ORIGINAL ARTICLE

CONTENTS

Exploring association between anxiety and infertility characteristics: A combined statistical and machine learning approach

Mariam Suhail[1], Atheer Kadhim Ibadi[2]

[1]DEPARTMENT OF COMMUNITY HEALTH TECHNOLOGIES, COLLEGE OF HEALTH AND MEDICAL TECHNOLOGIES, AL-FURAT AL-AWSAT TECHNICAL UNIVERSITY, KUFA, IRAQ

[2]DEAN OF TECHNICAL INSTITUTE, AL-FURAT AL-AWSAT TECHNICAL UNIVERSITY, KUFA, AL-NAJAF, IRAQ

ABSTRACT

Aim: To investigate the association between anxiety and infertility-related variables and to evaluate the performance of a random forest model in predicting and classifying infertility type using clinical and psychological features.

Materials and Methods: A cross-sectional study was conducted among 268 infertile women systematically recruited from the infertility center at Safeer Al-Imam Al-Hussain Surgical Hospital in Karbala, Iraq. Data were collected using standardized questionnaires covering sociodemographic characteristics, medical, obstetric, and infertility histories. Anxiety severity was assessed using the Generalized Anxiety Disorder-7 scale. Descriptive statistics and linear regression analyses were performed. A random forest model was developed using an 80/20 training-testing split to predict infertility type based on anxiety severity and related clinical variables.

Results: Anxiety was highly prevalent, affecting 83.9% of participants. Mild anxiety was observed in 35.1%, while moderate anxiety was reported in 31.3%. Linear regression showed that infertility duration and infertility type were significantly associated with anxiety severity. Longer infertility duration was associated with higher anxiety scores. The random forest model demonstrated high classification accuracy and low log loss in predicting infertility type. Secondary infertility was the most common type and was associated with longer infertility duration and higher anxiety severity.

Conclusions: Anxiety is strongly associated with infertility, particularly infertility duration and type. Combining conventional statistical analysis with machine learning may improve understanding of the clinical and psychological complexity of infertility and support more individualized patient care.

KEYWORDS: clinical features, psychological features, anxiety, machine learning

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INTRODUCTION

Infertility is a major public health concern with substantial effects on health, relationships, and quality of life. According to the World Health Organization, approximately one in six people of reproductive age experience infertility [1]. Infertility diagnosis and treatment impose a considerable psychological burden, increasing the risk of anxiety and depression and negatively affecting reproductive outcomes [2]. Evidence indicates that 25–60% of infertile individuals experience psychological symptoms, with significantly higher levels of anxiety and depression than fertile controls [3]. Furthermore, a systematic review and meta-analysis reported that infertile women have a significantly greater risk of mental health problems, particularly anxiety and depression, compared with the general population [4].Generalized anxiety disorder (GAD) is characterized by excessive and uncontrollable worry and affects approximately 1.65–5% of the general population. It is among the most common psychological disorders in infertile women, with a reported prevalence of 23.2% [5]. Infertile women experience higher levels of anxiety and hopelessness regarding conception compared with pregnant women [6]. Previous studies have demonstrated a significant association between infertility duration and anxiety, with longer infertility duration increasing the likelihood of anxiety disorders [7,8]. Infertility is classified as primary or secondary, depending on whether a woman has previously achieved pregnancy [9]. Studies from Iraq have reported a higher prevalence of primary infertility (60.7–61%) than secondary infertility (39–39.3%) among infertile couples [10, 11]. Evidence also suggests that women with primary infertility experience greater psychological distress, particularly anxiety, than those

with secondary infertility [12]. Similarly, primary infertility has been associated with an increased risk of mental disorders and has been identified as an independent risk factor for anxiety among infertile women [13,14]. Artificial intelligence (AI) enhances healthcare by facilitating the collection, organization, analysis, and interpretation of medical data, thereby supporting clinical decision-making and improving healthcare delivery [15,16]. Machine learning (ML), a major branch of AI, enables predictive modeling by learning patterns from data without explicit programming [17]. Among ML approaches, supervised learning uses labeled data to classify new observations [18]. Random Forest, a supervised learning algorithm based on multiple decision trees, is particularly effective for modeling complex and non-linear relationships [19]. Despite growing evidence linking psychological distress and infertility, their relationship remains insufficiently investigated within an integrated framework. In particular, the combined effect of infertility duration and type on anxiety has received limited attention, especially in Middle Eastern populations. Furthermore, traditional statistical methods may not adequately capture complex relationships among psychological, clinical, and demographic factors.

AIM

This study aimed to investigate the association between anxiety and infertility-related variables (infertility duration and type) and to evaluate the performance of a Random Forest (RF) model in predicting infertility type using clinical and psychological features.

MATERIALS AND METHODS

DESIGN AND SETTING OF THE STUDY

The study design used was cross-sectional. This research was carried out in the infertility center of Safeer Al-Imam Al-Hussain Surgical Hospital in Karbala, Iraq, between 7 November, 2025 and 15 January, 2026.

SAMPLE SIZE AND SAMPLING TECHNIQUES

The sample size was calculated using cross-sectional study formula [20], considering the prevalence of depression to infertile women, which was reported as 83.3 percent in a cross-sectional study that was conducted in Baghdad, Iraq (Shalan et al., 2019).

Sample size (n) = $[(Z1-\alpha/2)^2 \times P \times (1 - P)] / d^2$

At 95% Confidence interval=1.96, margin of error or precision (0.05)] n= $(1.96)^2 \times 0.833 \times (1-0.883) \div (0.05)^2 = 214$

The single-proportion formula was used to obtain the initial sample size (n). Adjusted sample size (n) was determined to accommodate any participant loss or non-response using the following formula: n=n/(1 - r). In this study, after taking into consideration similar cross-sectional studies, the rate of attrition was assumed to be 20% and thus the final adjusted sample size was approximately 268 people.

SELECTION CRITERIA AND EXCLUSION CRITERIA

Inclusion criteria: Women of childbearing age who fail to conceive after a year of regular unprotected sex, visiting Safeer Al-Imam Al-Hussain Al-Hospital in Karbala, Iraq.

EXCLUSION CRITERIA

Established irreversible birth control or sterilization (e.g., previous bilateral tubal ligation) as the principal cause of infertility. The existence of a confirmed mental health disorder (e.g., acute psychosis, severe cognitive impairment, and depression) during the study period.

DATA COLLECTION

The data was collected using a standardized questionnaire after translating it into an Arabic version. The first two section complete by the researcher by performing direct interviews with participants, and the third section was filled by participants themselves (self-report).

The questionnaire contains the following information:

Section 1/Sciodemographic characteristics of infertile women, involves (5) items such as age, educational level, occupational status, income level, and place of residence.

Section 2/consisted of obstetric, medical, surgical, and infertility histories.

Section 3/psychological assessment tools, using standardized tools included: Generalized Anxiety Disorder, used to measure anxiety symptoms.

RATING SCORING OF PSYCHOLOGICAL ASSESSMENT TOOLS

The 7-item GAD-7 self-report scale. Seven questions from the past two weeks disturbed participants. It was recommended for assessing GAD severity. None, several days, more than half the days, and practically every day are the options (Gui et al., 2021). The GAD-7 screens for signs of generalized anxiety disorder GAD-7 scores range from 0 to 21. GAD-7 scores indicate anxiety severity: 0-4 indicates minimal anxiety, 5-9 mild, 10-14 moderate, and 15-21 severe [21].

ARTIFICIAL INTELLIGENCE (MACHINE LEARNING)

Machine learning is a discipline within computer science that entails teaching computers to identify patterns in data through mathematical principles and statistical estimations. The main goal is to develop predictive models based on dataset feature statistical connections to predict binary responses, categorical labels, and continuous values [22]. In this study, the RF algorithm was selected because of its ability to model complex non-linear relationships while reducing overfitting through ensemble learning. To enhance model performance, the original dataset of 268 participants was augmented to 1,000 samples during preprocessing. The data were subsequently divided into training (80%) and testing (20%) sets for model development and evaluation [23].

ETHICAL CONSIDERATIONS

An official letter to facilitate this research was obtained from the College of Health and Medical Technologies / Kufa (Ref.No.4809 in 24/9/2025) An official permission was obtained from the Karbala Health Directorate to carry out this work in Safeer Al-Imam Al-Hussain Surgical Hospital in Karbala Province (Ref.No.3854 in 7/10/2025). Verbal consent was taken from all participants.

RESULTS

The total number of respondents is 268, with an age range of 17-46 years, with a mean ± STD of 28.9 ± 6.9. The data were normally distributed using the Kolmogorov-Smirnov test. The response rate was 100%. The majority of respondents were within the age group of 27-36 years 46.3%, followed by those in the age group 17-26 years 39.9%, indicating that the sample was predominantly composed of young to middle-aged individuals. Regarding educational level, the largest proportion of participants had primary education 31.7%, followed by those who could read and write 24.6% and those how not 14.6%. This reflects that the sample was characterized by low to moderate educational levels. In terms of occupation, the vast majority of infertile women were housewives 84.7. This reflected the non-working female population. Most participants reported having sufficient income 64.2%. According to residence, the majority are from urban areas, 67.9%, while 32.1% in rural stings, as seen in Table 1.

Obstetric history reported majority of participants had a marriage duration of ≥4 years 76.1%. Similarly, 67.9% reported infertility duration ≥4 years, suggesting a high prevalence of long –standing infertility in the sample. More than half of infertile women 54.1% had no previous pregnancies, and 80.3% had no history of childbirth, reflecting a considerable burden of nulliparity. Regarding pregnancy outcomes, 26.1% reported a history of abortion, while 10.1% had experienced stillbirth, and only 1.1%reported ectopic pregnancy. Menstrual period showed that 56.7% had regular cycles, whereas 43.3% experienced irregular menstruation. Most participants 64.2% reported no medical and surgical conditions, among those who reported polycystic ovarian condition were the most common 17.9%. Related to gynecological history, 71.3% had no prior gynecological intervention, while 14.9% had a history of cesarean section. In terms of infertility type, primary infertility was slightly more prevalent 54.1% than secondary infertility 45.9%, as shown in Table 2.

The findings show that anxiety was common among the study participants. The largest proportion of participants, 35.1%, experience mild anxiety, followed by moderate anxiety, 31.3%. Lower proportions were observed had severe anxiety, 17.5% and 16.0% had minimal anxiety, as shown in Table 3.

Linear regression analysis was performed to assess the association between GAD-7 anxiety scores and selected infertility-related variables. Type of infertility showed a statistically significant association with anxiety scores ($t=9.193$, $p<0.001$). Similarly, the duration of infertility was significantly associated with GAD-7 scores ($t=17.935$, $p<0.001$) as shown in Table 4.

RESULTS OF INFERTILITY TYPE ANALYSIS USING AI MODE

A machine learning model was used in this work using a dataset of 1000 samples, with 80% set reserve for training and 20% for testing. We used Google Collaborator (Google Collab) to build and analyze our models. The model was trained to classify individuals based on the infertility type using the questionnaire data. They are classified into two groups: primary infertility and secondary infertility. Secondary infertility represented the majority classes (60%), whereas primary infertility accounted for 40%.

MODEL VALIDATION

The machine learning model used for predicting infertility type (primary or secondary) showed good performance with high accuracy and low log loss, suggesting that it successfully predicted both the class labels and the probabilities of infertility type. These results are also supported by the confusion matrix, where most predictions fall on the diagonal (correct classifications), with only a few misclassifications. In particular, the model

Table 1. Sociodemographic characteristics of respondents

Items total (268)		Frequency	Percentage	Chi-square	P-value
Age Groups (Years)	17-26	107	39.9	95.694	0.001
	27-36	124	46.3		
	37-46	37	13.8		
Educational Levels	Not read or write	39	14.6	172.597	0.001
	Read and write	66	24.6		
	Primary	85	31.7		
	Secondary	31	11.6		
	Tertiary	20	7.5		
	Diploma	6	2.2		
	Bachelor	15	5.6		
	High education	6	2.2		
Occupation	Housewife	227	84.7	510.209	0.001
	Governmental Job	13	4.9		
	Privet Job	9	3.4		
	Other	19	7.1		
Income levels	More than sufficient	12	4.5	143.761	0.001
	Sufficient	172	64.2		
	Not sufficient	84	31.3		
Resident	Rural	86	32.1	34.388	0.001
	Urban	182	67.9		

*Chi-square test is significant at the 0.05 level.
Source: Authors own work

has a sensitivity of 100% for secondary infertility (no false negatives), and a specificity of nearly 100% (only one false positive, a case of primary infertility predicted to be secondary infertility). But this single false positive may indicate some overlap in characteristics between primary and secondary infertility, suggesting the multifactorial nature of infertility, as shown in Figure 1.

MACHINE LEARNING RESULTS: ASSOCIATION BETWEEN ANXIETY AND INFERTILITY TYPE

Machine learning analysis revealed that secondary infertility was associated with higher anxiety severity. The proportion of women with secondary infertility increased progressively across GAD-7 categories, from 58.3% among those with minimal anxiety to 71.3% among those with severe anxiety, as shown in Figure 2.

RESULT OF MACHINE LEARNING: ASSOCIATION BETWEEN ANXIETY AND INFERTILITY DURATION

Clear relationship between infertility duration and anxiety severity (GAD-7). Moderate anxiety was the most common category across infertility durations, particularly between 3 and 8 years. Severe anxiety became more frequent with longer infertility duration, suggesting an increasing psychological burden over time, as shown in Figure 3.

DISCUSSION

In line with prior evidence, the present study supports the view that psychological stress is not merely a consequence of infertility but also an important factor associated with its clinical profile. Limited studies have integrated psychological and infertility factors, particularly in Iraq. Using artificial intelligence in infertility studies appears to be virtually absent, especially concerning predicting the type. Most participants were aged 27–36 years, with a statistically significant association (χ^2=95.694, p=0.001). This finding is consistent with studies showing a decline in fertility with increasing age and a higher prevalence of infertility among women aged 30–35 years [24-25]. Regarding education, 31% of participants had primary-level education, indicating a relatively low educational status among infertile women, which partially agrees with previous findings [26]. Housewives represented the majority of respondents

Table 2. Obstetric, Medical & Surgical, and Infertility Histories

	Answer	Freq.	%
Infertility and Obstetric History			
Period of marriage	≤ 3	64	23.9
	≥ 4	204	76.1
Period of infertility	≤ 3	86	32.1
	≥ 4	182	67.9
Type of infertility	Primary	145	54.1
	Secondary	123	45.9
Pregnancy No.	None	145	54.1
	1	60	22.4
	2	21	7.8
	≥ 3	42	15.7
Birth No.	None	215	80.3
	1.00	33	12.3
	2.00	10	3.7
	≥ 3	10	3.7
History of Abortion	Yes	70	26.1
	No	198	73.9
Still Birth	Yes	27	10.1
	No	241	89.9
Ectopic Pregnancy	Yes	3	1.1
	No	265	98.9
Period	Regular	152	56.7
	Irregular	116	43.3
Medical &Surgical History			
	None	172	64.2
	Hypertension	13	4.9
	Diabetes	6	2.2
	Thyroid Disease	7	2.6
	Polycystic ovary disorder	48	17.9
	Other	20	7.5
	Migraine	2	.7
Gynecological history	None	191	71.3
	Tube Surgical	10	3.7
	Uterus	12	4.5
	Ovaries	12	4.5
	Virginal	3	1.1
	Cesarean section	40	14.9

Source: Authors own work

(84.7%), a factor that may affect their ability to cope with infertility and its psychosocial consequences [27]. Income was also significantly associated with study outcomes (p=0.001), and 64.2% of participants reported sufficient income, which may facilitate access to infertility treatment [28]. Furthermore, most participants lived in urban areas (67.9%), with a significant association (χ^2=34.388, p=0.001), reflecting disparities in access to infertility services between urban and rural populations [29]. Most infertile women had been married for ≥4 years (76.1%) and had experienced infertility for ≥4 years 67.9%. Similar findings were reported by Singh and Chand (2025), who highlighted the association between prolonged infertility and increased psycho-

Table 3. Distribution of anxiety scores of GAD7

Anxiety Levels	Freq.	%	Value-test	P-value
Minimal Anxiety	43	16.0	0.211	0.001
Mild Anxiety	94	35.1		
Moderate Anxiety	84	31.3		
Severe Anxiety	47	17.5		
Total	268	100.0		

*Significant at level 0.05.
Source: Authors own work

Table 4. Coefficient linear regression between the overall GAD-7 and infertility-related variables (infertility type and duration).

Model	R	Prediction	Df	T	Sig.
Types of Infertility	0.092	8.445	1	9.193	0.000
Duration of Infertility	0.0117	8.982	1	17.935	0 .000

Source: Authors own work

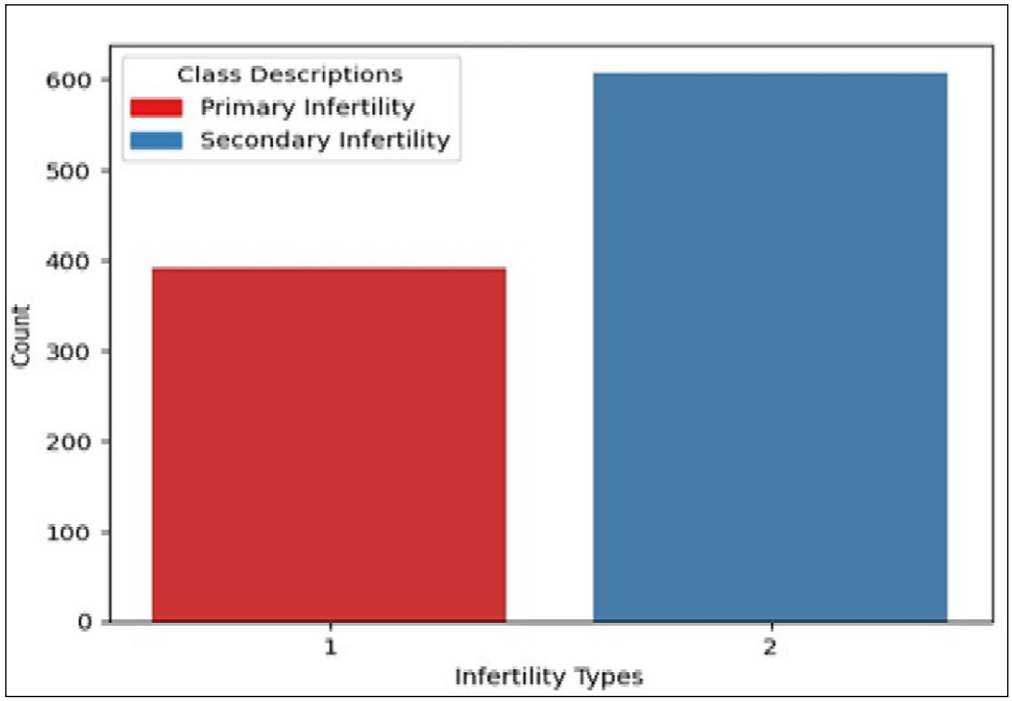


Fig. 1. Infertility type distribution
Source: Own materials

logical distress, anxiety, and depression [30]. Obstetric history was closely related to infertility type, as 54.1% of women had never been pregnant or given birth, corresponding to the prevalence of primary infertility 54.1%, while 45.9% had a history of pregnancy and childbirth, indicating secondary infertility. The higher prevalence of primary infertility is consistent with previous studies and regional patterns reported in North Africa and the Middle East [31-32]. Among women with previous pregnancies, 19.7% had experienced live births and 26.1% abortions, whereas stillbirth (10.1%) and ectopic pregnancy 1.1% were less frequent. These obstetric complications may adversely affect future fertility and contribute to secondary infertility through anatomical and functional reproductive disorders, including tubal blockage and impaired endometrial receptivity [33]. Polycystic ovary syndrome (PCOS) was the most frequently reported medical condition among participants 17.9%, consistent with the prevalence reported by Oriji (2019) (16.7%). PCOS is associated with menstrual irregularities, reduced fertility, and other reproductive complications [34]. Irregular menstrual cycles were reported by 43.3% of participants, a finding comparable to previous research 46.7% [35]. Most women 71.3% had no history of gynecological surgery, while 14.9% had undergone cesarean section, which has been linked to reduced fertility through factors such as uterine niche formation, intra-abdominal adhesions, and lower rates of future conception and live birth [36]. Anxiety was highly prevalent among infertile women

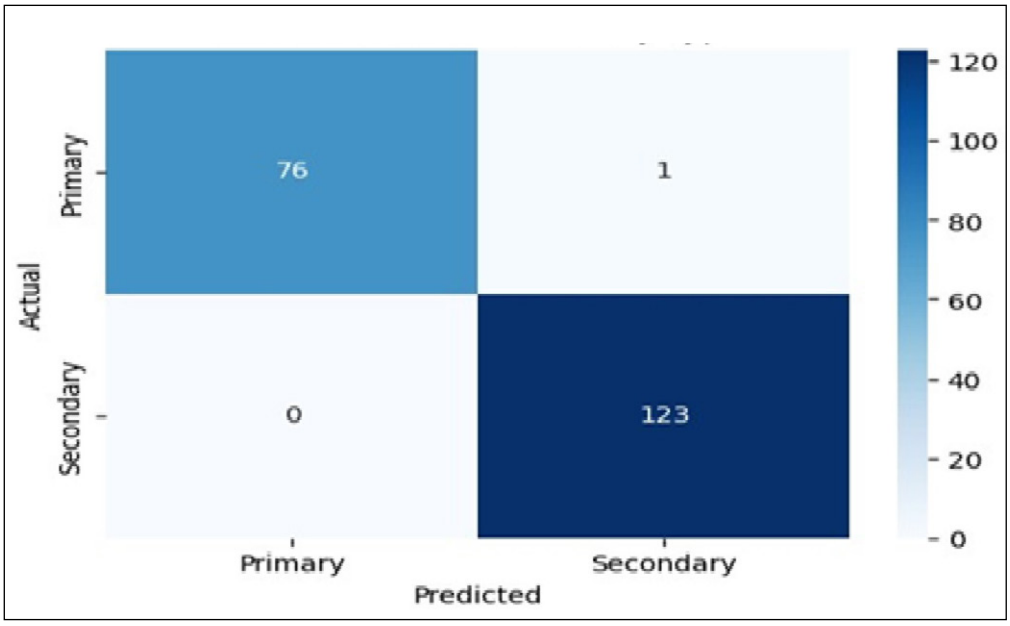


Fig. 2. Confusion matrix-infertility type
Source: Own materials

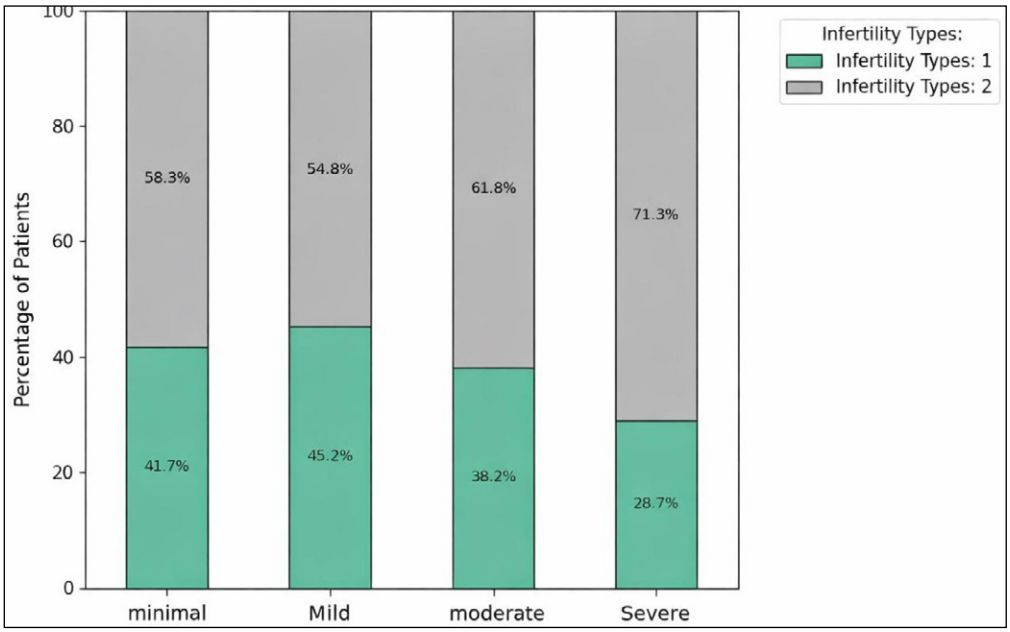


Fig. 3. Distribution within GAD-7 levels by infertility types
Source: Own materials

83.9%, exceeding the level reported in Erbil 36.6% [37], although lower than that reported in an Iranian study 92.5% [38]. Furthermore, mild anxiety was the most common level in the present study 35.1%, whereas moderate anxiety predominated among pregnant women in Al-Najaf 42.9% [27].The present study found a statistically significant association between anxiety levels (GAD-7) and infertility-related factors, particularly infertility duration and type $p<0.001$. Consistent with previous research, prolonged infertility was associated with higher anxiety levels, possibly due to increasing social pressure and the chronic nature of infertility over time [39]. However, some studies have reported no significant relationship between anxiety and infertility [40]. A significant association was also observed between anxiety and infertility type, suggesting that both primary and secondary infertility may contribute to elevated anxiety levels [41]. Previous studies reported increased odds of anxiety among women with secondary infertility (OR=1.27) and primary infertility (OR=1.24), while primary infertility was also identified as an independent risk factor for anxiety in men [42]. Overall, infertility duration appears to have a greater impact on psychological distress than infertility type or cause, highlighting the complex nature of infertility-related anxiety.

INTEGRATING AI AND TRADITIONAL STATISTICS

This research uses statistical and machine learning methods to study infertility. Statistics highlights significant

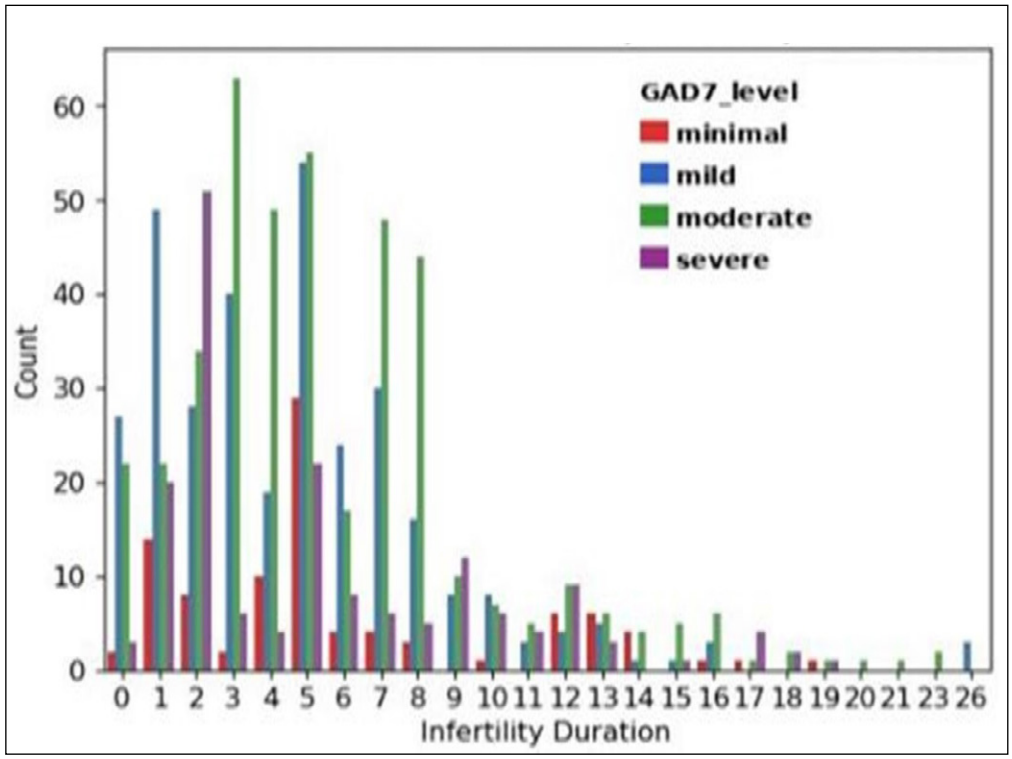


Fig. 4. Distribution of GAD-7 levels by Infertility duration
Source: Own materials

associations (e.g., between anxiety and infertility), and machine learning enhances infertility type prediction. They offer both explanation and prediction, enhancing the findings. The statistical analysis revealed anxiety was common among the participants, with the majority having mild and moderate anxiety, and a significant p=0.001. Linear regression also found a significant association between GAD-7 scores and infertility type and duration. Machine learning supported these findings, as the model showed excellent accuracy in predicting infertility type, with high sensitivity and low misclassification. Further, AI showed that secondary infertility was linked with greater anxiety across all GAD-7 levels, and anxiety levels increased as infertility duration increased.

CONCLUSIONS

This paper highlights the significant role of anxiety in infertility and shows that it is associated with the type and the duration of infertility. Elevated anxiety levels in infertile women are associated with both the duration and type of infertility, highlighting the necessity for prompt intervention. The research is a combination of traditional statistical methods and machine learning to increase the accuracy of the prediction of infertility phenotypes. It points out the importance of psychological support in the treatment of infertility and hints at the possibility of artificial intelligence in reproductive health studies, particularly in countries like Iraq. Longitudinal research and larger data sets should be the subject of future research to enhance predictive models in the treatment of infertility.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Atheer Kadhim Ibadi
Dean of Technical Institute, Kufa,
Al-Furat Al-Awsat Technical University,
Kufa, Al-Najaf, Iraq
e-mail: atheerkadhimibadi@yahoo.com

ORCID AND CONTRIBUTIONSHIP

Mariam Suhail: 0009-0000-0840-3240
Atheer Kadhim Ibadi: 0000-0001-8635-1052

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

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