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Functional nature of antral follicle count on the polycystic ovary syndrome women

Abstract

Polycystic ovary syndrome (PCOS) is a complex medical endocrine condition or disorder that affects a significant proportion of women at their reproductive ages worldwide. The current report examines the functional activity of antral follicle count (AFC) on the women at their reproductive ages. It examines the effects of AFC on women based on a real data set of 1000 subjects, and the data set is available in kaggle.dot com. The data source link is: https://www.kaggle.com/datasets/samikshadalvi/pcos-diagnosis-dataset. The outcomes have been derived in the report using statistical joint generalized linear models. It is derived herein that mean AFC is negatively associated with the joint interaction effect (JIE) of the subjects' body mass index (BMI) and menstrual irregularity (MIT) i.e., BMI*MIT (P=0.0009), while it is positively associated with MIT (P=0.0014), and it is independent of BMI (P=0.7212). Mean AFC is negatively associated with the JIE of MIT and testosterone (TET) levels i.e., MIT*TET (P=0.0718), while it is positively associated with MIT (P=0.0014) and indifferent of TET (P=0.7018). Mean AFC is positively associated the JIE of BMI and the subject's polycystic ovary syndrome (PCOS) diagnostic status i.e., BMI*PCOS (P=0.0051), while it is indifferent of both BMI (P=0.7212) and PCOS (P=0.1413). On the other hand variance of AFC is negatively associated with PCOS (P<0.0001). This report concludes that AFC has many significant effects on PCOS women, and it is associated with BMI, MIT, TET and PCOS. These above findings may be helpful for the researchers, PCOS women and the practitioners. Care should be taken on abnormal BMI, menstrual irregularity, testosterone level and antral follicle count for PCOS women.

Keywords: ovary syndrome, testosterone, antral follicle, gamma fitted

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Abbreviations: AFC, antral follicle count; JGLMs, joint generalized linear models, BMI, body mass index; MIT, menstrual irregularity; PCOS, polycystic ovary syndrome, JIE, joint interaction effect

Introduction

Polycystic Ovary Syndrome (PCOS) is a complex endocrine disorder that affects a significant proportion of women of reproductive age worldwide.[1,2] It is characterized by a heterogeneous set of symptoms, including irregular menstrual cycles, testosterone level, antral follicle count, and polycystic ovarian morphology.[3,4] Despite its prevalence, the diagnosis and management of PCOS remain challenging due to the variability in its clinical presentation and underlying pathophysiology. Early identification of PCOS is crucial, as the syndrome is associated with long-term health risks such as infertility, type 2 diabetes mellitus, cardiovascular disease, and endometrial cancer.[5,6]

One of the critical indicators of ovarian function is the antral follicle count (AFC), which reflects the number of immature follicles in the ovaries and is often elevated in women with PCOS.[7,8] AFC is a fundamental factor in diagnosing PCOS and assessing ovarian reserve in women. PCOS is individualized by an increased antral follicle number, typically prescribed as 12 or more follicles with size measuring 2-9 mm in diameter, or an ovarian volume >10 cm^3. However, current guidelines indicate a higher threshold of ≥20 antral follicles for diagnosis, particularly when adopting high-resolution ultrasound.[9,10] Several research articles have also inquired about the relationship between AFC and age, revealing that the rate of follicle loss is slower in women with PCOS compared to those without.[11,12] Many research articles indicate that biochemical markers such as metabolic age, body mass index (BMI), and serum testosterone (TET) are intricately linked with both the manifestation and severity of PCOS.[4,9,13] Menstrual irregularity (MIT) patterns are also another PCOS hallmark that is associated with the variation of follicular development and ovarian reserve.[11,14]

Recently, different statistical techniques such as simple correlation coefficient, mean absolute error, relative absolute error, root mean squared error, multiple regression, and different tests are used in the PCOS data analysis.[13,15] In addition, different machine learning algorithms such as Locally weighted learning, Multilayer Perceptron, Decision Table 1, Random Tree, Random Forest etc. are used in the PCOS data analysis.[9,11,15,16] Traditional statistical models such as linear regression with constant variance and normal distribution, generalized linear models etc., may be inappropriate for clinical data that are often non-normal and heteroscedastic in nature. The current PCOS data set is a physiological and heteroscedastic data set. The previous PCOS articles do not consider that the considered PCOS data set is of a heteroscedastic nature. So, most of the earlier reports invite many debates and doubts. In addition, the previous reports do not use any appropriate model fitting diagnostic tools for selecting the final models. So, the research may not have a strong faith on the previous PCOS analysis outcomes. The functional roles of antral follicle count (AFC) on PCOS women are very little investigated based on probabilistic modelling. The present article searches the following research hypotheses related to PCOS women.

a) Is there any association of AFC values with irregular menstrual cycles, testosterone level, age, BMI and polycystic ovarian morphology of PCOS women?

b) If it is positive, how can we obtain the most probable AFC values association model?

c) What is the most probable AFC values statistical model?

d) What are the effects of AFC values on PCOS women?

The present article examines the above research hypotheses adopting the following portions as materials & methods, statistical analysis & results, discussions, and conclusions. The present article has derived the AFC values statistical model that has been displayed in (Table 1) using the considered PCOS data set that is reported in the materials section. The statistical AFC values mean-variance models have been derived by joint generalized linear models (JGLMs), which is shortly reported in the methods section. The current derived AFC model outcomes are illustrated in the results section, and the present AFC analysis results are illustrated in the discussion section. Based on the present derived AFC values mean and variance statistical models, the obtained necessary information are noted in the conclusions section.

Materials and methods

Materials

The considered dataset contains information related to Polycystic Ovary Syndrome (PCOS) women, while PCOS is a common hormonal disorder affecting women of reproductive age. The dataset consists of 1000 entries, each representing a woman patient, and it includes six key features that are typically associated with the diagnosis and PCOS risk factors. These features provide valuable insights into the patients' health and they can be used for exploratory data analysis such as feature engineering, machine learning and statistical model development for predicting PCOS diagnoses. The data is available in Kaggle.com and the site is: https://www.kaggle.com/datasets/samikshadalvi/pcos-diagnosis-dataset

Six characters such as age, body mass index (BMI), menstrual irregularity (MIT) (0=No, 1= Yes), testosterone level (TET), antral follicle count (AFC), and polycystic ovary syndrome (PCOS) (0=No, 1=Yes) diagnosis are studied of each study subject. A total 1000 random study subjects' records are considered in the present study. The ages of the study women patients are ranging from 18 to 45 years. This group of women ages are significantly reproductive health age group. The body mass index (BMI) is a measure of body fat based on height and weight, ranging from 18 to 35. A binary indicator showing whether the patient has irregular menstrual cycles (0 = No, 1 = Yes). The testosterone level in the patient's blood is an important hormonal indicator of PCOS, ranging from 20 to 100 ng/dL. The number of antral follicles detected during an ultrasound is ranging from 5 to 30, which helps in assessing ovarian reserve and PCOS presence. A binary indicator of whether the patient has been diagnosed with PCOS (0 = No, 1 = Yes), based on a combination of risk factors such as high BMI, testosterone levels, menstrual irregularity, and antral follicle count.

Statistical methods

The present article considers the number of antral follicle counts (AFC) is the targeted response random variable, which is to be modeled with the remaining five variables such as age, BMI, MIT, TET and PCOS. It is examined that the response AFC values are non-normally and heteroscedastic distributed random variable. The variance of AFC values can't be stabilized with the help of any suitable transformation, therefore it is modeled in the report adopting joint generalized linear models (JGLMs) under both the gamma and log-normal distribution that is clearly described in.[17–20] A detailed discussion about JGLMs is given in the book by Lee, Nelder and Pawitan[17] and in the book by Das.[18] JGLMS for both the log-normal and gamma distribution are shortly reported herein.

JGLMs for log-normal distribution: For the positive response Y_i (=AFC) with E (Y_i=AFC) = μ_i (mean) and Var (Y_i=AFC) = σ_i^2 $\iota_i^2 = \sigma_i^2 V(\mu_i)$ say, where σ_i^2's are dispersion parameters and $V_i(\cdot)$ reveals the variance function. Generally, log transformation Z_i = log(Y_i=AFC) is adopted to stabilize the variance $Var(Z_i) \approx \sigma_i^2$, but the variance may not always be stabilized.[21] For developing a AFC improved model, JGLMs for the mean and dispersion are considered. For the response AFC, assuming log-normal distribution, JGL mean and dispersion models (with Z_i = log(Y_i=AFC)) are as follows:

$$E(Z_i) = \mu_{zi} \text{ and } Var(Z_i) = \sigma_{zi}^2,$$

$$\mu_{zi} = x_i^t \beta \text{ and } \log\left(\sigma_{zi}^2\right) = g_i^t \gamma,$$

Where x_i^t and g_i^t are the explanatory factors/variables vectors of AFC associated with the mean regression coefficients β and dispersion regression coefficients γ, respectively.

JGLMs for gamma distribution: In the above stated Y_i's (=AFC), the variance has two portions such as $V(\mu_i)$ (based on the mean parameters μ_i's) and σ_i^2 (free of μ_i's). The variance function $V_i(\cdot)$ displays the GLM family distributions. For instance, if $V(\mu) = 1$, it is normal, Poisson if $V(\mu) = \mu$, and gamma if $V(\mu) = \mu^2$ etc. Gamma JGLMs mean and dispersion models of GLU are as follows:

$$\eta_i = g(\mu_i) = x_i^t \beta \text{ and } \varepsilon_i = h(\sigma_i^2) = w_i^t \gamma,$$

Where $g(\cdot)$ and $h(\cdot)$ are the GLM link functions attached with the mean and dispersion linear predictors respectively, and x_i^t, w_i^t are the explanatory factors/variables vectors of AFC attached with the mean and dispersion parameters respectively. Maximum likelihood (ML) method is used for estimating the mean parameters, while the restricted ML (REML) method is applied for estimating the dispersion parameters, which are explicitly stated in the book by Lee, Nelder and Pawitan.[17]

Statistical analysis & results

Statistical analysis

The article aims to derive the effects of AFC values on the PCOS women. Probabilistic model of AFC values has been derived on the remaining five (05) explanatory variables such as age, BMI, MIT, TET and PCOS. Final AFC values model has been taken based on the smallest Akaike information criterion (AIC) value (within each class) that reduces both the squared error loss and predicted additive errors.[22] Based on the AIC rules, JGLMs Gamma fit (AIC= 6672.528) is better than Log-normal fit (AIC=6736). Table 1 displays the summarized JGLMs results of the AFC values analysis of both the mean and variance models under both the Log-normal and Gamma distribution.

In the mean model some insignificant marginal effects such as BMI, TET and PCOS are included in the Gamma (or Log-normal) fitted model due to the marginality rule of Nelder.[23] According to the marginality of Nelder,[23] if any higher order interaction effect is significant, then all its lower order interaction effects and marginal effects should be included in the model. For example, in the Gamma fitted mean model (Table 1), BMI*MIT is significant (P=0.0009), so the insignificant marginal effect BMI (P=0.7212) should be included in the model. Similarly, for other insignificant effects in the final selected Gamma fitted model.

The generated AFC values Gamma fitted probabilistic JGLM (Table 1) is a data derived model that is to be tested by model checking tools. All the valid conclusions about AFC values are obtained from the data derived Gamma fitted AFC values probabilistic model (Table 1) that should be taken based on appropriate graphical diagnostic

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tools, which is shown in (Figure 1). (Figure 1(a)) presents the absolute residuals plot for the Gamma fitted AFC values model (Table 1) with respect to the fitted values, which is approximately flat linear, indicating that variance is constant with the running means. (Figure 1(b)) reveals the normal probability plot for the Gamma fitted AFC values mean model (Table 1) that does not reveal any lack of fit. So, both the (Figures 1(a) and (1b)) do not show any discrepancy in the Gamma fitted AFC values models (Table 1). The above (Figure 1(a)) and (Figure 1(b)) confirm that the Gamma fitted AFC values model is an approximate form of the unknown true AFC values model.

Table 1 Results for mean and dispersion models for Antral Follice Count (X5) from Log-normal & Gamma fit

Model	Covariates	Gamma fit				Log-normal fit			
		estimate	s.e.	t(992)	P-value	estimate	s.e.	t(992)	P-value
Mean	Constant	2.7806	0.1289	21.56	<0.0001	2.6567	0.1364	19.46	<0.0001
	BMI	0.0016	0.0045	0.35	0.7212	0.0027	0.0048	0.55	0.5763
	MIT	0.6456	0.2009	3.21	0.0014	0.7028	0.2119	3.31	0.0009
	BMI*MIT	-0.0239	0.0071	-3.34	0.0009	-0.0269	0.0075	-3.55	0.0004
	TET	0.0004	0.0009	0.38	0.7018	0.0002	0.001	0.21	0.8329
	TET*MIT	-0.0022	0.0012	-1.8	0.0718	-0.0022	0.0013	-1.66	0.097
	PCOS	-0.3677	0.2497	-1.47	0.1413	-0.3611	0.2558	-1.41	0.1586
	BMI*PCOS	0.0249	0.0088	2.81	0.0051	0.0276	0.0091	3.03	0.0025
Dispersion	Constant	-1.542	0.0503	-30.64	<0.0001	-1.398	0.0503	-27.77	<0.0001
	PCOS	-0.981	0.11492	-8.53	<0.0001	-1.073	0.11488	-9.34	<0.0001
AIC		6672.528				6736			

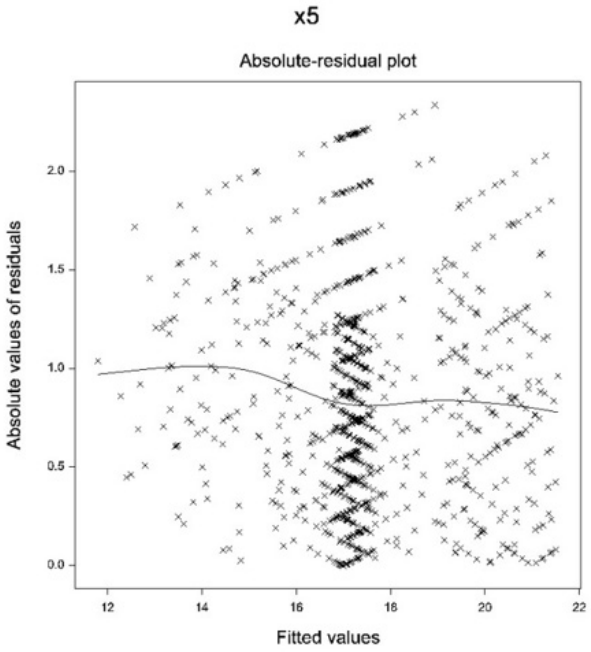

Figure 1(a)

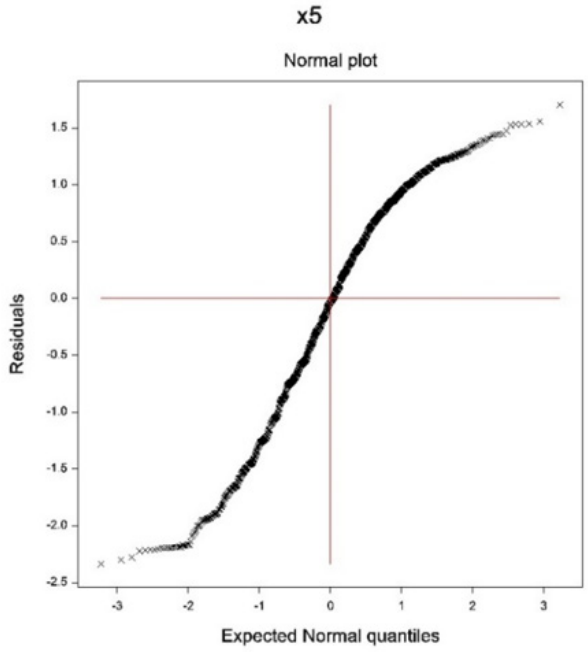

Figure 1(b)

Figure 1 For the joint Gamma fitted model of Antral Follicle Count (Table 1), the (a) absolute residual plot with the fitted values, and (b) the normal probability plot for mean model.

Results

Table 1 displays the AFC values analysis summarized results. On the basis of AIC rule, Gamma fitted JGLM gives better results than Log-normal fitted model. So, the final selected AFC values model is Gamma fitted JGLM. These two fitted models have almost similar interpretations, but there are some discrepancies between these two fitted AFC values models (Table 1). Some discrepancies between the Gamma and Log-normal fitted models are well illustrated in.[24,25]

Here AFC is considered as the response variable, and the rest five others are treated as the explanatory variables. It is derived herein that mean AFC is negatively associated with the joint interaction effect (JIE) of the subjects' body mass index (BMI) and menstrual irregularity (MIT) i.e., BMI*MIT (P=0.0009), while it is positively associated with MIT (P=0.0014), and it is independent of BMI (P=0.7212). Mean AFC is negatively associated with the JIE of MIT and testosterone (TET) levels i.e., MIT*TET (P=0.0718), while it is positively associated with MIT (P=0.0014) and indifferent of TET

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(P=0.7018). Mean AFC is positively associated the JIE of BMI and the subject's polycystic ovary syndrome (PCOS) diagnostic status i.e., BMI*PCOS (P=0.0051), while it is indifferent of both BMI (P=0.7212) and PCOS (P=0.1413). On the other hand variance of AFC is negatively associated with PCOS (P<0.0001).

From (Table1), Gamma fitted AFC values mean ($\hat{\mu}$) model is

$\hat{\mu}$ = exp (2.7806 + 0.0016 BMI + 0.6456 MIT – 0.0239 BMI*MIT + 0.0004 TET - 0.0022TET*MIT – 0.3677 PCOS + 0.0249 BMI*PCOS), and from (Table 1), the Gamma fitted AFC values variance ($\hat{\sigma}^2$) model is

$\hat{\sigma}^2$ = exp.(- 1.542 – 0.981 PCOS).

From the above, AFC values mean ($\hat{\mu}$) model is explained by many factors and their interaction effects such as BMI, MIT, BMI*MIT, TET, TET*MIT, PCOS, BMI*PCOS, while the variance ($\hat{\sigma}^2$) model is explained by only PCOS

Discussions

The summarized AFC values analysis outcomes are presented in (Table 1). From (Table 1), the most appropriate AFC values Gamma fitted mean and variance models are shown in the above results section. These two AFC value models show the associations of AFC values with the remaining factors such as age, BMI, MIT, TET and PCOS. These different associations of AFC values are discussed in the following paragraphs.

From the AFC's mean model (Table 1), it is observed that mean AFC is negatively associated with the joint interaction effect (JIE) of the subjects' body mass index (BMI) and menstrual irregularity (MIT) i.e., BMI*MIT (P=0.0009), while it is positively associated with MIT (P=0.0014), and it is independent of BMI (P=0.7212). This implies that AFC values increase as the joint effect of BMI*MIT decreases. Note that if the joint interaction effect is significant, the marginal effects are not important. Here it is observed that AFC is positively associated with the marginal effect MIT (0=No, 1=Yes), indicating that AFC values increase for the women with irregular menstrual, but it is not always possible as AFC value is negatively associated with the joint interaction effect BMI*MIT. Note that AFC value is independent of the marginal effect BMI.

Mean AFC is negatively associated with the JIE of MIT and testosterone (TET) levels i.e., MIT*TET (P=0.0718), while it is positively associated with MIT (0=No, 1=Yes) (P=0.0014) and indifferent of TET (P=0.7018). This indicates that AFC values increase as the joint effect of MIT*TET decreases. Here it is observed that AFC is positively associated with the marginal effect MIT (0=No, 1=Yes) (P=0.0014), indicating that AFC values increase for the women with irregular menstrual, but it is not always possible as AFC value is negatively associated with the joint interaction effect MIT*TET. Note that AFC value is independent of the marginal effect TET.

Mean AFC is positively associated the JIE of BMI and the subject's polycystic ovary syndrome (PCOS) diagnostic status i.e., BMI*PCOS (P=0.0051), while it is indifferent of both BMI (P=0.7212) and PCOS (P=0.1413). This indicates that AFC values increase as the joint effect of BMI*PCOS increases. It means that obese women with PCOS have higher values of AFC. These women are at higher risk of PCOS, even though the marginal effects BMI and PCOS are insignificant.

From the variance model, it is observed that variance of AFC is negatively associated with PCOS (0=N0, 1=Yes) (P<0.0001), indicating that AFC values are highly scattered for the women with no polycystic ovary syndrome (PCOS). It is derived herein that the lower joint effects BMI*MIT and TET*MIT are highly risk factors for AFC or equivalently for PCOS women. Also, the higher joint effect BMI*PCOS is a risk factor for AFC or equivalently for PCOS women. Note that marginal effects of BMI (P=0.7212) and TET (P=0.7018) are insignificant with AFC, while their joint effects BMI*MIT and TET*MIT are significantly associated with AFC. In addition, TET level is a biomarker of PCOS women, it will be discussed in our subsequent article. Marginal associations of AFC values are easily understandable, while the joint interaction effects are not so simple. Note that the joint interaction effects on AFC values can be identified using only statistical modeling. Best of our knowledge, no earlier article identifies any joint interaction association of AFC values.

Recently an article[26] focuses on PCOS is a complex endocrine disorder that affects 6–21% of reproductive aged women, characterized by hyper-androgenism, chronic anovulation, and polycystic ovarian morphology. Recent clinical management counts on symptom-targeted therapies and lifestyle modifications due to the absence of curative interventions. The article[27] has reported that glucose-lipid metabolism and hormonal imbalances have minimal influence on embryo development in PCOS women. However, PCOS women with high BMI and along with hormonal factors may affect pregnancy outcomes such as risk of miscarriage due to high BMI and androgen levels. It is noted in the article[28] that Anti-Müllerian Hormone (AMH) may be involved in regulating impaired ovarian granulosa cells development in PCOS rats via SMAD family member 4 (SMAD4). Also a recent article[29] has pointed out that reduced miR-338-3p levels have strong predictive value in discriminating between individuals with PCOS women from the normal population. Interested authors may go through many new concepts for studying PCOS diagnosis and management systems.

Conclusion

The present article has derived the functional roles of AFC values on the PCOS women. The report has derived the associations of AFC values with age, BMI, menstrual irregularity, testosterone levels and PCOS status. The fitted AFC values probabilistic model has been obtained herein based on the smallest AIC rule, on comparison of the standard error of the estimates, joint Gamma and Log-normal models, and graphical diagnostic checking plots (Figure 1). Both the Gamma and Log-normal fitted models have similar interpretations (Table 1), but we have discussed the interpretations based on the Gamma fitted models. Most of the derived findings of AFC associations herein focus on the real facts that are observed in practice. The obtained findings regarding AFC values on PCOS women herein though not completely eventual but are expressive. Advanced scientific research approaches should have complete faith on these AFC values obtained findings, as the AFC values fitted models have been selected with graphical diagnostic checking and comparison of two different models.

The fitted AFC value models (Table 1) are derived from the data set as reported in the material section. It is expected that for any similar PCOS data sets, the findings will be almost similar to the present AFC outcomes, which are not verified herein as similar data sets are not available. The present AFC value outcomes reveal many real facts, which are rarely reported in the earlier articles. Most of the AFC value findings in the report are completely new in the endocrine disorder studies literature. In addition, the report may help PCOS women, medical practitioners and researchers. It is concluded that AFC values have very complex functional roles (Table 1) on the PCOS women

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that should be known to the practitioners for appropriate treatment processes. All women should care on BMI, menstrual irregularity, antral follicle count and testosterone level.

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Ethical approval

Note that the current study has been performed based on a secondary data set, which is available in the site-https://www.kaggle.com/datasets/samikshadalvi/pcos-diagnosis-dataset. The ethics approval and the subject consents are not required for a secondary published data set.

Data availability statement

The data is available in the site- https://www.kaggle.com/datasets/samikshadalvi/pcos-diagnosis-dataset

Informed consent statement

Not applicable

Sample availability

The authors declare no physical samples were used in the study

Conflicts of interest

The authors confirm that this article content has no conflict of interest.

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References

1. Azziz R, Carmina E, Chen Z, et al. Polycystic ovary syndrome. *Nat Rev Dis Primers.* 2016;2:16057.
2. Jain S, Sharma TK, Chauhan K. Predicting polycystic ovary syndrome (PCOS) using machine learning: a comprehensive approach to data integration, feature engineering, and model optimization. *Int J Creative Res Thoughts.* 2024;12(5):332–337.
3. Zhao H, Qin Y, Kovacs P, et al. Genetic studies on polycystic ovary syndrome (PCOS): recent advances and perspectives. *Curr Mol Med.* 2019;19(4):218–226.
4. Dapas M, Dunaif A. The contribution of rare genetic variants to the pathogenesis of polycystic ovary syndrome. *Curr Opin Endocr Metab Res.* 2021;19:36–43.
5. Bairagi VK, Vanjale MS, Dolas A, et al. Polycystic ovarian syndrome (PCOS) detection through deep learning. *Int J Eng Trends Technol.* 2024;72(10):159–170.
6. Kavitha K, Tangudu N, Sahu SR, et al. Detection of PCOS using machine learning algorithms with grid search CV optimization. *Int J Trends Technol.* 2023;71(7):201–208.
7. Al-Muqaren HM, Mansor MB, Ibrahim Z. Predictive modelling of polycystic ovary syndrome using machine learning. *J Med Syst.* 2020;44(5):91.
8. Shah P, Litt B, Kendall F, et al. Artificial intelligence and machine learning in clinical development: a translational perspective. *NPJ Digit Med.* 2019;2:69.
9. Teede HJ, Misso ML, Costello MF, et al. Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome. *Hum Reprod.* 2018;33(9):1602–1618.
10. Wang R, Mol BW, Steegers-Theunissen RP, et al. Machine learning in prediction of polycystic ovary syndrome using clinical characteristics and lifestyle factors. *J Clin Endocrinol Metab.* 2019;104(9):4227–4235.
11. Carmina E, Lobo RA. Polycystic ovary syndrome: arguably the most common endocrinopathy is associated with significant morbidity in women. *J Clin Endocrinol Metab.* 1999;84(6):1897–1899.
12. Dong J, Rees DA. Polycystic ovary syndrome: pathophysiology and therapeutic opportunities. *BMJ Med.* 2023;2(1):e000548.
13. World Health Organization. Polycystic ovary syndrome. WHO Fact Sheet. 2025.
14. Patel S. Polycystic ovary syndrome (PCOS), an inflammatory, systemic, lifestyle endocrinopathy. *J Steroid Biochem Mol Biol.* 2018;182:27–36.
15. Modi N, Kumar Y. Detection and classification of polycystic ovary syndrome using machine learning-based approaches. In: *2024 IEEE International Conference on Interdisciplinary Approaches in Technology and Management for Social Innovation*; 2024; Gwalior, India:1–6.
16. Li X, Dai J, Tang Y, et al. Machine learning-based prediction models for polycystic ovary syndrome risk assessment: a review. *Front Endocrinol (Lausanne).* 2022;13:835477.
17. Lee Y, Nelder JA, Pawitan Y. *Generalized Linear Models with Random Effects: Unified Analysis via H–Likelihood.* 2nd ed. London: Chapman & Hall; 2017.
18. Das RN. *Robust Response Surfaces, Regression and Positive Data Analyses.* London: Chapman & Hall; 2014.
19. Das RN, Lee Y. Log-normal versus gamma models for analyzing data from quality-improvement experiments. *Qual Eng.* 2009;21(1):79–87.
20. Qu Y, Tan M, Rybicki L. A unified approach to estimating association measures via a joint generalized linear model for paired binary data. *Commun Stat Theory Methods.* 2000;29:143–156.
21. Myers RH, Montgomery DC, Vining GG. *Generalized Linear Models with Applications in Engineering and the Sciences.* New York: John Wiley & Sons; 2002.
22. Hastie T, Tibshirani R, Friedman J. *The Elements of Statistical Learning.* New York: Springer-Verlag; 2009.
23. Nelder JA. The statistics of linear models: back to basics. *Stat Comput.* 1994;4:221–234.
24. Das RN. Discrepancy in fitting between log-normal and gamma models: an illustration. *Model Assist Stat Appl.* 2012;7(1):23–32.
25. Das RN, Park JS. Discrepancy in regression estimates between log-normal and gamma: some case studies. *J Appl Stat.* 2012;39(1):97–111.
26. Ding K, Wang X, Liu W, et al. Engineering modification of human umbilical cord mesenchymal stem cell-derived small extracellular vesicles ameliorates polycystic ovary syndrome by enhancing the ovarian environment and regulating follicular development. *Stem Cell Res Ther.* 2025;16(1):481.
27. Wang L, Yu X, Xiong D, et al. Hormonal and metabolic influences on outcomes in PCOS undergoing assisted reproduction: the role of BMI in fresh embryo transfers. *BMC Pregnancy Childbirth.* 2025;25(1):368.
28. Dong A, Yu X, Zhang Y, et al. Anti-Müllerian hormone regulates ovarian granulosa cell growth in PCOS rats through SMAD4. *Int J Gynaecol Obstet.* 2025;170(1):209–221.
29. Liang L, Lv J, Li W, et al. Reduced miR-338-3p contributes to polycystic ovarian syndrome by inhibiting proliferation and enhancing apoptosis. *Hereditas.* 2025;162(1):126.