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Original Article

Association between 2D:4D Digit Ratio and Anatomy Performance Among Basic Medical and Allied Health Students at Lead City University: A Cross-Sectional Study

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ABSTRACT

Introduction: The second-to-fourth digit ratio (2D:4D) is considered a proxy marker of prenatal androgen exposure and has been associated with various biological, behavioural, and cognitive traits. However, its relationship with academic performance remains inconclusive, particularly across different populations and measurement techniques.

Aim: This study investigated the association between 2D:4D ratio and academic performance among undergraduate students, and compared anatomical and conventional methods of digit measurement.

Methods: A cross-sectional study was conducted among 84 undergraduate students from four departments at Lead City University, Nigeria. Participants were selected using multistage sampling. Bilateral digit lengths were measured using a digital caliper via anatomical and conventional techniques, and 2D:4D ratios were calculated. Academic performance was assessed using Anatomy examination grades converted into ordinal scores. Paired t-tests, ANOVA, chi-square tests, and Spearman's correlation were used for analysis, with significance set at $p < 0.05$.

Results: The mean age was 20.86 ± 3.30 years, with 60.7% females. Anatomical and conventional digit measurements differed significantly ($p < 0.001$). However, no significant associations were found between 2D:4D ratios and academic performance ($p > 0.05$). Correlation analyses showed weak, non-significant relationships across all digit variables. Sex was not associated with academic performance ($p = 0.971$), whereas department showed a significant association ($p < 0.001$).

Conclusion: The 2D:4D ratio demonstrated no meaningful relationship with academic performance, suggesting limited predictive value in this context.

Keywords: 2D:4D ratio; digit ratio; academic performance; undergraduate students; cross-sectional study

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INTRODUCTION

The second-to-fourth digit ratio (2D:4D) is defined as the ratio of the length of the second digit (index finger) to that of the fourth digit (ring finger), this has been argued to be a marker for prenatal testosterone exposure relative to prenatal oestrogen exposure (Manning, 1998). Among the various digit ratios that have been studied, the 2D:4D ratio has received the greatest attention because of its reported association with several human phenotypic, behavioural and biological traits (Trivers, *et al.,* 2006). A 2D:4D ratio greater than 1 indicates that the index finger is longer than the ring finger, whereas a ratio less than 1 indicates that the ring finger is longer than the index finger. The 2D:4D ratio is generally sexually dimorphic, with males often exhibiting lower mean ratios than females (Loehlin, *et al.,* 2012). It has been reported to remain relatively stable from birth and sexual dimorphism in digit ratio has also been reported across several species, including humans, mice, and zebra finches (Bailey and Hurd, 2005).

It was reported that, beyond its sexual dimorphism, the mean 2D:4D ratio also varies across ethnic groups (Manning *et al.,* 2004). Similarly, a study among children found that Caucasian participants had higher 2D:4D ratios than Black participants and individuals of Han Chinese ethnicity (Xi *et al.,* 2014). This suggests that digit ratio may be influenced not only by sex-related biological factors but also by population-specific variation. In addition, developmental genetic factors may contribute to variation in digit ratio. The HOXA gene family, which is highly conserved in mammals, plays an important role in digit differentiation and has also been implicated

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in sex determination, fertility, and hematopoiesis (Zhang *et al.,* 2013).

The 2D:4D ratio has been widely proposed as an indirect marker of prenatal androgen exposure during fetal development. It is generally believed to be negatively associated with prenatal testosterone exposure and positively associated with prenatal oestrogen exposure. Since male fetuses are thought to experience greater prenatal testosterone exposure than female fetuses, males tend to exhibit lower 2D:4D ratios than females (Hönekopp, J., & Watson, S. 2010). Beyond its biological significance, fetal testosterone has also been reported to influence cognitive and behavioural traits in humans (Baron-Cohen, 2003).

Several studies have explored the relationship between 2D:4D ratio and cognitive or behavioural traits, including empathizing and systemizing tendencies (Manning et al., 2010; Voracek & Dressler, 2006). In the domain of mathematical and numerical ability, Luxen and Buunk (2005) reported a significant association between right-hand digit ratio and numerical skills, with lower, more masculinised ratios associated with better performance. Similarly, Kempel et al. (2005) found that females with more masculinised digit ratios performed better on a numerical intelligence task involving continuing number series.

Evidence linking 2D:4D ratio to academic performance has also been reported, although findings remain inconsistent. Hopp et al. (2012) observed that lower 2D:4D ratios were associated with practical and theory examination scores among Brazilian male dental students. In contrast, this association was not observed among female students in the same study, suggesting possible sex-specific effects. Similarly, Coco et al. (2011) reported a significant relationship between 2D:4D ratio and performance in medical school admission tests among Italian male students. However, the overall evidence remains inconclusive, particularly across different populations and academic settings.

Furthermore, variations in digit-length measurement techniques may influence the calculated 2D:4D ratio and, by extension, any observed association with academic outcomes. Despite growing interest in the 2D:4D ratio, few studies have examined how different measurement methods may affect its relationship with academic performance, especially in African student populations.

This study aimed to investigate the relationship between 2D:4D digit ratio and academic performance in Anatomy among undergraduate students at Lead City University. Specifically, the study compared conventional and anatomical methods of digit-length measurement, assessed differences between the two approaches, and examined whether 2D:4D ratio derived from either method was associated with students' academic performance.

MATERIALS AND METHODS

Materials

The materials used in this research are; Electronic digital caliper, personal computer and standardized questionnaire. The standardized questionnaire consists of three parts, the first part includes question items to assess the participants' sociodemographic characteristics. The second parts include questions about the digit lengths and 2D:4D ratio, which will be evaluated objectively by the researcher. The third part includes questions regarding the test and examination score of samples in both practical and theoretical anatomy.

Methods

Study Design

A quantitative cross-sectional study design was adopted to determine the relationship between 2D:4D ratio and Academic Performance among ninety (90) consented undergraduate Basic Medical and Allied Health Science students at Lead City University, Ibadan from. Data collection from March 2024 to April 2024.

Study population

The study population comprised undergraduate students from four departments: Anatomy, Nursing, Medical Laboratory Science, and Human Nutrition, all of whom had taken at least one Anatomy course prior to the study.

Sampling Technique

This study used multistage sampling technique:

Stage 1: All departments that offer anatomy course work at lead city university were collected from the student affairs division of the institution.

Stage 2: Four departments were randomly selected from the list given by the student affairs division which included Anatomy, Nursing, Medical Laboratory Science and Human Nutrition

Stage 3: Proportion to size allocation was used to compute the number of students that would be recruited from each department and students were randomly recruited.

The number of students sampled from each department i was determined by:

$n = N \times (N_i / \Sigma N_j)$

where N is the total sample size and N_i is the total number of students enrolled in department i, and ΣN_j is the combined enrolment across the four departments. Human Nutrition = 133; Nursing = 178; Medical Laboratory Science = 154; Anatomy = 63. Total enrolment = 528.

Eligibility criteria

Inclusion criteria: Students from any of the following four departments (Anatomy, Nursing, Medical Laboratory Science and Human Nutrition) and students who had taken at least one anatomy course as at the time of this study.

Exclusion criteria: Students with prior history of fracture, students that are not in college of medicine, students that do not offer Anatomy as a course and students that do not agree to participate in the research were not included in this research.

Sample size estimation

Sample size was calculated for correlation analysis using Fisher's z transformation. To detect a medium effect size (r = 0.30) which was considered appropriate given the absence of a robust prior effect estimate in the target population and the expectation that any association between digit ratio and academic performance would likely be modest. with 80% power (β = 0.20) at the 5% two-tailed significance level (α = 0.05).

calculated using the Fisher z transformation method:

$$z_r = \frac{1}{2}\ln\left(\frac{1+r}{1-r}\right)$$

$$z_r = \frac{1}{2}\ln\left(\frac{1+0.30}{1-0.30}\right) = z_r = \frac{1}{2}\ln(1.85711429)$$

$$z_r = \frac{1}{2}\,(0.6190) = 0.3095$$

Using:

$Z_{(1-\alpha/2)}$=1.96 and $Z_{(1-\beta)}$=0.842.

Substituting values:

$$N = \left(\frac{Z_{1-\alpha/2} + Z_{1-\beta}}{z_r}\right)^2 + 3$$

$$N = \left(\frac{1.96 + 0.842}{0.30952}\right)^2 + 3$$

$$N = \left(\frac{2.802}{0.30952}\right)^2 + 3$$

$= (9.055)^2 + 3$

= 81.00 + 3 ≈ 84 respondents

Thus, the calculated minimum sample size required was 84 participants.

Proportion to sample size allocation

Table 1: Table showing the number of students recruited from each department after using the formula for proportion to size allocation.

Department	Population (Ni)	Proportion (Ni/ΣN)	n	Percentage (%)
Anatomy	63	0.119	10	11.9%
Human Nutrition	133	0.252	19	22.6%
Medical Laboratory Science	154	0.292	26	31.0%
Nursing	178	0.337	29	34.5%
Total	528	1.000	84	100%

Data Collection

Following ethical approval from the Department of Human Anatomy, Lead City University, an informed consent form was given out to participants after carefully explaining the research's methodology, aim and objectives. Consented participants were asked to fill their socio-demographic characteristics at the first section of the standardized questionnaire. The measurement carried out included measurements of the hand digit length using a digital vernier caliper (Neiko) which has an accuracy of about 0.05mm. All digit measurements were taken by the principal investigator to minimize inter-observer variation. Using a direct method, conventional digital lengths of the participants from the tip of their phalanx to the proximal digital flexion crease of both the ring and index fingers. In contrast, the Anatomical digital lengths of the participants were taken from the tip of the distal phalanx to the metacarpophalangeal joints of both the ring and index finger (Bonte *et al.,* 2017). After measuring the digit lengths and calculating the digit ratios.

Academic performance was defined as the most recent Anatomy examination result available for each participant. This result was derived from the combined theory and practical Anatomy examination scores, which were averaged and expressed as a percentage score out of 100. The percentage scores were subsequently converted into letter grades using the institution's standard grading system as follows: A (70% and above), B (60–69%), C (50–59%), D (45–49%), E (40–44%), and F (0–39%).

For statistical analysis, letter grades were converted into ordinal numerical values as follows: A = 5, B = 4, C = 3, D = 2, E = 1, and F = 0. All study variables, were entered into and analyzed using the Statistical Package for the Social Sciences (SPSS) version 27.

RESULTS

Summary statistics table is shown in table 2. The mean age of respondents was 20.86 ± 3.30 years. Females constituted 60.7% of the sample, while males accounted for 39.3%. Participants were drawn from Anatomy (11.9%), Human Nutrition (22.6%), Medical Laboratory Science (31.0%), and Nursing (34.5%). Regarding academic performance, most students obtained grades within the average to good range, with C (28.6%), B (27.4%), and A (23.8%) being the most common grades. Fewer students recorded D (17.9%) and F (2.4%).

Figure 1 shows the age range of the participants of this research to be 16 to 37 years. The most frequent age is 19 years. Ages 18, 20, 21 and 24 have notable frequencies of 10, 11, 13 and 10. The least represented ages with only 1 participant are 16, 25, 26, 27, 29, 31 and 37. The concentration of participants in the age range of 18-24.

Table 3 summarizes the mean, standard deviation, standard error, maximum, and minimum for various variables measured using both anthropometric landmarks.

Left second digit length Anatomical has the highest mean of 9.449 while left second digital length conventional has a lower mean of

7.031. Similarly, left fourth digital length Anatomical and right fourth digital length have higher means (9.717 and 9.908, respectively) compared to their conventional counterparts (7.380 and 7.361). The ratio values like 2D:4DL Anatomical and 2D:4DR Conventional show the difference in measurements, where the means are close to 1 (0.976 and 0.969, respectively), indicating slight variability in anatomical vs. conventional measurements.

There were statistically significant differences between anatomical and conventional measurements for all digit lengths ($p < 0.001$).

According to table 4, all paired differences (e.g D2L ANAT vs. D2L CONV) were statistically significant differences between anatomical and conventional measurements for all digit lengths ($p < 0.001$). Although the differences observed in the 2D:4D ratios (e.g. 2D:4DL CONV and 2D:4DL ANAT) were smaller in magnitude, they remained statistically significant (2D:4DL: $p = 0.008$; 2D:4DR: $p = 0.011$).

Analysis of variance (table 5) shows 2D:4D ratios (anatomical and conventional) across letter grade categories were no statistically significant. (2D:4DL anatomical: $p = 0.261$; 2D:4DL conventional: $p = 0.799$; 2D:4DR anatomical: $p = 0.966$; 2D:4DR conventional: $p = 0.817$), as all p-values were greater than 0.05.

The chi-square analysis (table 6) examined the relationship between academic performance and two categorical variables: sex and department of respondents. The results show that there was no statistically significant association between sex and academic performance ($\chi^2 = 0.059$, $p = 0.971$).

In contrast, a statistically significant association was observed between department of study and academic performance ($\chi^2 = 40.919$, $p < 0.001$). A closer examination of the distribution shows that students from Anatomy were entirely represented in the good performance category, while a substantial proportion of Medical Laboratory Science students clustered within the average performance group. In comparison, Human Nutrition students had a higher proportion of poor performance, whereas Nursing students showed a more mixed distribution but with a larger share in the good performance category.

The findings from table 7 indicates a consistent absence of evidence for an association between digit lengths and digit ratios and students' academic performance measured in letter grades. None of the associations reached statistical significance, as all p-values exceeded the conventional 0.05 threshold. The confidence intervals for all estimates further reinforce this interpretation, as they all included zero, indicating substantial uncertainty around the direction and magnitude of the associations and no clear evidence of either positive or negative effects.

Although a few variables showed slight positive or negative trends, these were small in magnitude and inconsistent across measures. There was no coherent pattern suggesting that any dermatoglyphic feature reliably relates to academic performance.

Table 2: Summary statistics table

Variable	Category	Frequency	Percent
Age (Mean±S.D): 20.86±3.30			
Sex	Female	51	60.7
	Male	33	39.3
Department	Anatomy	10	11.9
	Human Nutrition	19	22.6
	Medical Laboratory Science	26	31
	Nursing	29	34.5
Letter Grade	A	20	23.8
	B	23	27.4
	C	24	28.6
	D	15	17.9
	E	0	0
	F	2	2.4

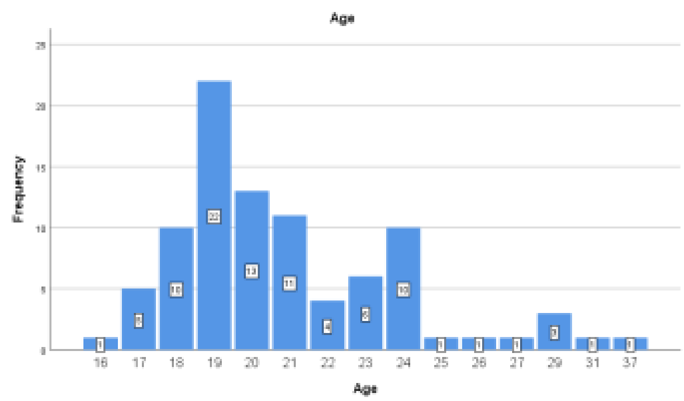

Figure 1: Graph showing the frequency of ages of the participants

Table 3: Table showing the mean, standard deviation, standard error, minimum and maximum of the anthropometric data.

Column	Mean	Std Dev	Std. Error	Max	Min
D2L ANAT (cm)	9.449	0.624	0.0658	11.200	8.000
D2L CONV (cm)	7.031	0.541	0.0571	8.800	5.700
D2R ANAT (cm)	9.380	0.583	0.0615	11.500	8.200
D2R CONV (cm)	7.110	0.531	0.0560	8.800	6.000
D4L ANAT (cm)	9.717	0.731	0.0770	11.400	7.030
D4L CONV (cm)	7.380	0.573	0.0604	9.300	6.200
D4R ANAT (cm)	9.908	0.668	0.0704	11.500	8.500
D4R CONV (cm)	7.361	0.667	0.0703	10.000	6.000
2D:4DL ANAT	0.976	0.0727	0.00766	1.351	0.848
2D:4DL CONV	0.954	0.0492	0.00519	1.090	0.836
2D:4DR ANAT	0.949	0.0541	0.00570	1.150	0.852
2D:4DR CONV	0.969	0.0618	0.00652	1.133	0.710

Abbreviation: D2L ANAT (Left second digit length Anatomical), D2L CONV ((Left second digit length Conventional), D2R ANAT (Right second digit length Anatomical), D2R CONV (Right second digit length Anatomical), D4L ANAT (Left fourth digit length Anatomical), D4R ANAT (Right fourth digit length Anatomical), D4L CONV (Left fourth digit length Conventional), D4R CONV (Right fourth digit length Conventional), 2D:4DL ANAT (Left second digit and fourth digit ratio anatomical), 2D:4DL CONV (Left second digit and fourth digit ratio conventional), 2D:4DR ANAT ((Right second digit and fourth digit ratio anatomical), 2D:4DR CONV (Right second digit and fourth digit ratio conventional).

Table 4 presents the results of paired sample t-tests comparing anatomical and conventional measurements.

Variable	Mean	Std. Deviation	Std. Error Mean	T-value	P value
D2L ANAT - D2L CONV	2.4178	0.5826	0.06	39.37	<0.001
D2R ANAT - D2R CONV	2.27	0.5626	0.06	38.28	<0.001
D4L ANAT - D4L CONV	2.337	0.6528	0.07	33.96	<0.001
D4R ANAT - D4R CONV	2.5467	0.6084	0.06	39.71	<0.001
2D:4DL ANAT - 2D:4DL CONV	0.0216	0.07531	0.008	2.72	0.008
2D:4DR ANAT - 2D:4DR CONV	0.02043	0.07509	0.008	-2.58	0.011

Table 5: Table comparing the 2D:4D ratios (both Anatomical and Conventional) by letter grade

	F	P-value	Interpretation
2D:4DL ANAT – Letter Grade	1.343	0.261	Not significant
2D:4DL CONV – Letter Grade	0.413	0.799	Not significant
2D:4DR ANAT – Letter Grade	0.142	0.966	Not significant
2D:4DR CONV – Letter Grade	0.388	0.817	Not significant

Table 6: Chi square analysis of academic performance and categorical variables

Variable	Academic performance n(%)			Chi square/ Fishers exact	P value
	Good	**Average**	**Bad**		
Sex				0.059	0.971
Male	17(39.5)	9 (37.5)	7 (41.2)		
Female	26 (60.5)	15 (16.25)	10 (58.8)		
Department of respondents					
Anatomy	10 (23.3)	0 (0)	0 (0)	40.919*	**<0.001***
Human Nutrition	5 (11.6)	3 (12.5)	11 (64.7)		
Medical laboratory science	8 (18.6)	17 (70.8)	1 (5.9)		
Nursing	20 (46.5)	4 (16.7)	5 (29.4)		

**represents Fischer's exact test*

Table 7: Spearman's correlation between students' academic performance (letter graded) and digit length and digit ratio variables

Variable	Spearman's ρ	95% CI (Lower – Upper)	p-value
D2L ANAT	0.054	−0.168 - 0.272	0.623
D2R ANAT	0.099	−0.124 - 0.313	0.371
D4L ANAT	0.152	−0.071 - 0.360	0.168
D4R ANAT	0.121	−0.103 - 0.332	0.274
D2L CONV	0.035	−0.187 - 0.253	0.755
D2R CONV	0.011	−0.210 - 0.231	0.922
D4L CONV	−0.002	−0.223 - 0.218	0.982
D4R CONV	−0.007	−0.227 - 0.214	0.951
2D:4DL ANAT	−0.098	−0.312 - 0.125	0.375
2D:4DR ANAT	−0.031	−0.250 - 0.190	0.777
2D:4DL CONV	0.094	−0.129 - 0.308	0.393
2D:4DR CONV	0.015	−0.207 - 0.234	0.895

Confidence intervals were estimated using Fisher's r-to-z transformation. Statistical significance was set at p < 0.05.

DISCUSSION

This study investigated the relationship between the 2D:4D digit ratio and academic performance among undergraduate students in the College of Medicine Basic medical and Allied health students in the college of medicine at Lead City University, using both anatomical and conventional measurement techniques. The findings revealed statistically significant differences in digit lengths measured using anatomical versus conventional landmarks. However, these differences did not translate into significant correlations with academic performance.

The average age of the participants was 20.86 ± 3.30 years, which is typical of an undergraduate population. Most of the students fell within the 18–24 age range, consistent with what has been reported in similar university-based studies (Arikan, 2025). Because the age range is relatively narrow, it helps reduce age-related biological differences, making the sample more suitable for examining subtle anthropometric relationships such as the 2D:4D ratio.

More females (60.7%) participated in the study compared to males (39.3%). Sex differences are often important in 2D:4D research because digit ratios tend to differ between males and females, with males usually having lower ratios due to higher prenatal testosterone exposure (Nama & Opatha, 2024). However, in this study, sex did not significantly affect academic performance (p = 0.971). This suggests that although biological differences exist between males and females, they do not appear to translate into differences in academic outcomes in this population.

In terms of academic performance, most students fell within the average-to-good range. The majority had grades B (27.4%), C (28.6%), and A (23.8%), indicating a fairly balanced academic group with few extreme performers. This relatively even distribution may have reduced variability in performance and could partly explain why no strong relationship was observed between academic outcomes and biological variables.

The paired sample t-test revealed clear differences in digit length measurements depending on the method used, which in turn affected the calculated 2D:4D ratios. This finding highlight how sensitive digit ratio measurements are to the technique applied, supporting earlier reports by Xi et al. (2014). It reinforces the need for consistency and standardization in measurement methods when conducting 2D:4D research.

Both the ANOVA (Table 5) and Spearman's correlation (Table 7) analyses showed no significant relationship between 2D:4D ratios and academic performance. The confidence intervals for all variables included zero, further indicating a lack of a clear or consistent effect. Although there were slight positive and negative trends in some cases, these were weak and not statistically meaningful. This finding is consistent with previous studies. For example, Nama and Opatha (2024) reported very weak correlations between digit ratio and GPA, while Adenowo and Oladokun (2019) also found that digit ratio does not predict academic performance. Overall, these results suggest that 2D:4D is not a reliable indicator of academic success.

While some theories propose that prenatal hormone exposure (reflected by the 2D:4D ratio) may influence cognitive abilities, the evidence remains mixed. Although certain studies have linked digit ratio to specific cognitive functions such as attention and executive functioning (Arikan, 2025), these do not necessarily translate into overall academic performance.

One of the most important findings in this study is the strong association between department of study and academic performance ($p < 0.001$). Students in Anatomy tended to perform consistently well, whereas those in Human Nutrition showed higher levels of poorer performance. Medical Laboratory Science students were mostly in the average category, while Nursing students displayed a more varied performance pattern. This suggests that academic performance is influenced more by contextual and academic factors, such as field of study, rather than biological markers.

Limitations

This study is limited by its cross-sectional design, reliance on letter grades as proxies for academic performance, and the use of a single institution sample, hence the small sample size, which may limit generalization and advanced statistical methods. In addition, while digit measurements were obtained by a single investigator and repeated two to three times to enhance consistency, the study did not formally assess intra-observer reliability using statistical indices such as the intraclass correlation coefficient or technical error of measurement. Potential confounding variables such as handedness, age, ethnicity, socioeconomic and educational background using multivariate analytical approaches, which may have influenced the observed relationships.

Conclusion

This study shows that 2D:4D ratios have limited value in explaining academic performance. Although different measurement methods can slightly influence the results, the overall evidence indicates that digit ratio is not a meaningful indicator of academic achievement. Future studies with larger and more diverse samples, along with better control of potential confounding factors, are needed to further clarify any possible links between biological traits and academic outcomes.

DECLARATIONS

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Conflict of Interest Declaration
The authors declare that there are no conflicts of interest regarding the publication of this paper.

Author contributions
DTO conceptualized and designed the study, supervised data collection, performed data analysis, and drafted the initial manuscript. OOA contributed to the study design, data interpretation, and critical revision of the manuscript. AA contributed to data analysis, literature review, and manuscript drafting. SRO participated in data collection and manuscript review. BOA and FOO assisted with data collection and data management. TKA contributed to the interpretation of results and critical revision of the manuscript. REM assisted with manuscript proofreading. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate
Ethics approval was gotten from Lead City University Ethics review board with number LCU-REC/ANA/030/25. Informed consent was obtained from all participants prior to participation in the study. Participants were adequately informed about the purpose of the study, procedures involved, and their right to withdraw at any time without penalty. They were assured of confidentiality and anonymity.

Data Availability

The data supporting the findings of this study are available within the article. Additional data are available from the corresponding author upon reasonable request.

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