code to track their responses across both phases. The study instrument is included as supplementary material (Appendix 1).

Statistical analysis

Mean ± standard deviation (SD) was calculated for continuous variables. Frequencies and percentages were calculated for categorical variables. The normality of distribution for both the knowledge and confidence scores were assessed using the Shapiro-Wilk test. As they both violated the assumption of normality (Shapiro-Wilk $p < .001$), non-parametric statistical tests were employed for subsequent analyses. Comparisons were done using Wilcoxon signed rank test to investigate differences between pre-test and post-test scores. Intragroup comparison was done using Kruskal-Wallis and Mann-Whitney U tests. A Spearman correlation was used to investigate whether there were any correlations between the pre-test score and post-test score. A p-value < 0.05 was considered statistically significant. All statistical analyses were done using R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria) and the IBM SPSS Statistics software Version 27 (Armonk, NY: IBM Corp).

Ethical considerations

The aim and objectives of the study were clearly communicated to the participants, and each participant was assured of the confidentiality of all information provided, voluntary participation, and the right to withdraw from the study at any point in time. Informed consent was obtained before participation. Ethical clearance for the study was obtained on the 12th of February, 2026 from Ambrose Alli University, Ekpoma Health Research Ethics Committee with assigned number 081/26.

Results

Sociodemographic Characteristics of Participants

The study initially enrolled 424 participants who provided informed consent. Of these, 188 participants (44.3%) attended at least 75% of the training sessions and completed both the pretest and post-test assessments. This corresponds to an attrition rate of 55.7%. The mean age was 25 years (± 5 SD). There were slightly more males (52.7%) than females (47.3%). Most participants were medical students (81.4%), while the remainder comprised house officers (12.8%), medical officers (4.3%), and resident doctors (1.6%). Among medical students, the distribution across academic levels was as follows: 600 level (34.6%), 500 level (29.4%), 400 level (27.5%), and preclinical students (8.5%). Most participants (82.4%) reported no prior formal ECG training. Detailed sociodemographic data are presented in Table 1.

Table 1
Sociodemographic characteristics of participants (N = 188)

Variable		Frequency (N = 188)	Percentage (%)
Age (years) mean ± SD		25 ± 5	
Gender	Male	99	52.7%
	Female	89	47.3%
Training Status	Resident Doctor	3	1.6%
	Medical Officer	8	4.3%
	House Officer	24	12.8%
	Medical Student	153	81.4%
Academic Level (Medical Students only)	600 level	53	34.6%
	500 level	45	29.4%
	400 level	42	27.5%
	Preclinical	13	8.5%
Prior ECG Training	No	155	82.4%
	Yes	33	17.6%

Comparison between pre- and post-test results

Knowledge Change

The mean knowledge score increased from 42.6% in the pretest to 67.9% in the posttest, with a percentage improvement of 25.3%. The 95% confidence interval for the knowledge change was 3.05 to 4.03. The distribution of knowledge change scores was not normal (Shapiro-Wilk $p < .001$). Therefore, the Wilcoxon signed-rank test was used, revealing a statistically significant increase in knowledge scores ($Z = -10.376$, $p < .001$) as shown in Table 3.

Confidence Change

Participants' self-reported confidence in ECG interpretation also improved significantly. The percentage confidence score increased from 39.2% to 72.6%, yielding a percentage increase of 33.5%, with a 95% CI of 15.33 to 18.15. The change in confidence scores was also not normally distributed (Shapiro-Wilk $p < .001$). As shown in Table 3, the Wilcoxon signed-rank test confirmed a significant improvement ($Z = -11.420$, $p < .001$). Table 2 presents the pre- and posttest knowledge and confidence score distributions.

Table 2
Distribution of pre- and post-test scores

Variable		Percentage (%)	Mean	SD	95% CI
Knowledge	Pretest knowledge score	42.6%	5.97	3.364	5.48–6.45
	Posttest knowledge score	67.9%	9.51	3.062	9.06–9.95
	Knowledge improvement	25.3%	3.54	3.413	3.05–4.03
Confidence	Pretest confidence score	39.2%	19.58	9.376	18.23–20.93
	Posttest confidence score	72.6%	36.32	8.457	35.10-37.54
	Confidence improvement	33.5%	16.74	9.796	15.33–18.15

Table 3
Comparison of pre- and post-test scores using Wilcoxon signed-rank test

Variable	Pretest Median (IQR)	Posttest Median (IQR)	Z value	Effect size (r)	p-value
Knowledge score	6.00 (3–8)	10.00 (8–12)	-10.376	0.76	**< .001**
Confidence score	18.00 (11–26)	38.00 (30–41)	-11.420	0.83	**< .001**

Participants Satisfaction with the Training Program

Overall, participants reported high satisfaction with the training. The mean satisfaction score across all items was 4.3 ± 0.8 on a 5-point Likert scale. Specifically, 90.4% agreed or strongly agreed that the course content was well-organized, 91.5% found the speakers to be knowledgeable and engaging, 77.1% felt the pacing and duration of the sessions were appropriate, 83.0% agreed the course met their expectations, and 85.1% indicated that they would recommend the course to others. Detailed data on the satisfaction survey are presented in Table 4.

Table 4
Participant satisfaction survey responses (N = 188)

Variable		Frequency (n)	Percentage (%)
Mean Satisfaction score ± SD		4.3 ± 0.8	
The course content was well organized	Disagree	18	9.6%
	Agree/Strongly agree	170	90.4%
The speakers were knowledgeable and engaging	Disagree	16	8.5%
	Agree	172	91.5%
The pacing and duration of the sessions were appropriate	Disagree	43	22.9%
	Agree	145	77.1%
The course met my expectations	Disagree	32	17.0%
	Agree	156	83.0%
I would recommend this course to others	Disagree	28	14.9%
	Agree	160	85.1%

*Note: The likert responses were dichotomized, with scores 1–3 categorized as “Disagree” and scores 4–5 categorized as “Agree”.

Association between Knowledge Improvement and Sociodemographic variables

No significant difference in knowledge gain was found between male and female participants (U = 3886.0, p = .161). Similarly, among medical students, improvement in knowledge did not differ significantly across academic levels (H = 0.441, p = .932).

A Kruskal-Wallis test was conducted to compare improvement in knowledge across different training statuses (resident doctor, medical officer, house officer, medical student). The result was statistically significant (H = 10.643, p = .014), suggesting that the magnitude of knowledge improvement varied by professional category. Medical students showed the highest mean rank in knowledge improvement.

Participants without prior ECG training (n = 155) had a higher median knowledge improvement (4 [IQR: 2–6]) compared to those with prior training (n = 33, 2 [IQR: 1–4]). The Mann-Whitney U test showed this difference was statistically significant (U = 1962.5, p = .035), indicating that those without prior training benefited more from the intervention. More detailed findings are presented in Table 5.

Table 5
Association between knowledge improvement and Sociodemographic variables

Variable		Median knowledge improvement (IQR)	Mean rank	Test statistic	p-value
Gender	Male	3(1–5)	89.25	Z = -1.401	.161
	Female	4(2-6.25)	100.34		
Training Status	Resident Doctor	1(-)	50.00	H = 10.643	**.014**
	Medical Officer	2.5(1.25–5.25)	88.44		
	House Officer	2(0–3)	65.65		
	Medical Student	4(1–6)	100.22		
Academic Level (Medical Students only)	600 level	4(1–6)	74.70	H = .441	.932
	500 level	4(2–6)	78.61		
	400 level	3.5(1.75-6)	79.43		
	Preclinical	3(1.5–5.5)	72.96		
Prior ECG Training	No	4(2–6)	98.34	Z = -2.106	**.035**
	Yes	2(1–4)	76.47		

Association between Confidence Improvement and Sociodemographic variables

The change in confidence following the ECG training was also analyzed in relation to key demographic variables. No significant difference in confidence improvement was observed between male and female participants. The Mann-Whitney U test confirmed no statistically significant difference (Z = -0.786, p = .432).

Confidence improvement differed significantly across professional categories (Kruskal-Wallis H = 11.120, p = .011). House officers showed the highest median increase (17 [IQR: 14.25–20.75]), followed by medical students (17 [IQR: 10–24]), medical officers (8 [IQR: 4–19]), and resident doctors (4). The low sample size of resident doctors (n = 3) limits interpretation for this subgroup.

Among medical students, confidence gain varied significantly by academic level (H = 7.972, p = .047). Students in 400 level reported the largest median improvement (20 [IQR: 14–26)], followed by 500 level (17 [IQR: 10.5–25.5]), preclinical (15 [IQR: 8.5–22.5]), and 600 level (15 [IQR: 9-21.5]).

Participants without prior ECG training experienced a significantly greater increase in confidence compared to those with prior training. The median confidence gain was 18 (IQR: 12–25) for the no-prior-training group versus 10 (IQR: 8.75-15) for the prior-training group. The Mann-Whitney U test confirmed this difference was statistically significant (Z = -2.683, p = .007). More detailed findings are presented in Table 6.

Table 6
Association between Confidence improvement and Sociodemographic variables

Variable		Median knowledge improvement (IQR)	Mean rank	Test statistic	p-value
Gender	Male	17(12–24)	91.55	Z = − .786	.432
	Female	17(9.76-25)	97.79		
Training Status	Resident Doctor	4(-)	15.17	H = 11.120	**.011**
	Medical Officer	8(4–19)	56.19		
	House Officer	17(14.25–20.75)	102.15		
	Medical Student	17(10–24)	96.86		
Academic Level (Medical Students only)	600 level	15(9-21.5)	66.08	H = 7.972	**.047**
	500 level	17(10.5–25.5)	79.59		
	400 level	20(14–26)	90.77		
	Preclinical	15(8.5–22.5)	68.04		
Prior ECG Training	No	18(12–25)	99.41	Z = -2.683	**.007**
	Yes	10(8.75-15)	71.44		

Correlation Between Knowledge and Confidence Scores

Spearman's rank correlation revealed moderate positive correlations between pretest knowledge and pretest confidence (ρ = 0.655, p < .001), and between posttest knowledge and posttest confidence (ρ = 0.511, p < .001). Pretest knowledge was also positively correlated with posttest knowledge (ρ = 0.427, p < .001), indicating that baseline knowledge was associated with post-intervention performance. Findings are presented in Fig. 1.

Discussion

ECG interpretation is a core clinical competency expected of medical students and early-career doctors, particularly in resource-limited settings such as Nigeria, where access to specialist cardiology services is

often limited. Therefore, evaluating the effectiveness of structured ECG training among Nigerian medical trainees is essential for strengthening clinical competence, improving early detection and management of cardiovascular conditions, and ultimately enhancing patient outcomes within the healthcare system.

Our study found that more than four-fifths (82.4%) of participants reported having no prior formal ECG training, indicating a substantial gap in ECG education within Nigerian undergraduate medical curricula and early postgraduate training programs. This finding is consistent with previous studies that have reported deficiencies in structured ECG training among medical trainees, underscoring the persistent need for targeted educational interventions within medical education programs.[4,9,11] This gap may reflect limited curricular time allocation for ECG interpretation and insufficient opportunities for supervised, hands-on ECG practice.[12]

Our study demonstrated suboptimal baseline levels of knowledge and confidence in ECG interpretation, with only 42.7% of participants demonstrating good knowledge and 39.2% reporting a good level of confidence at the pre-intervention assessment. These findings are similar to previous reports by Kashou et al.[13] and Kopec et al.[14], who observed good ECG knowledge in 56.4% and 66% of participants, respectively, indicating that baseline ECG competence remains suboptimal across different training contexts. This gap may be attributable to inadequate formal ECG instruction in undergraduate curricula, inconsistent opportunities for hands-on interpretation during clinical rotations, and overreliance on self-directed learning, which together may be insufficient to foster competence and confidence.[9]

Our study observed a substantial improvement in ECG knowledge, with a 25.3% increase from pretest to posttest scores and a large effect size ($r = 0.76$), consistent with existing evidence that focused ECG training programs significantly enhance learners' interpretative abilities.[9.15] The observed improvement is consistent with results from blended and workshop-based ECG interventions, highlighting the importance of structured training programs that prioritize pattern recognition, repeated practice, and application to clinically relevant scenarios.[2]

The participants' self-reported confidence in ECG interpretation also increased substantially, with a 33.5% improvement and a very large effect size ($r = 0.83$). Confidence is a critical component of clinical competence, particularly in ECG interpretation, where hesitation or misinterpretation can delay diagnosis and management.[16,17] The marked improvement in confidence is consistent with previous studies showing that educational interventions combining didactic instruction with interactive, hands-on elements significantly enhance learners' self-efficacy.[4,15]

Our study found that medical students demonstrated the greatest improvement in ECG knowledge compared to house officers and resident doctors, which may reflect larger baseline knowledge gaps among students and consequently more room for improvement. This interpretation is supported by the significantly higher gains observed among participants without prior ECG training. Similar trends have been reported in previous studies, where novice learners derived the most benefit from structured ECG instruction.[2,8] These findings highlight the importance of introducing formal ECG training early in medical

education to address foundational knowledge gaps before clinical practice. Conversely, the smaller gains observed among resident doctors should be interpreted cautiously, given the very small sample size in this subgroup.

The magnitude of confidence improvement differed across professional categories and academic levels. House officers and medical students experienced the largest gains, likely due to greater baseline knowledge deficits and limited prior formal ECG instruction.[15,16] The findings underscore the importance of implementing structured ECG instruction during pivotal phases of training, such as clinical clerkships and early postgraduate practice, to maximize educational impact. These findings suggest that ECG workshops may be most beneficial when integrated during critical learning stages, such as clinical clerkships or the early postgraduate period, to maximize skill development and build confidence in ECG interpretation.[4,11]

This study has several limitations that should be considered when interpreting the findings. First, the use of a one-group pretest–posttest quasi-experimental design without a control group limits internal validity and precludes definitive causal inference regarding the observed improvements. Second, the relatively high attrition rate may have introduced selection bias, as participants who completed at least 75% of the training and both assessments were likely more motivated or academically engaged than those who withdrew. Despite these limitations, the findings provide important preliminary evidence that structured ECG training can enhance ECG knowledge and perceived competence among medical trainees in Nigeria, underscoring its potential value in resource-limited healthcare settings.

Conclusions

This study highlighted that structured online ECG training significantly improved both ECG interpretation knowledge and self-reported confidence among medical students and early-career doctors in Nigeria. Participants showed substantial gains in post-intervention knowledge and confidence scores, highlighting the effectiveness of focused, interactive ECG education delivered via a virtual platform. The greatest improvements were observed among medical students and participants without prior ECG training, underscoring the value of early and structured exposure to ECG interpretation during medical training.

Given the high prevalence of inadequate baseline ECG training and suboptimal competence in this cohort, these findings reveal a critical gap in undergraduate and early postgraduate medical education in Nigeria. Structured ECG workshops, particularly those incorporating interactive, clinically oriented teaching methods, represent a feasible and scalable approach to enhancing ECG competence in resource-limited settings.

By addressing these educational gaps, it is possible to equip medical trainees with the knowledge and confidence necessary to make informed clinical decisions on ECG interpretation, ultimately contributing to a more effective and equitable healthcare system in Nigeria.

Abbreviations

CAD
Coronary artery disease
CI
Confidence interval
CVDs
Cardiovascular disease(s)
ECG
Electrocardiogram
FoEM
Foundations of Emergency Medicine
FTP
Focused teaching program
HEARTS
Heart rate/rhythm, Electrical conduction, Axis, R-wave progression, Tall/small voltages, and ST/T changes
IMGN
Internal Medicine Interest Group of Nigeria
IQR
Interquartile range
SD
Standard deviation
SDL
Self-directed learning
SPSS
Statistical Package for the Social Sciences

Declarations

Ethics approval and consent to participate

Ethical clearance for this study was obtained from the Ambrose Alli University, Ekpoma Health Research Ethics Committee on the 12th of February, 2026 (reference number: 081/26). The study was conducted in accordance with the principles of the declaration of Helsinki. All participants provided informed consent before participation. The aim and objectives of the study were clearly communicated, and participants were assured of confidentiality, voluntary participation, and the right to withdraw at any point.

Consent for publication

Not applicable.

Availability of data and materials
All data obtained and analyzed are available in the manuscript. The main dataset generated during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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Authors' contributions
AY, HO, and OSC conceptualized and designed the study. OSC, OV, and ODU planned and executed the intervention. AY, ON, OO, IE-H, HO, ABO, OSC, OV, and ODU contributed to data acquisition. AY conducted data analysis. AY, ON, and OO drafted the manuscript. ABO and OSC critically revised the manuscript for important intellectual content. All authors read and approved of the final manuscript.

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Figures

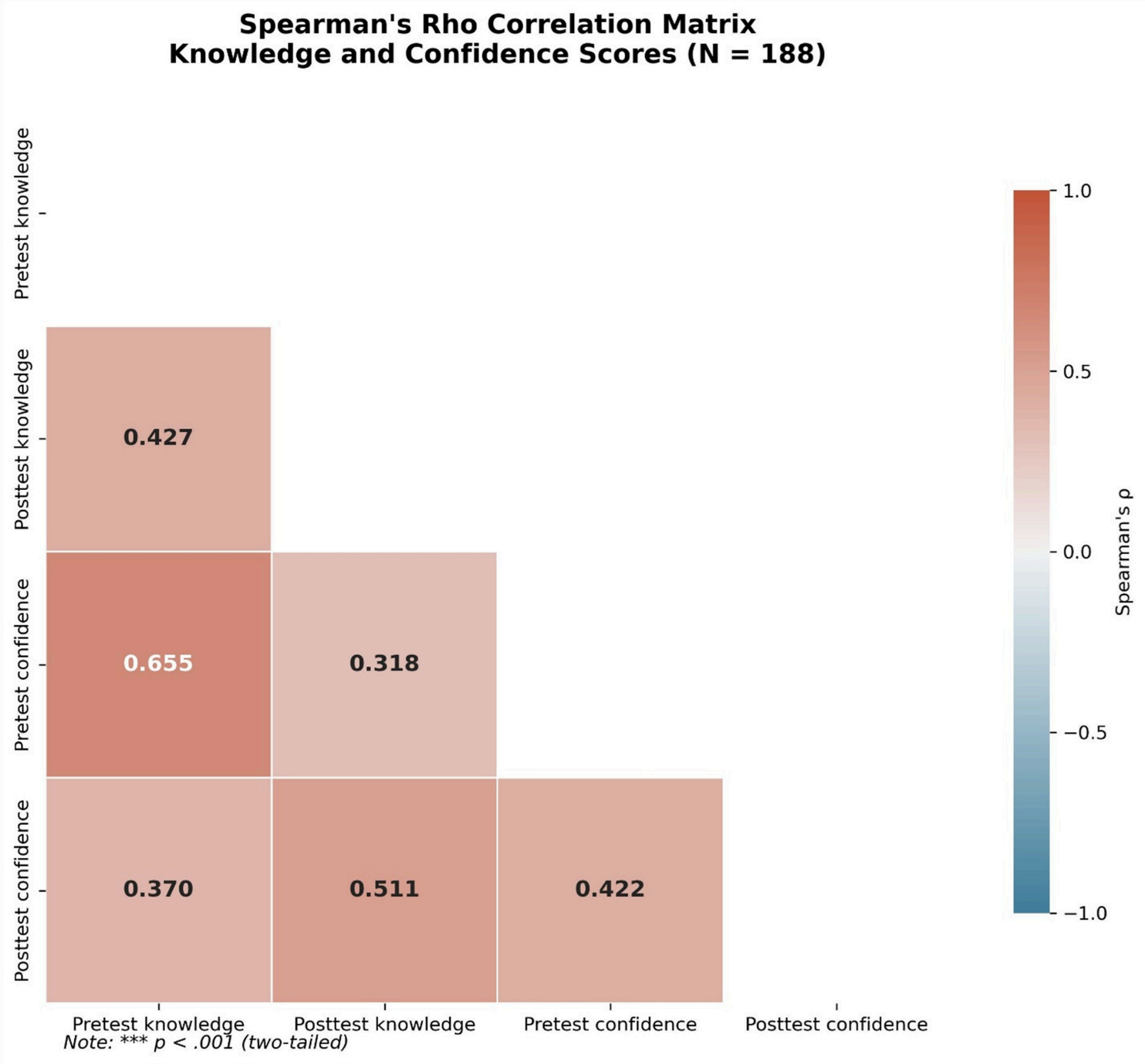


Figure 1

Correlation between Knowledge and Confidence scores

Supplementary Files

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