Assessment of Foot Length as a Predictor of Stature and Weight in the Ikwerre Population of Rivers State, Nigeria

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DOI: https://dx.doi.org/10.51244/IJRSI.2025.12110032

Received: 21 November 2025; Accepted: 28 November 2025; Published: 04 December 2025

ABSTRACT

Stature refers to a person's height when standing upright. Estimating stature is crucial in the investigation of unidentified individuals during mass casualties and natural disasters. Foot anthropometry provides valuable predictive information regarding a person's height and weight. The study aimed to develop a regression model to estimate height and weight from foot length measurements of adult Nigerians from the Ikwerre ethnic group. For this study, 200 males and 200 female Ikwerre participants were randomly selected from ages 18-50 years, without foot deformities. Foot length (cm), weight (kg), and height were measured with a tape, scale, and a stadiometer, respectively. Data analysis using IBM SPSS 25 included descriptive (mean, standard deviation, error) and inferential tests (independent t-test, Pearson's correlation, regression) at $\alpha = 0.05$ with a 95% confidence interval, resulting in a regression model to estimate height and weight from foot length. The average height for males was 175.70 cm, while for females it was 164.05 cm. Males also had an average weight of 69.38 kg, compared to 64.44 kg for females. In terms of foot length, males measured an average of 28.09 cm, whereas females averaged 25.72 cm. There were statistically significant differences between males and females in all measured variables. Correlation analysis showed that height and foot length have a stronger positive relationship compared to the relationship between weight and foot length. Conclusively, the results indicate a noteworthy positive relationship between height and foot length, which is stronger than the relationship between weight and foot length. This suggests that foot length may serve as a more effective predictor of height compared to weight.

Key Words: Anthropometry, Foot length, Height, Weight, Ikwerre.

INTRODUCTION

Anthropometry is a valuable field that explores human measurements to gain insights into the physical diversity found within various populations. Its significance is particularly evident in forensic investigations, where it aids in the identification of unknown or commingled human remains in situations such as mass casualties and natural disasters. A crucial aspect of this process is estimating stature, which contributes significantly to the development of a biological profile essential for personal identification (1, 2)

Stature, defined as an individual's height when standing upright, is a critical component of personal identification. It is an anatomical construct determined by the dimensions of the legs, pelvis, vertebral column, and skull, with each contributing variably across different individuals and populations. Hand anthropometry, for instance, offers valuable predictive insights into a person's stature, aiding in the narrowing of potential matches through hand impressions often recovered at crime scenes and during mass disaster investigations (3). Moreover, the relationships between various body dimensions can be pivotal in solving crimes when complete evidence is lacking. In cases where only partial remains, such as a hand or foot, are available, these measurements can be used to estimate stature, thereby assisting in identifying both suspects and victims (2, 4).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XI November 2025

Age, gender, stature, and race are essential elements that shape an individual's identity, with stature and gender playing particularly impactful roles. The variability of the human foot in length, width, and height, shaped by genetic, natural, and environmental influences, holds significant value in anthropological, clinical, and forensic studies (2, 5, 6). To enhance our understanding of stature estimation, researchers have developed both anatomical and mathematical methods. Anatomical approaches, initially proposed by Dwight and refined by Fully, focus on summing the heights of key skeletal elements such as the cranium, vertebral column, and lower limb bones (7, 8). On the other hand, mathematical methods employ regression formulas based on one or more bones. These methods emphasise the importance of sex- and population-specific calibrations to account for genetic and environmental variations (8, 9). Together, these approaches provide a comprehensive framework for estimating stature and advancing our knowledge in various fields.

The Ikwerre ethnic nationality comprises about 1,390,893 individuals in Rivers State. They own and inhabit four Local Government Areas (LGAs) of Rivers State, which are: Ikwerre, Emohua, Obio/Akpor and Port Harcourt LGAs (10). This study presents a unique research opportunity, particularly in understanding the correlation between height and foot length, and weight and foot length within this group. Currently, there is a limited amount of information available on this relationship. By developing a regression model tailored to this population, we can significantly enhance the process of identification. Thus, this study aims to establish a regression model that facilitates the estimation of height and weight based on foot length measurements of Ikwerre indigenes.

MATERIALS AND METHODS

This study employed a cross-sectional correlational design. Approximately 400 subjects were randomly selected from Ikwerre, equally divided into 200 males and 200 females. By including an equal number of males and females, the study aims to explore gender-specific variations in foot length, body weight, and height. This approach enhances the reliability and applicability of the findings across both sexes in the population.

The inclusion criteria for this study are as follows: Participants must be Nigerian individuals from Ikwerre, with both parents and grandparents originating from Ikwerre. They should be adults aged between 18 and 50 years, able to provide verbal informed consent to participate in the study. Additionally, participants must not have a history of foot deformities or significant foot injuries that could affect the measurements. They should also be capable of standing unassisted for the duration of the foot and height measurements, and must not be pregnant or breastfeeding. Individuals who do not meet these inclusion criteria were excluded from the study.

The Ikwerre Ethnic population is about 1,390,893 (10). Utilising the Taro Yamane formula to determine the sample size from this population.

$$n = \frac{N}{1 + \mathrm{N}\,(e)^2}$$

Where:

n = sample size

N = population size (1,390, 893)

e = margin of error (5%; 0.05).

$$n = \frac{1{,}390{,}893}{1 + \ 1{,}390{,}893\ (0.05)^2}$$

n = 399.99 ≈ 400

The measurement process involved the use of a measuring tape to assess foot length in centimetres, a weighing scale to determine weight in kilograms, and a stadiometer to record height in centimetres. Foot length was accurately measured from the tip of the longest toe to the back of the heel, while height was measured from the

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XI November 2025

top of the head down to the soles of the feet. This systematic approach ensured precise data collection for each subject.

The data collected was statistically analysed using IBM Statistical Package for the Social Sciences version 25 (IBM-SPSS 25). Descriptive statistics, including mean, standard deviation, standard error, range, minimum, and maximum, were calculated for both male and female groups. For inferential statistical analysis, Pearson's correlation coefficient was utilised to assess the strength and direction of associations between variables. An independent t-test was conducted to compare the means of the variables between males and females. Furthermore, regression analysis was performed to create predictive models aimed at estimating height and weight based on foot length measurements. This study employed a statistical significance level of $\alpha = 0.05$ and a confidence interval of 95%.

The research and ethics committee at the University of Port Harcourt approved this study. Each participant was provided with information regarding the objectives and procedures involved in the research, and all individuals willingly gave their consent to participate.

RESULTS

The results of this study were presented in tables and graphs.

Table 1: Descriptive statistics of the measured variables in male and female subjects.

Variables	**Males (n=200)**				**Females (n=200)**			
	Range	**Min.**	**Max.**	**Mean±SD**	**Range**	**Min.**	**Max.**	**Mean±SD**
Height (cm)	37.70	157.00	194.70	175.70±7.39	36.50	146.00	182.50	164.05±6.39
Weight (kg)	60.10	50.00	110.10	69.38±10.98	66.00	40.00	106.00	64.44±13.05
RFL (cm)	7.00	25.00	32.00	28.09±1.57	6.50	23.00	29.50	25.74±1.10
LFL (cm)	6.50	25.00	31.50	28.08±1.59	6.00	23.00	29.00	25.70±1.11
FL (cm)	7.00	25.00	32.00	28.09±1.58	6.25	23.00	29.25	25.72±1.10

n *= Number of samples,* ***Min*** *= Minimum,* ***Max*** *= Maximum,* ***SD*** ***=*** *Standard Deviation,* ***cm****= Centimeter,* ***kg****= Kilogram,* ***RFL****= Right Foot Length,* ***LFL****= Left Foot Length,* ***FL****= Foot Length.*

The male foot length (28.09cm) was calculated as the average of the right male foot length (28.09cm) and left male foot length (28.08cm). The female foot length (25.72cm) was calculated as the average of the right female foot length (25.74cm) and left female foot length (25.70cm), Table 1.

Table 2: Independent sample t-test of all measured variables between male and female subjects.

Variables	**t-value**	**p-value**	**MD**	**SED**	**95% Confidence Interval of the Difference**		**Inference**
					Lower	**Upper**	
Height(cm)	16.84	0.000	11.64	0.69	10.28	13.00	Significant
Weight (kg)	4.10	0.000	4.94	1.21	2.57	7.31	Significant
RFL (cm)	17.27	0.000	2.34	0.14	2.08	2.61	Significant

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LFL (cm)	17.33	0.000	2.37	0.14	2.10	2.64	Significant
FL (cm)	17.39	0.000	2.36	0.14	2.10	2.63	Significant

***SED**= Standard Error Difference, **MD** = Mean Difference, **cm**= Centimeter, **kg**= Kilogram, **RFL**= Right Foot Length, **LFL**= Left Foot Length, **FL**= Foot Length.*

From table 2, it was noted that at a 95% confidence interval and α level of 0.05, there are statistically significant differences ($p<0.05$) between the means of height, weight and foot length of male and female subjects.

Table 3: Correlation analysis of the measured variables for male subjects.

		Height (cm)	**Weight (kg)**	**RFL (cm)**	**LFL (cm)**	**FL(cm)**
Height (cm)	*r*	1	0.454	0.536	0.516	0.521
	p-value		0.000	0.000	0.000	0.000
Weight (kg)	*r*	0.454	1	0.437	0.462	0.475
	p-value	0.000		0.000	0.000	0.000
RFL (cm)	*r*	0.536	0.437	1	0.979	0.981
	p-value	0.000	0.000		0.000	0.000
LFL (cm)	*r*	0.516	0.462	0.979	1	0.981
	p-value	0.000	0.000	0.000		0.000
FL (cm)	*r*	0.521	0.475	0.981	0.981	1
	p-value	0.000	0.000	0.000	0.000	

***r** = Pearson correlation, **cm**= Centimeter, **kg**= Kilogram, **RFL**= Right Foot Length, **LFL**= Left Foot Length, **FL**= Foot Length*

The Pearson correlation analysis revealed a positive association between height and foot length (r= 0.521), and weight and foot length (r= 0.475). However, height and foot length have a stronger positive relationship compared to weight and foot length in the male subjects (Table 3.

Table 4: Correlation analysis of the measured variables for the female subjects

		Height (cm)	**Weight (kg)**	**RFL (cm)**	**LFL (cm)**	**FL (cm)**
Height (cm)	R	1	0.288	0.543	0.525	0.548
	p-value		0.000	0.000	0.000	0.000
Weight (kg)	*r*	0.288	1	0.415	0.394	0.408
	p-value	0.000		0.000	0.000	0.000
RFL (cm)	*r*	0.543	0.415	1	0.954	0.984

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XI November 2025

	p-value	0.000	0.000		0.000	0.000
LFL (cm)	*r*	0.525	0.394	0.954	1	0.985
	p-value	0.000	0.000	0.000		0.000
FL (cm)	*r*	0.548	0.408	0.984	0.985	1
	p-value	0.000	0.000	0.000	0.000	

***r** = Pearson correlation, **cm**= Centimeter, **kg**= Kilogram, **RFL**= Right Foot Length, **LFL**= Left Foot Length, **FL**= Foot Length.*

The Pearson correlation analysis presented in Table 4 for the female subjects showed a positive relationship between height and foot length (r= 0.548), and weight and foot length (r= 0.408). However, height and foot length have a stronger positive relationship compared to weight and foot length.

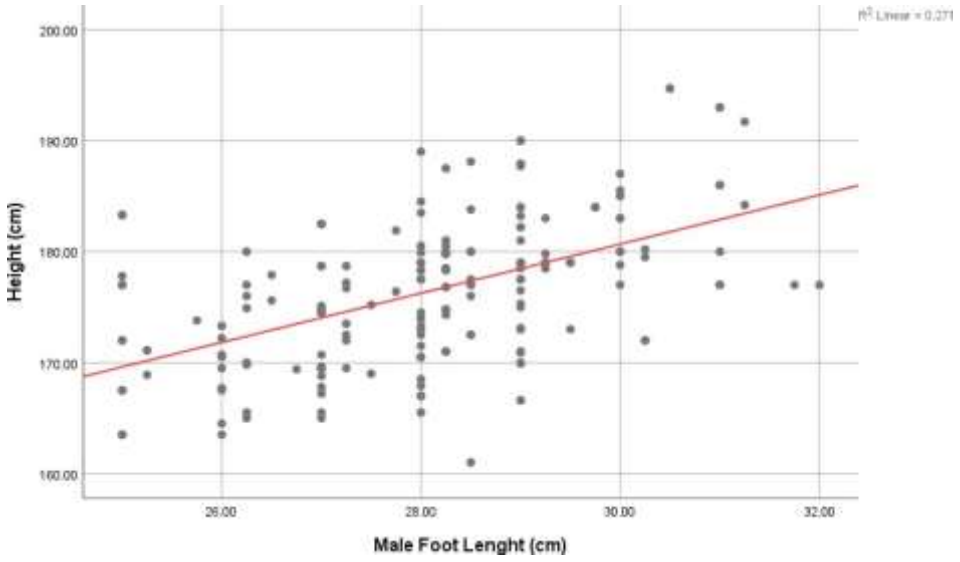

Figure 1: Scatter plot of male height (cm) and male foot length (cm). This shows the strength and direction of the association between height and foot length in the male subjects.

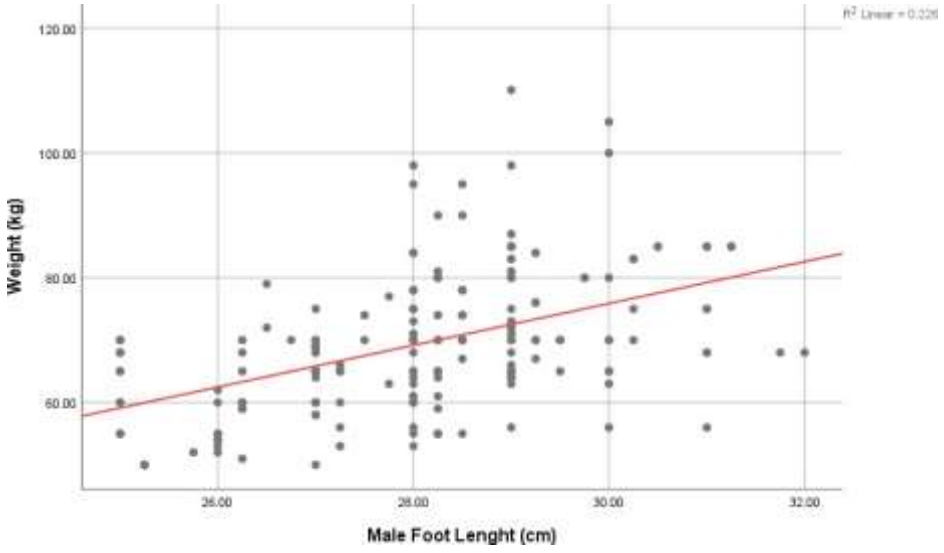

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Figure 2: Scatter plot of male weight (kg) and male foot length (cm), showing the strength and direction of the relationship between weight and foot length for the males.

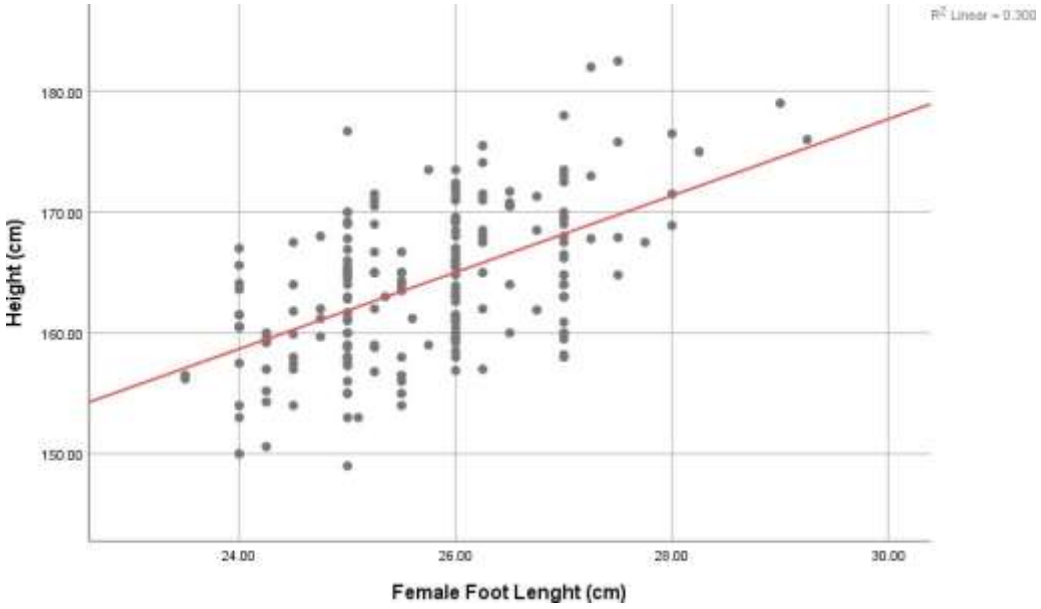

Figure 3: Scatter plot of female height (cm) and female foot length (cm), depicting the direction and strength of their relationship.

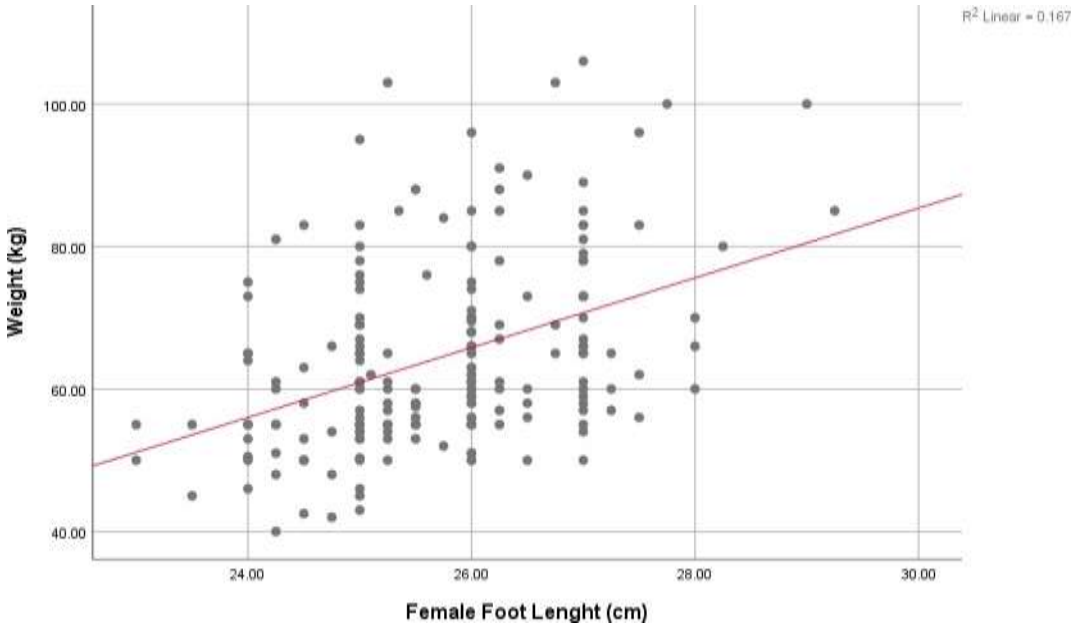

Figure 4: Scatter plot of female weight (kg) and female foot length (cm). A graphical presentation of the strength and direction of the relationship between weight and foot length for the females.

Table 5: A regression model to estimate stature using foot length (cm), for males and females.

Subjects	R	R Square	Adjusted R Square	Std. Error of the Estimate	t-value	p-value	Regression equation
Male	0.453	0.205	0.201	6.61050	7.14	0.000	H=116.35+2.11(FL)
Female	0.539	0.291	0.287	5.39894	9.00	0.000	H= 82.70+3.16(FL)

R= Coefficient; H= Height; FL= Foot Length

Table 6: A regression model to estimate weight using foot length (cm), for males and females.

Subjects	R	R Square	Adjusted R Square	Std. Error of the Estimate	t-value	p-value	Regression equation
Male	0.448	0.201	0.197	9.83572	7.057	0.000	W= -17.90+3.11(FL)
Female	0.409	0.167	0.163	11.93380	6.308	0.000	W= -61.47+4.90(FL)

R= Coefficient; W= Weight; FL= Foot Length

DISCUSSION

Foot length has long been considered a valuable anthropometric measurement due to its positive correlation with height, observed across various populations and demographic groups. In this study, the average height for men was 175.70 cm, with an average foot length of 28.09 cm. In contrast, women averaged 164.05 cm in height and 25.72 cm in foot length (see Tables 1 and 2). Statistical analysis using a t-test revealed that the differences between men and women are significant ($p < 0.05$, Table 3). Additionally, a strong positive relationship exists between height and foot length for both groups: for men, the correlation coefficient was $r = 0.521$, and for women, it was $r = 0.548$ (both $p < 0.05$). This suggests that taller individuals in Ikwerre tend to have longer feet.

The connection between foot length and height offers important insights into the proportions of the human body, showing how different body parts develop in concert during early growth stages. Research by Krishan et al. (1) indicates a significant link between foot size and height among an Indian population, suggesting that foot length can be a useful indicator of height when comprehensive body measurements are not feasible. This idea is further supported by similar results noted in various ethnic groups, emphasising the possibility of using foot length as a general measure for height estimation (11). Additionally, the positive relationship between foot length and height suggests that taller individuals typically have longer feet, a pattern seen in other populations (12). The findings of Ozden et al. (13) highlight the practicality of this strong correlation, providing a quick and dependable means for height estimation. This relationship is especially advantageous in sports science, as foot dimensions can assist in evaluating an athlete's overall height and physique, which is vital for assessing potential in sports such as basketball and soccer. Utilising this data allows coaches and trainers to make more educated decisions regarding athlete development and performance (14, 15).

In this study, we observed interesting trends in the anthropometric measurements of male and female participants. Male participants had an average weight of 69.38 kg alongside an average foot length of 28.09 cm, whereas female participants had an average weight of 64.44 kg and an average foot length of 25.72 cm (refer to Tables 1 and 2). Notably, males demonstrated higher values in these measurements compared to females, as illustrated in Table 3. Furthermore, we found a significant positive correlation between weight and foot length in both groups. Specifically, for males, the correlation coefficient was $r = .475$ ($p < 0.05$), while for females, it was $r = .408$ ($p < 0.05$). The data indicate a noteworthy trend where weight increases are correlated with increases in foot length for both genders. Research consistently supports the relationship between foot length and body weight, particularly in males. For example, Agnihotri et al. (12) observed that larger foot sizes often correspond with greater body mass. This relationship is largely expected, as body structures, including feet, tend to grow proportionally. Such proportionality may be attributed to evolutionary factors, suggesting that larger feet could offer improved balance and support for heavier bodies. This understanding can enhance our awareness of the physical development patterns across populations.

CONCLUSION

In conclusion, there exist significant differences in height, weight, and foot length between male and female

individuals within the Ikwerre population, indicating the presence of sexual dimorphisms in the variables examined. The results demonstrate that foot length exhibits a stronger positive correlation with height compared to weight. This finding suggests that foot length may serve as a more reliable predictor of height than weight within the Ikwerre ethnic group.

ACKNOWLEDGMENTS

We extend our heartfelt gratitude to all the individuals from the Ikwerre community who participated in this study. Their willingness to cooperate was crucial to the success of our research. This acknowledgement emphasises our commitment to ethical research practices and highlights the significance of community involvement in scientific inquiry.

Authors' Contribution

All authors contributed significantly to the development of this study. They collectively participated in the study conception and design, data collection, data analysis and interpretation, manuscript drafting, critical revision for intellectual content, and final approval of the version to be published. All authors agree to be accountable for all aspects of the work.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. All relevant datasets were generated and analysed during the current research and can be provided for academic or research purposes.

Ethical Approval

Before the commencement of the study, ethical approval was granted by the Research Ethics Committee of the University of Port Harcourt.

Conflict Of Interest

The authors confirm no conflicts of interest regarding this manuscript.

Conflict of Interest: The authors confirm that they have no conflicts of interest regarding this manuscript.

Source of Support: The authors state that they did not receive any grants or equipment support.

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ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XI November 2025

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