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RESEARCH ARTICLE

DeepFert: An Intelligent Fertility Rate Prediction Approach for Men Based on Deep Learning Neural Networks

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ABSTRACT Men's fertility depends on their bodies making normal sperm and delivering them. Semen analysis has been the test of choice for assessing the male partner in an infertile couple using a single threshold value to distinguish 'abnormal' and 'normal' parameters. In the semen analysis process, rA©gime issues might affect the semen morphology, quality, and spermatozoa, and also reduce the risks of fertility due to food regimen including glycemic content and limited intake of nutrients. Determination of the connotation between adjustable rA©gime and semen morphology is a complex task to determine fertility. The goal is this study is the prediction of men's fertility rate to analyze the connection between spermatozoa and the level of lifeblood. Impaired semen parameters alone cannot be used to predict fertility more accurately. Some factors might affect the spermatozoa, like impairing sperm function, morphology, and sustainability, and can reduce the men's fertility rate. In this article, deep learning on convolutional neural network (DLNN) is used to predict the men's fertility rate more quickly, accurately, and consistently from different age spam of men between 18-50 years old. The convolutional neural network performs the segmentation of sperm heads, while the deep learning algorithm allows us to calculate the movement speed of sperm heads. After the application of DLNN, we have achieved semen prediction 80.952% and sperm concentration 85.714% accuracy of sperm head detection on human spermatozoa sperm samples. The results of the experiments presented below will show the applicability of the proposed method to be used in automated artificial insemination workflow.

INDEX TERMS Fertility, deep learning, neural networks, dwindled, spermatozoa.

I. INTRODUCTION

The men's body makes tiny cells called sperm. Men's fertility depends on their bodies making normal sperm and delivering them. Most researchers focus only on analyzing fertility with an association between male fertility and age. Conversely, the outcomes show dependencies with the age of the female partner. Comparisons between men over 50 and men under 30 found 38% and 23% relatively decreased pregnancy rates along with the control of less female age [1], [2]. In a hospital in Saudi Arabia, this research was conducted on patients diagnosed with infertility who experienced full assessments in-out-patient log books in the Quadra med system. The description of the patients includes the age of marriage, number of years, personal smoking habits, alcohol drinking, and primary or secondary infertility. Complete blood image, testosterone count, progressive motility, semen analysis, volume, and morphology were performed in laboratory

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tests. The data were analyzed by using the method of T-test. The mean spermatozoa limits were matched with the normal reference values defined by the WHO. Throughout the study period, the blood samples and semen of patients were available for analysis [3].

The purpose of this study is the prediction of men's fertility rate. In humans, semen analysis has been the test of choice for assessing the male partner in an infertile couple using a single threshold value to distinguish 'abnormal' and 'normal' parameters. Impaired semen parameters alone cannot be used to predict fertility more accurately [4]. The semen analysis helps to evaluate the association between spermatozoa and the level of lifeblood. Spermatozoa are important in semen parameters regarding male fertility and generative hormones. Some factors might affect the spermatozoa, like impairing sperm function, morphology, and sustainability, and can reduce the men's fertility rate [5].

A. WORLD HEALTH ORGANIZATION GUIDELINES FOR SEMEN ANALYSIS

Assessment of male infertility is still based on semen quality analysis according to World Health Organization (WHO) standards, including total sperm number, concentration, motility, and morphology. According to WHO standards, the assessment of male fertility is based on the evaluation of sperm quality parameters as fertility indicators. This article reviews the recent advances in evaluating various sperm-specific quality characteristics and methodologies [6], [7]. Semen primarily consists of two main components: the sperm and seminal fluid. Both of these components are examined in semen analysis regarding sperm count and semen volume. Semen analysis is mostly carried out to predict the men's fertility rate. However, carrying out this kind of prediction is a complex task. The analysis of men's semen characteristics is also carried out through potential neural networks to evaluate sperm donor candidates and the low quality of semen in fertility studies. This semen analysis consists of four parameters, including

- progressive mortality($\geq$25 μm/s)
- non-progressive mortality (<25μm/s and tail beat)
- mortality progression speed (5-25μm/s)
- level of immortality (beat less tail).

Semen quality may therefore be a fundamental biomarker of overall male health. According to WHO, the motility is often vigorous with a frantic shaking motion, but sometimes the spermatozoa are so agglutinated that their motion is limited. Any motile spermatozoa that stick to each other by their heads, tails, or midpieces should be noted. Whereas, according to Copenhagen Sperm Analysis Laboratory Report 2001, mortality decreases as the sperm concentration increases up to a threshold of 40 million/ml. As the percentages of motile and morphologically normal spermatozoa and semen volume increased. The decrease in mortality among men with good semen quality was due to a decrease in a wide range of diseases and was found among men both with and without children.

According to World Health Organization (WHO) standards, Motility is categorized as progressive, non-progressive, or immotile. The number of progressive motilities was assessed first, then the number of non-progressive motility and immortality. Further, progressive and non-progressive motilities are important in counting the percentage of motile sperm cells. For example, a sperm that vibrates in place would be considered motile but non-progressive. A sperm that zigzags but makes forward progression would be considered progressive. Progressive motility is needed for the sperm to swim their way up the female reproductive tract. Non-progressive motility refers to sperm that move but don't make the forward progression or swim in very tight circles. Non-progressive motility has different patterns of trajectory without progression. Total motility refers to the percentage of sperm making any movement. This movement can include non-progressive movements. However, very few spermatozoa with very poor motility can be found after several hours of initially immotile spermatozoa. Immotile sperm means sperm cells that do not show any movement. It's normal to have a small percentage of immotile sperm in a specimen. For a man to be fertile, he will need total motility of at least 40%, and his sperm needs to have progressive motility o 32% or more [8]. Semen is a type of fluid that is expostulated in the reaction of cellular segmentations (e.g., spermatozoa, juvenile germs, and epithelial germs) and non-cellular segmentations (e.g., formative plasma, formative vesicles, bulbourethral and prostate glands).

In Table 1, a comparison between semen meditation and semen motility based on different factors is shown.

Table 1 contains the number of questions normally used in the medical to understand the semen meditation and semen motility of a normal male in a week. In this questionnaire, the male age plays an important role in the analysis process at different times and places. To analyze semen meditation, germinal epithelium plays an important role, whereas to analyze semen motility, spermatozoa play an important role.

B. MEN's FERTILITY PREDICTION ISSUES

Smoking cigarettes is one of the most noxious causes of male fertility. The relationship between infertility and cigarette smoking has been premeditated for many years. However, studies on a large-scale population are still lacking premeditation. The bulk of the present work is within the reviewing studies dedicated to the significance of smoking on semen quality [9]. Individual discussions were accompanied and alcoholic subjects to get related clinical data, history of alcohol drinking, history of medical illness, infertility position and treatment, sexual resolution and frequency, history of smoking, and sexual pre-marital and post-marital detail. Sexual function like ejaculation frequency, erectile purpose, and effectiveness was also collected through a survey [10], [11]. This research was conducted by the University of

TABLE 1. Comparison between semen meditation and semen motility.

Relevant Factors	Semen Meditation	Semen Motility
Birthplace	Men's age at the time of sample exploration	Men's age at the time of sample exploration
Disease and Procurement	Disease types in Children (i.e., chickenpox, measles mumps, polio)	Matrimonial Prestige: Vaccinated
Syndrome Type	Surgical intercession	Number of siblings
Syndrome Reason	Severe trauma	Previous Radiation exposure time and date
Significant radiations exposure	Alcohol ingesting frequently	Daily Sleeping hours
Number of cigarettes used daily	Number of hours spent with chain smokers daily	
Years of smoldering convention		
Years of alcohol ingesting		
Time since wearing close-fitting clothes		
Number of playing sports hours daily		
Average secretion per week		

Graz, between January 1993 and September 2000, in the Department of Urology of Infertility Unit. The historical environment of men's unproductiveness for, at any rate, one year, who had the option to give a discharge, was successively evaluated. Work-up for barrenness unified a clinical history and actual assessment, just as the appraisal of hormone and semen boundaries. Particularly any history and especially medical past of former genital illness were measured using a survey including the duration of smoking and number of cigarettes smoked per day. Men who stopped smoking for more than six months before the inspection for infertility were considered non-smokers, and also who had never smoked as non-smokers. Those who smoked for more than six months and were still smokers were considered smokers. Smokers were characterized as mild (less than equal to 10 cigarettes per day), moderate (greater than ten and less than equal to 20 cigarettes per day), and heavy smokers (greater than 20 cigarettes per day). A urologist did physical tests. All men were studied to exclude the presence of a varicocele. Intravenous reflux was confirmed by Doppler ultrasound. However, a vast capacity of surveying data using IVF about smoking and its effects on semen analysis IVF outcomes and parameters, significant and population-wise effects of smoking in pregnancies are absent. However, the analyzed data of men with infertility, or those having strain perceiving, should leave smoking to enhance their likelihood of a positive beginning [7], [12].

In spermatozoa analysis, rA©gime issues might reduce the risk of fertility due to the food regimen, including glycemic contents and limited intake of nutrients that might affect the semen morphology, quality, and spermatozoa. However, there are possibilities of underestimation and overestimation of sperm number depending on the coffee, alcohol, and smoking used [7], [13]. The connection between the age of a male and semen morphology, with the deficiency of semen morphology, semen motility might also be decreased by 3% to 37% and semen volume by 3% to 22% between different ages of people [14].

In Table 2, it is shown that alcohol drinking is common in the Western world as well as Eastern World. Researches show a negative linkage between alcohol ingestion and spermatozoa quality. A high amount of alcohol drinking can affect the fertility of a man. Alcohol directly impacts the male genetic system and causes hormone imbalance in the body. Alcohol affects the male genetic system and causes a low sperm count. Alcohol may affect human health in the form of sexual or reproductive. Excessive drinking can shrink the genitals. Alcohol kills the cells that produce sperm. Thus infertility may occur. It can also make a lady less fertile; it may cause problems for the women conceiving. If a lady becomes pregnant and continues drinking alcohol, she may have a greater risk of miscarriage. Pre-term or underweight babies can also be born. There is a 40% chance that the child of the alcoholic mother may be affected by the fetal disease that is alcohol syndrome. These people suffer from heart and brain abnormalities, reduced growth hormones, and imperfect behavioral problems [15].

The references from fertility studies also support the harmful rising claim of the damaging effect on sperm using mobile phones, leading to lessened fertility in males. However, some other readings disclosed no distinctive linkage between the usage of cell phones and male infertility usage. The uncertainty of these faulty results is the cause of excessive usage of cell phones which are inflicting centralized damage to spermatozoa and the nervous system. Many aspects must be even before making assumptions [16]. Some recent report shows a connection between mobile phone use and male productivity. The apprehension has risen that ringing a cell phone near the generative system, such as the testicles, might be caused paralysis and, predominantly, a reduction in sperm production and growth, thus decreasing semen in men. A study examined the effect of the free radical structure due to mobile phone

TABLE 2. List of the variables for prediction of semen rate in men.

Feature Explanation	Range	Values
Season when analysis of semen features is performed	Winter, Spring, Summer, fall	-1, -0.5, 0.5, 1
Men's age at the time of exploration	21-30, 31-40, 41-50	0,1
Coffee Consumption	No, Yes	0,1
Alcohol Consumption	No, Yes	0,1
Smoking habit (cigarettes per day)	0, 1-5, 6-11, 11-20, More than 20	0,1
Number of hours spent with chain smokers daily	0-12	0,1

knowledge and the effect on productiveness patterns in male Wister rats. The male reproductive system makes stores and transports sperm. Chemicals in the human body called hormones control this. In this study, they disapprove of all the harms of pesticide effects on the male reproductive system. The result indicates that numerous factors affect sperm quality exposed to pesticides. Most pesticides include phosphorus that affects the male reproductive system, including deficiencies like reduction of sperm counts, density, motility, testis weights, increasing abnormal sperm morphology, change in plasma levels, reduced weight of testes, and damaged sperm DNA and enzymes level. Damage to the reproductive system can cause low or no sperm. About 4 out of every ten men with a total lack of sperm have an obstruction within the tubes the sperm travel through. A birth defect or a problem such as an infection can cause an obstruction [17].

Results revealed that semen parameters containing spermatozoa morphology, volume, viability, progressive motility, and declining cells were weak in the physically inactive set compared to the physically active group. The value of moribund spermatozoa was considerably different in both sets. However, spermatozoa DNA damage, mitochondrial potential, and lipid peroxidation were not dissimilar in both groups. Hence the physical movement demonstrations improved spermatozoa parameters more than the inactive set. Regular physical activities benefit sperm fertility, and men's parameters and fertility status could be enhanced by adopting such a lifestyle [18], [19]. Polycystic Ovary Syndrome (PCOs) is an important factor caused for ovulation disorder and infertility issues in women due to ovulatory dysfunction. Chronic dysfunction may cause female infertility and can induce hypo-estrogenism. These issues can be handled by managing disorder ovulation induction through Myo-inositol, D-chiro-inositol natural insulin sanitizer, and vitro fertilization sperm injection [20].

Infertility is a global health issue affecting women and men of reproductive age with increasing incidences, partly due to greater awareness and better diagnosis. There is an association between thyroid autoimmunity and male infertility. In previous research, significant progress has been achieved in cell and gene therapies as an emerging treatment option for infertility. Cell therapies utilize living cells to restore healthy tissues, usually involving platelet-rich plasma and various stem cells. Cell and gene therapies hold great potential for treating autoimmune conditions [21].

II. LITERATURE REVIEW

Contact with pesticides may affect the reproductive system and different body parts. Recent decades have been at the center of attention, which has led to infertility and disorder of the reproductive system. According to current knowledge, pesticides might lessen the semen quality in bare working conditions. However, many studies have proposed that these actions are not clarified yet. This paper's objective was to disapprove all the harms of pesticide effects, as the study shows on the male reproductive system. The result indicates that numerous factors in working scenarios affect sperm quality exposed to pesticides. Most pesticides include phosphorus that affects the male reproductive system, including deficiencies like reduction of sperm counts, density, motility, testis weights, increasing abnormal sperm morphology, change in plasma levels, reduced weight of testes, and damaged sperm DNA and enzymes level. Although a damaging consequence of insecticides on male sperm quality is not refuse able, to clarify all the possible affecting variables, well-proven and long-term studies are required [22]. Corpulence can ruthlessly affect human fertility. While plumpness can annoy a little in male fertility, it is concurrent with fertility loss and abnormality in the female hormonal profile. This study shows the unsuccessful pregnancy achievement by getting the samples of 153 donors who had tried for over 12 months. The men's age and Body Mass Index (BMI) were recorded and intended. All samples were tested for morphology, volume, motility, and concentration to conclude the effect of eminent BMI. On the contrary, increasing age might affect the expostulate fertility quality. Chromatin reliability is a main factor that might affect fertility instead of basic spermatozoa factors in men [23]. Studies have been conducted that cigarette smoke depressingly affects seminal plasma, sperm parameters, and various other fertility aspects. Nonetheless, the effect is clear as it escalates the existence of reactive oxygen kind. The impact of smoking on semen boundaries is predicated by using well-developed genetic verdict that leads to oxidative anxiety. OS has stressful effects on spermatozoa parameters, like impairing sperm function, morphology, and sustainability, finally reducing male fertility. This study enlightens the doubtful linkage between smoking and male fertility to calculate male infertility with tobacco consumption [24]. In this study, Polychlorinated biphenyls and organochlorine pesticides were analyzed in the plasma of 20 men with poor semen quality, 20 with normal semen quality, and female factor subfertility. A sample of seminal fluid was also analyzed to assess the relationship between the levels in blood and semen. The levels of organochlorines in the seminal fluid were proportional to the levels in plasma but approximately 40 times lower. Men with poor semen quality were three times more likely to be plump than men with normal semen quality. There was a significant negative correlation between semen quality parameters and body mass index among men with normal semen quality. The prevalence of inactive work was lowest among men with the best semen quality [25].

In this study, the potential effects of xenoestrogens on fertility or sperm parameters were investigated by comparing groups of subjects exposed to different levels of these chemicals. One group of men with poor semen quality and another with normal semen quality were selected to determine the organochlorine blood contents. From these groups, organochlorine compounds, including polychlorinated biphenyls and metabolites, were detected. These concentrations were compared to semen parameters. A comparison of both groups did not reveal significant differences in organochlorine levels. The finding of a significantly decreased sperm count about an elevated polychlorinated biphenyl metabolite level in the subgroup of men with normal semen quality [26].

Tobacco smoke contains over 4000 elements, including tar, nicotine, carbon monoxide, polycyclic hydrocarbons, and weighty metals. As a result of the unpredictability of tobacco segments, the toxicological system is extraordinarily convoluted. Most examinations have detailed decreased semen quality, conceptive hormone framework brokenness and weakened spermatogenesis, sperm development, and spermatozoa work in smoker's contracts. In this survey, an attempt was made to overcome this system from these hidden unsafe impacts, but current examinations concerning this harm stay deficient [27].

A study was implemented to calculate the spermatozoa eminence of 1346 healthy men resident of the Chongqing area of China in 2007. A framework was developed to inspect the factors of sperm quality according to spermatozoa parameters given by World Health Organization (WHO) standards and was compared. According to WHO standards, healthy males in southwest China had unusual values of spermatozoa parameters in quantity. The semen parameters, other than Chinese, USA, and European populations, were distinctly different from those in the study reported. These differences remain mysterious and may be due to environmental factors, demographic appearances, genetic variation, or lifestyle [28].

It has been proposed that obesity (BMI) is especially connected with infertility in men as spermatogenesis plays a role in semen parameters regarding male fertility and generative hormones. In men, the procreative phase of this study aimed to inspect the linkage between reproductive hormones and BMI with semen parameters. This analysis didn't find evidence of a linkage between spermatozoa parameters and increased BMI. From most studies, data is not accumulated from meta-analysis as population-based studies need higher vast and longitudinal studies and more sample sizes [29].

In this study, we have collected semen sample data from 85 men for cross-validation. As a sample, we took 20 normal men's semen data and 25 men with poor sperm quality data. We examined organochlorine pesticides and polychlorinated biphenyl by applying machine learning, K−1 clusters, and neural network techniques. The sample data is analyzed to judge the connection between spermatozoa and the level of lifeblood. Later on, for cross-validation purposes, the semen data is erratically classified into 5 and 10 subsets. In each iteration, we have calculated the mean accuracy rate. After analysis, it was observed that the outcomes specify no variance in the stages of organochlorine in fluid but approximately 40 times lower the plasma level [30].

Reproduction and fertility are compromised by activities like smoking a cigarette, alcohol intake, and substance abuse. However, the strength of these relations is not uncertain. There is debate in the scientific literature about the relationship between adversative effects on human generative health and exposure to environmental contaminants. These have been spread into drawing enlarged regulatory and public attention. With exposure to environmental contaminants, the human reproductive system is theoretically under attack, particularly with those chemicals that expose the effect of endocrine homeostasis. Consequently, the paper's objective was to assess the bondage between adverse effects on fertility and lifestyle exposures and investigate the role of environmental pollutants in the decline of the pathophysiology of subfertility, semen quality, endometriosis, and polycystic ovarian syndrome. The conclusion was that cigarette smoking is strongly related to opposing reproductory results and exposures to other lifestyle factors have a weak connection with a negative fertility rate. Finally, there is no clear sign that having no positive or negative outcome on reproductive health [31].

Obsessed and overweight men have been testified to have inferior spermatozoa value. The purpose of this study was to calculate that changes in semen parameters relate to body mass index (BMI). 852 sperm parameters were studied with the reproductive age of 25-50 of normal and healthy men. Body mass index was separated into four sets: normal, overweight, underweight, and obese. The sperm concentration of normal BMI was 71, while the overweight BMI was 63, and the obese men were 62. Compared with normal body mass index, sperm motility and spermatozoa count in obese and overweight men were considerably lower, while sperm morphology was alike. The results revealed a significant opposite association between sperm parameters and BMI [32].

On male propagative health, to investigate the probable effects of lifestyle factors, signs of a worldwide weakness in human spermatozoa value since last some decades have been analyzed. Modifiable, professional, eco-friendly life aspects might be subsidized in failure. The proposed framework emphasizes major lifestyles related to male infertility, like the use of drugs, alcohol intake, obesity, psychological stress, smoking cigarettes, and excessive coffee ingesting. Other features, such as testicle heat stress and prolonged sleep duration, are shortly discussed. Within the last decade, a wide-ranging writing search was made to detect and produce all relevant evidence, generally on the major for a long time of sitting, related to male infertility and sperm quality. Data storage was limited to articles and reports published in various magazines [33]. It is found that there is no association between the uses of alcoholics' biomedical tests such as blood glucose, creatinine, cholesterol, high and low hypertension level, protein, total bilirubin serum glutamate, etc. No notable changes originating intended the two sets for hematologic parameters like hemoglobin white blood cells, red blood cells, average corpuscular volume, platelet count, average corpuscular hemoglobin concentration, and packed cell volume [10]. According to [34], deep learning approaches showed that video-based analysis could provide important characteristics of spermatozoa. As deep learning algorithms generally require large amounts of data to perform well, this circumstance might have prevented the MLP from achieving better results. According to [35], deep learning is a promising method for human sperm analysis. According to the authors, deep learning is based on CNN to predict sperm motility and sperm morphology. All experiments aim to utilize the information in videos. The experiments can primarily be split into four distinct groups. Firstly, combine multiple frames channel-wise and feed this directly into the DLNN. Secondly, we vary the number of frames used in each sample to see how this may affect the algorithm's prediction performance. Thirdly, we threshold the color of each frame in an attempt to separate the spermatozoa's bright color from the darker background and use this information for prediction. Lastly, we add the patient data to the video analysis to see how this may help the prediction. Reference [36] used Sperm morphology analysis for diagnosing male infertility. They first analyze the existing sperm detection techniques chronologically, from traditional image processing and deep learning method in segmentation and classification. They evaluate the efficiency of deep learning techniques over sperm microscopic videos of human sperm and related parameters to automate the prediction of human sperm fertility.

III. MATERIAL AND METHODS

A. SEMEN ANALYSIS

Infertility is a global health issue affecting women and men of reproductive age with increasing incidences, partly due to greater awareness and better diagnosis. There is an association between thyroid autoimmunity and male infertility. In previous research, significant progress has been achieved in cell and gene therapies as an emerging treatment option for infertility. Cell therapies utilize living cells to restore healthy tissues, usually involving platelet-rich plasma and various stem cells. Cell and gene therapies hold great potential for treating autoimmune conditions [21]. Semen analysis is a central part of infertility investigation, but the clinical value in predicting male fertility is uncertain, particularly in the absence of a relation with traditional semen parameters. Sperm DNA damage may play a role, as drinking$>$3 cups of coffee daily has been described as a risk factor for sperm DNA damage independent of age [37].

Some factors such as dietary fiber, prebiotics, probiotics, polyunsaturated fatty acids, antioxidants, and different herbals are suitable to enhance men's fertility. Nutraceutical supplement foods might play a significant role in human health by maintaining and modifying some physiological functions to keep them healthy. This study also discussed that the proposed system would work only when genes, hormone levels, and environmental conditions are right [38]. Different nutraceutical supplementation factors such as dietary fibers, antioxidants, and herbs might play a significant role in human health, especially in women's health. These supplement factors might also be used to handle different health problems in women, such as obesity, cardiovascular, cancer, arthritis, diabetes, cholesterol, etc. [38].

B. DEEP LEARNING FOR SEMEN RATE PREDICTION

This study looks at the possibilities of deep-learning approaches for predicting sperm fertility. The goal of this study is to develop a model that is more accurate and trustworthy than current state-of-the-art models. The current work examines many deep-learning approaches in semen prediction [39]. This study uses a deep learning-based convolutional neural network approach to predict sperm motility from the semen sample to yield good results. The proposed system would evaluate sperm head motility in the human semen data [39]. Different deep-learning methods are used on the VISEM dataset to predict spermatozoa motility. The deep learning method might give consistent results and generalize well. Deep learning might be feasible in building a consistent and autonomous system. Our novelty is the application of a faster neural network for sperm head segmentation and identification for motility evaluation [40]. DLNN model can learn a compressed representation of the semen data and can be utilized in the context of sperm fertility prediction.

C. NEURAL NETWORK FOR SEMEN RATE PREDICTION

This research aims to develop an autonomous system with a combination of a neural network and a series of deep learning algorithms (DLNN) as a valuable tool to diagnose aridity patients with seminal disorders. Before developing a ‘‘Deep Learning Neural Network'' model, we studied dif-

TABLE 3. A comparison between different machine learning algorithms.

Random Forest	SVM+MLP+DT	DLNN
The random forest outputs a numerical value between 0 and 1. It was determined from these data that there were three roughly evenly sized groups: those with a low, equivocal, or high likelihood of clinically significant sperm concentration upgrade [40].	[41] conducted a study on male fertility analysis using Support Vector Machine (SVM), Mutlilayered Perceptron (MLP), and Decision Tree classifiers. According to the authors, the accuracy of these techniques in detecting sperm concentration and morphology is between 69% to 86%, respectively.	In humans, semen analysis has been the test of choice for assessing the male partner in an infertile couple using a single threshold value to distinguish 'abnormal' and 'normal' parameters. Impaired semen parameters alone cannot be used to predict fertility more accurately. The contribution of the Deep Learning Neural Network is to discuss the role and reliability of semen analysis in evaluating infertility more accurately, consistently, and quickly [4].

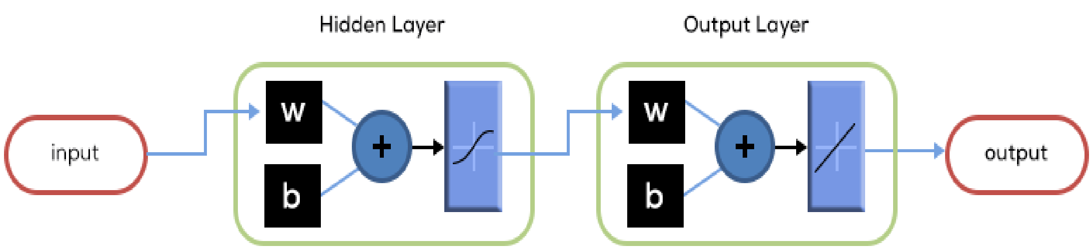

FIGURE 1. The figure depicts the architecture neural network model.

ferent AI tools, namely flow cytometry, Spectrophotometer, random forest support vector machine, multi-layered perceptron, decision tree, and deep learning-based neural network with a balanced dataset for prediction of men's infertility rate [39]. In this research, a comparison between different machine learning algorithms like Random Forest, Support Vector Machine, Multi-layered Perceptron, Decision Tree, and Deep learning-based Classical Neural Network for men's infertility rate prediction is given in Table 3:

To analyze men's semen more efficiently, accurately, and quickly, computer-assisted sperm analysis systems, convolutional neural networks,s and deep learning algorithms are used. A neural network (NN), just like the logical working structure of the human brain, is inspired by it. In this study, we have used DLNN for the reliability, accuracy, consistency, and quick analysis of semen data and to predict the fertility rate. In the men's semen sample data, a convolutional neural network has been adopted for the segregation and recognition of relevant semen image data, which is the limitation of the proposed model [4]. In this system, a neural network is used to analyze the men's semen fertility rate to predict semen mortality under spermatozoa's progressive, non-progressive, and movable prostatic fluid. For analysis of semen quality in men, the neural network has been adopted for men's sperm

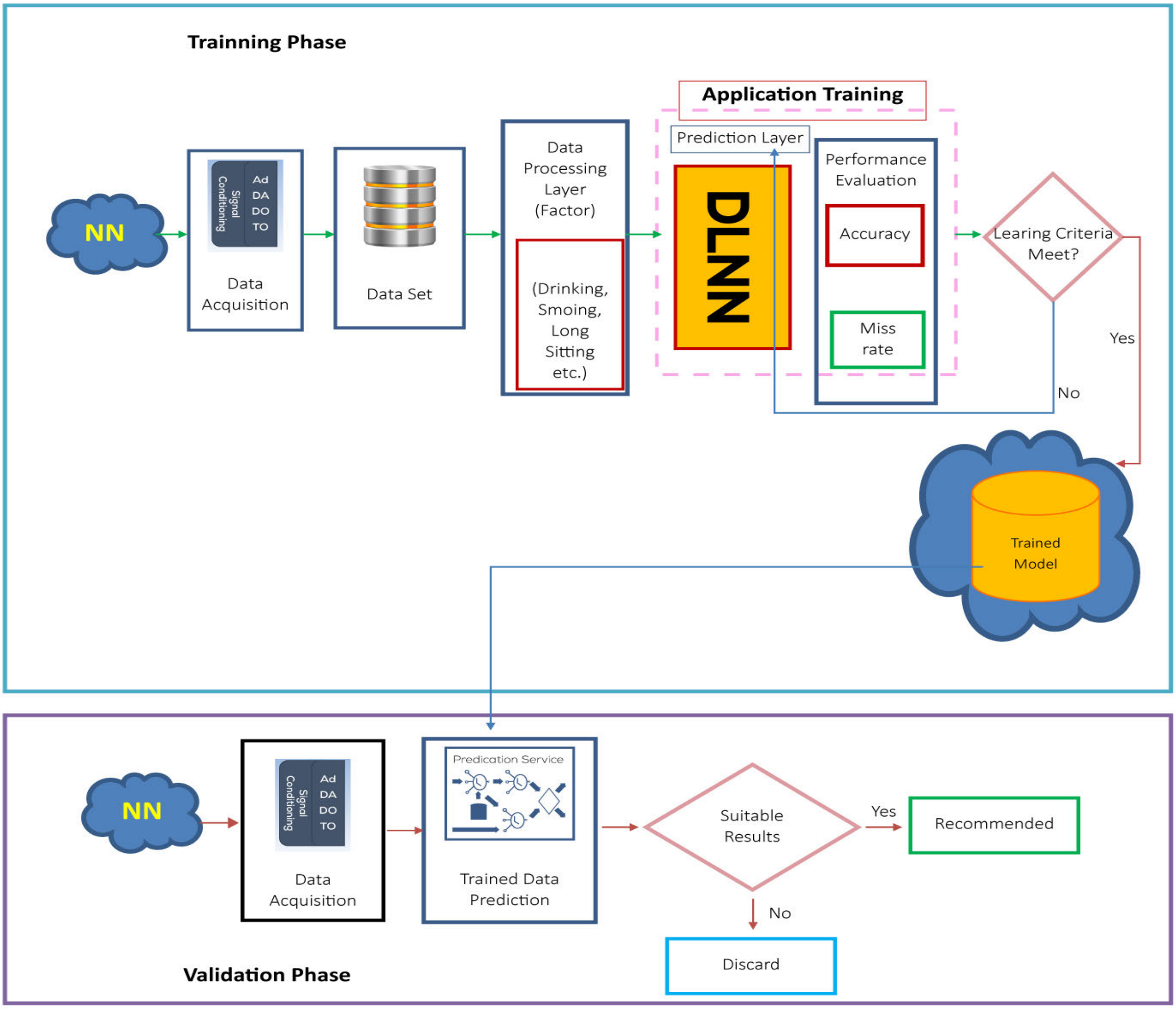

FIGURE 2. The figure illustrates men's Semen prediction system.

cell segmentation and recognition in semen sample images. A neural network (NN), just like the logical working structure of the human brain, is inspired by it. A neural network consists of artificial intelligence techniques and many neurons that generate the output with different amalgamations of input data after training the neurons. The elementary neuron is presented by a model shown in Figure 1.

A Neural network has become widely used in classification problems because of its excellent performance in recent years. The neural network consists of three layers, and each layer is trained through the weightage of the previous layer's output; the combined output of the model is calculated as follows:

$$h(n) = y(n-1)\, w\ (n) + bias \tag{1}$$

where h(n) denotes the hidden layer from 1 to N. $y(n-1)$ is the output of the input layer, $w(n)$ is the weights applied on the middle layer (hidden layer) and f is an activation function which is required to calculate the output of the model. The activation function used in hidden layers for feed-forward and modeled as:

$$f(x) = \max(0, x) \tag{2}$$

The sigmoid function shown in equation 3 is used on the output layer for predicting the class.

$$f(x) = \text{sigmoid}\ (\text{x}) = \frac{1}{1+e^{-x}} \tag{3}$$

However, recent advancements in semen prediction with CNN and DL can assess sperm concentration and the concentration of progressively motile spermatozoa. High precision and detailed analysis of sperm parameters are the advantages

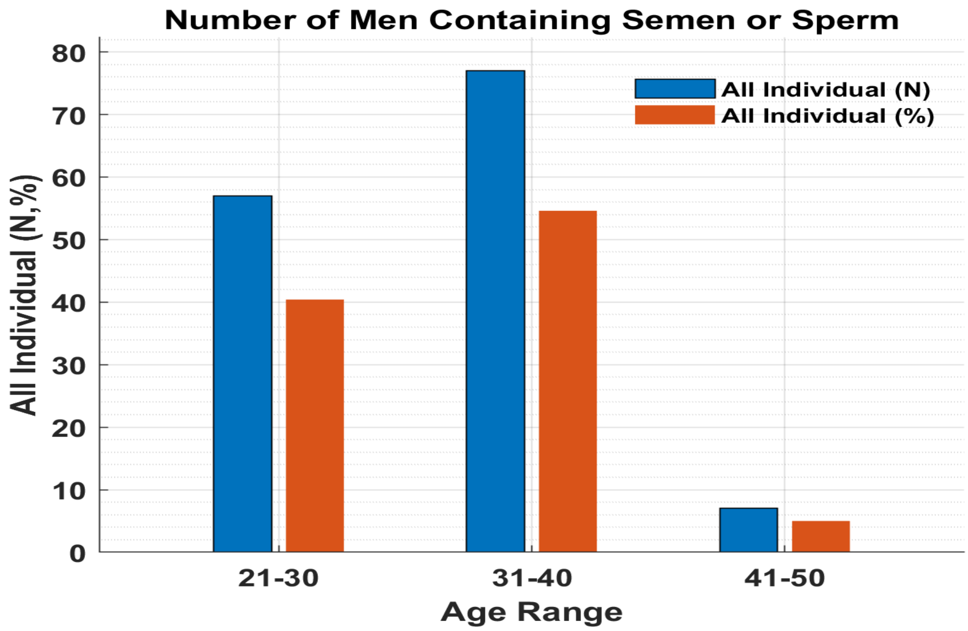

FIGURE 3. The figure illustrates number of men containing semen or sperm.

TABLE 4. Number of Men containing semen or sperm.

Age Range (Years)	All Individuals	
	(N)	(%)
21-30	57	40.4
31-40	77	54.6
41-50	7.0	5.0

of the proposed system over the manual methods. Generally, the proposed system classifies the sperm head and mid-piece as normal or abnormal based on the dimension of the head and mid-piece, head ellipticity, and regularity and measures the acrosome area using different staining methods. The autonomous system has greater precision and reproducibility than manual assessment. However, the accuracy of sperm morphometric assessment is compromised by methodological discrepancies and technical difficulties distinguishing sperm heads from debris, especially when sperm concentration is low.

In Figure 2, the neural network is used to analyze the men's semen fertility rate to predict semen mortality under the progressive, non-progressive, and movable prostatic fluid of spermatozoa based on the semen's images sample [4]. In this Figure 2, in the first stage, immediately after ejaculation, semen is typically a semisolid coagulated mass. Within a few minutes, in the second stage, the semen usually begins to thinner. For some time, liquefaction continues, the semen becomes more homogeneous and quite watery, and in the final stage, only small areas of coagulation remain. DLNN is proposed to limit the area accessed during three stages for scoring. Assess progressive motility first, then non-progressive motility and immobility. Then the number of spermatozoa was assessed to examine for motility. If there are problems with the technique, reverse the analysis order [42]. The Figure 1 shows that the Artificial Neural Network and its three layers, i.e., the Input layer used for taking data from the external environment, the hidden layer used for assigning weights to the input patterns, and the output layer to give an outcome of the system. In Figure 2, we have shown a Deep Learning based Neural Network, a combination of Classical Neural Network and Deep learning for analyzing the men's semen sample data based on Figure 1. In Figure 2, the upper part defines the processing of the men's semen sample data received from the Visem dataset, training the CNN using deep learning algorithms, and the below part shows the validation of the outcome of DLNN. If the outcome of the DLNN is not according to the desired outcome, the validated data is reprocessed until the desired outcome is obtained. Several regression models are trained to automatically predict the percentage (0–100) of progressive, non-progressive, and immotile spermatozoa. To improve the functionality of the DLNN, the layers of the neural network are trained through

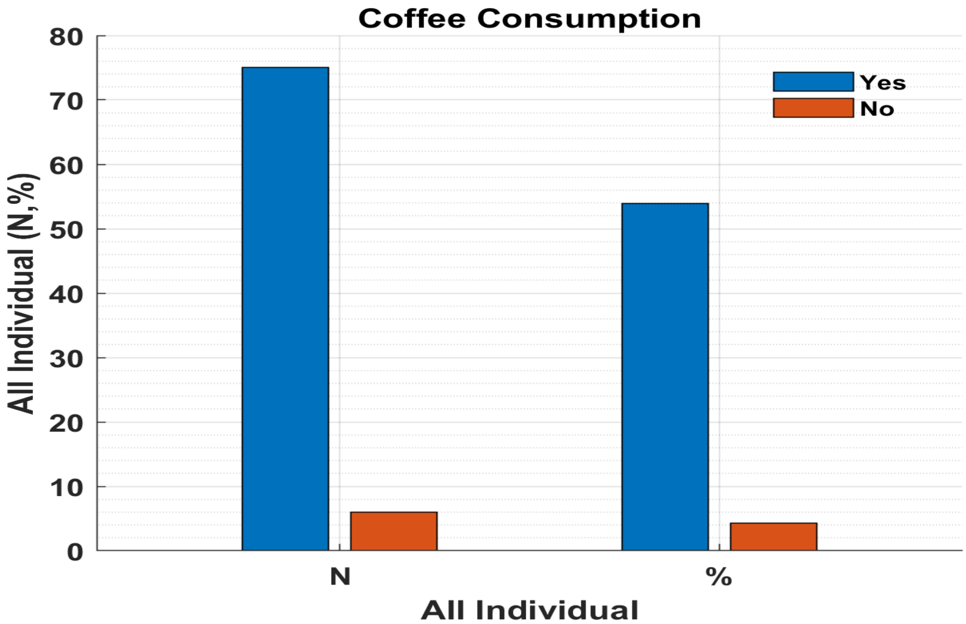

FIGURE 4. The figure illustrates number of men taking coffee.

a series of deep learning algorithms. In this process, a neural network is used to improve the accuracy of the aridity patients' valuation process and select the most appropriate features from the huge data of aridity patients.

Sample data of 85 men from age 18-50 years for cross-validation. As a sample, we have taken 20 normal men's semen data and 25 men with poor sperm quality data. Each sample was annotated with both motility and morphology characteristics. These values form the ground truth for the experiments conducted in this paper. Further, the dataset includes results of a standard semen analysis and a set of sperm characteristics, i.e., the level of sex hormones measured in the participants' blood and levels of fatty acids in spermatozoa. Additionally, WHO analysis data, e.g., the ground truth for sperm quality assessment, could be accessed [43]. In this system, the Deep Learning Algorithm for the prediction of men's semen quality by taking a sample of semen from different ages of people from 18-50 years shown in Table 4 and Figure 3. In this system, we have semen samples based on different habits like, coffee consumption shown in Table 5 and Figure 4, alcohol drinking daily based in Table 6 and Figure 5, smoking shown in Table 7 and Figure 6 that might affect the semen rate between different age people more accurately, more quickly, and more consistently. Convolutional Neural Network analyzes the men's semen fertility rate to predict semen motility under spermatozoa's progressive, non-progressive, and movable prostatic fluid based on the semen sample.

D. DATA SET VALIDATION

Semen samples were earlier obtained in a laboratory and processed under WHO recommendations. In compliance with the WHO 2010 protocol, sperm concentration and motility assessments were conducted. Semen samples were used to measure sperm motility, and one experienced laboratory worker examined each sample. To obtain a more reliable and broadly applicable evaluation for all trials, we provide the Root Mean Square Propagation (RMSP), which calculates the absolute error over three-fold cross-validation. Root Mean Square Propagation (RMSP), an objective function, is used to classify the instances and classes appropriately. It is also used to update the model's parameters and reduce errors. A powerful optimizer that can be used for mini-batch learning is RMSP. In RMSP, a moving average of the squared gradient is kept for each weight step:

$$r_t = (1-\gamma) f\,(\theta_t)^2 + \gamma r_{t-1} \tag{4}$$

where γ the decay is the term and θ is the network parameter.

$$v_{t+1} = \frac{\eta}{\sqrt{r_t}} f(\theta_t) \tag{5}$$

where η is the learning rate.

$$\theta_{t+1} = \theta_t - v_{t+1} \tag{6}$$

In this study, we use machine learning techniques with a dataset of 85 videos of human semen samples and related participant data to predict sperm motility automatically. Used techniques include linear regression and more sophisticated methods using convolutional neural networks. Our results indicate that sperm motility prediction based on deep learning using sperm motility videos is rapid and consistent. Our main approach uses CNN to analyze sequences of 250 frames from video recordings of human semen under a microscope to predict sperm motility in progressive, non-progressive,

TABLE 5. Number of men taking coffee.

Coffee Consumption	All individuals	
	(N)	(%)
Yes	100	70.9
No	41	29.1

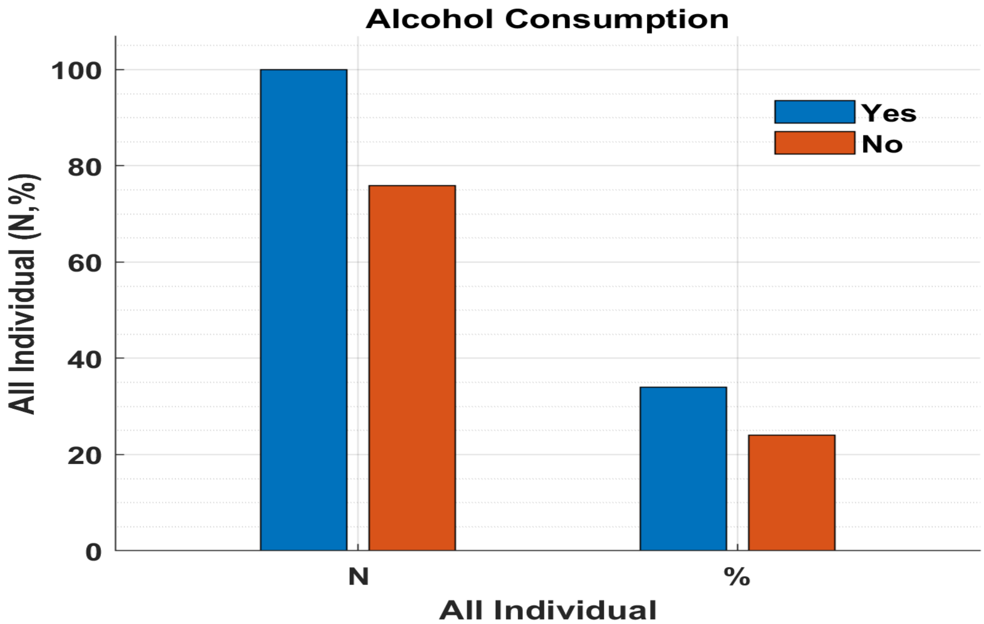

FIGURE 5. The figure illustrates number of men taking alcohol.

TABLE 6. Number of men taking alcohol.

Alcohol Consumption	All individuals	
	(N)	(%)
Yes	100	75.9
No	34	24.1

TABLE 7. Number of men smoking cigarettes per day.

Smoking Cigarettes(per day)	All individuals	
	(N)	(%)
0	76	53.9
1-5	6	4.3
6-10	20	14.2
11-20	31	22.0
More than 20	8.0	5.7

and immotile spermatozoa. As there are no related works to compare directly, we first trained a series of machine learning algorithms to set a baseline for how well we can expect our deep learning-based algorithms to perform. The presentation of our method is into three parts. Firstly, we describe the 70% dataset used for training and the 30% for validation of

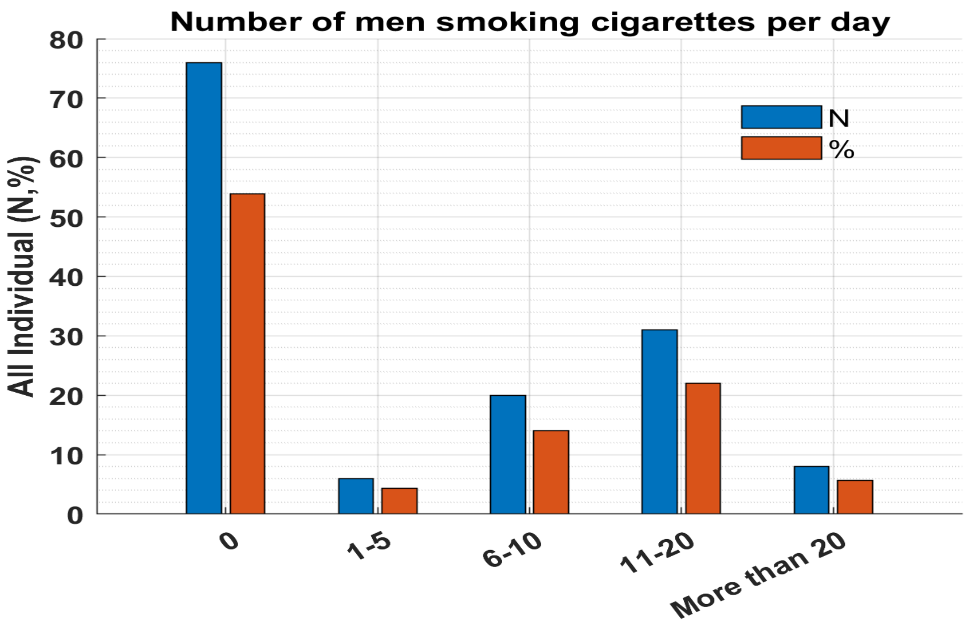

FIGURE 6. The figure illustrates Number of men smoking cigarettes per day.

the presented methods and the statistical analysis. Secondly, we detail how we trained and evaluated the method based on machine learning algorithms. Lastly, we describe our primary approach of using deep learning-based algorithms to predict sperm motility in terms of progressive, non-progressive, and immotile spermatozoa [34]. Normal sperm densities range from 15 million to over 200 million sperm per milliliter of semen. You are considered to have a low sperm count if you have fewer than 15 million sperm per milliliter or less than 39 million sperm total per ejaculate. The classification of human sperm heads can be simplified to a two-class recognition problem, such as normal and abnormal sperm heads. The developed deep learning method based on the CNN architecture for sperm head detection was tested on the dataset of sperm videos. The response of DLNN to different learning rates and the number of iterations were investigated experimentally. The algorithm achieved the best results by choosing the learning rate and the number of iterations. These parameters are optimal for sperm cell image segmentation to detect small objects such as sperm heads efficiently. Further work will include the validation of the DLNN on the human sperm head morphology dataset [1]. Figure 7, as a sample, we have taken 20 normal men's semen data and 25 men with poor sperm quality data, and examined organochlorine pesticides and polychlorinated biphenyl through applying machine learning, K-1 clusters, and neural network techniques. The sample data is analyzed to judge the connection between spermatozoa and the level of lifeblood. Later on, for cross-validation purposes, the semen data is erratically classified into 5 and 10 subsets. In each iteration, we have calculated the mean accuracy rate. After analysis, it was observed that the outcomes specify no variance in the stages of organochlorine in fluid but approximately 40 times lower than the plasma level.

E. CNN PERFORMANCE

Predicting of sperm parameter's class is the goal of DLNN. The outcomes of the CNN classification model are nominal, even though sperm variables are continuous quantitative data. To employ the semen evaluation class in this investigation, it was required to establish precise cutoff values. The suggested model will provide either normal or altered answers in this study. The full dataset (n=141) was divided into a test file, and several cases (n-43) from that file were used to control the learning network independently during the learning process. The output value that was produced was contrasted with the predicted value. Calculated was the difference between any of these numbers. In recent years, thyroid disorders have been the most common problems in men and women, such as infertility and miscarriages. Thyroid disorders require some care in pregnant women, as untreated hypothyroidism during pregnancy might lead to infertility, fetal deaths, premature deliveries, and abortions in women. The complexity of diagnosing some thyroid pathologies based on distinctive clinical and ultra-sonographic characteristics can be overcome by developing a deep-learning AI model to assist physicians [44].

The DLNN algorithm is suggested in this study to classify the fertility dataset successfully. Deep learning is utilized to build a feed-forward neural network for the simulation. There are numerous attempts to choose the various control parameters for the DLNN. After that, the output layer is subjected to sigmoid logistic regression using four hidden layers, each containing 48, 3612, and six neurons. The proposed

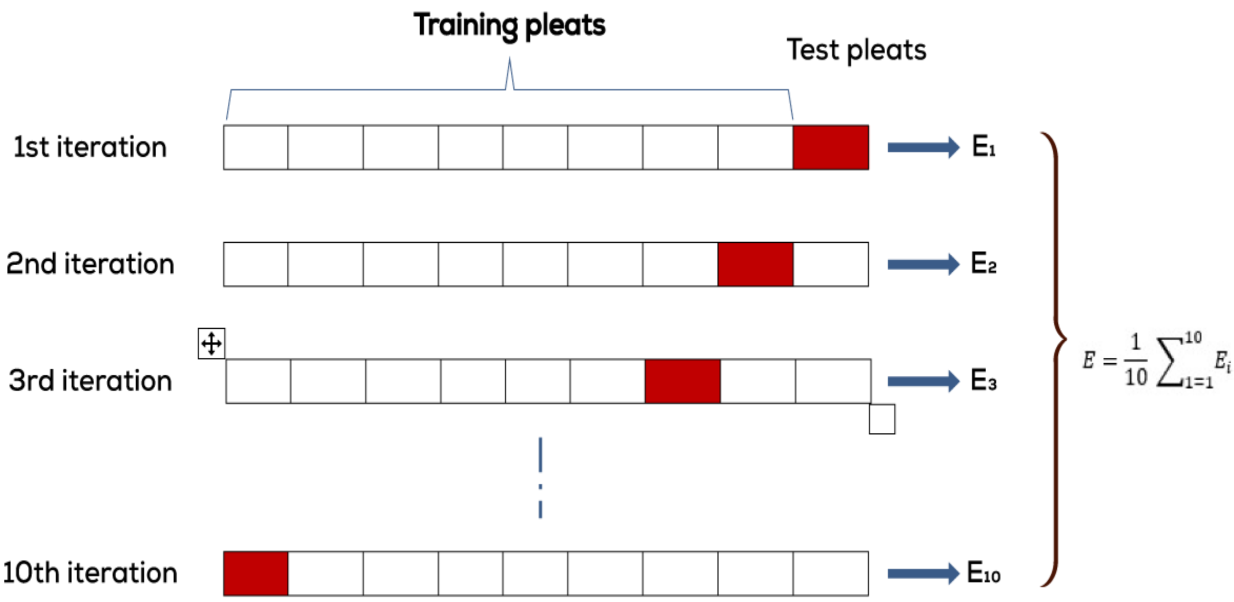

FIGURE 7. The figure depicts the three fold cross-validation methods.

TABLE 8. Table Sperm concentration and sperm motility classification matrix.

Matrix	Predicted	
	Normal	Altered
Sperm Concentration		
Normal	TP=84	FN=4
Altered	FP=5	TN=6
Sperm motility		
Normal	TP=75	FN=9
Altered	FP=9	TN=7

TABLE 9. Performance analysis of Men's Semen and sperm prediction system.

Parameters	Random Forest (%)	SVM (%)	MLP (%)	DT (%)	DLNN(%)
Semen Prediction	47.0	80.82	93.3.0	80.88	85.859
Sperm Concentration	75.0	69.0	69.0	67.0	92.259

model is optimized using the RMSP technique. The network's predictive values were determined based on the classification procedure outcomes.

$$Accurary = \frac{TP + TN}{TP + FN + TN + FP} \times 100 \quad (7)$$

$$True\ Positive\ (TP) = \frac{TP}{TP + FN} \times 100 \quad (8)$$

$$True\ Negative\ (TN) = \frac{TN}{TN + FP} \times 100 \quad (9)$$

$$FalsePositive\ (FP) = \frac{TP}{TP + FP} \times 100 \quad (10)$$

$$False\ Negative\ (FN) = \frac{TN}{TN + FN} \times 100 \quad (11)$$

where TP (True Positive): Semen of sperm concentration is normal and is properly classified. FP (False Positive): Semen or sperm concentration is altered and is improperly classified. FN (False Negative): semen or sperm concentration is normal and is improperly classified. TN (True Negative): semen or sperm concentration is changed and is properly classified [45]. Sperm concentration is the seminal parameter that shows the highest prediction accuracy. Although the accuracy of motility is slightly lower than concentration, it is possible

TABLE 10. Training set for analyzing the performance of the prediction system.

Fertility data (epoch)	Performance Validation		
	Train	Validation	Test Best
0	$10^{-1.6}$	$10^{-1.6}$	$10^{-1.6}$
2	$10^{-1.7}$	$10^{-1.5}$	$10^{-1.5}$
4	$10^{-1.8}$	$10^{-1.5}$	$10^{-1.4}$
6	$10^{-1.8}$	$10^{-1.5}$	$10^{-1.4}$
8	$10^{-1.8}$	$10^{-1.4}$	$10^{-1.4}$
10	$10^{-1.9}$	$10^{-1.4}$	$10^{-1.3}$
12	$10^{-1.9}$	$10^{-1.4}$	$10^{-1.3}$
14	$10^{-1.9}$	$10^{-1.5}$	10^{-1}
16	$10^{-1.9}$	$10^{-1.3}$	$10^{-0.8}$
18	$10^{-1.9}$	$10^{-1.5}$	$10^{-0.7}$
20	$10^{-1.9}$	$10^{-1.2}$	$10^{-0.6}$

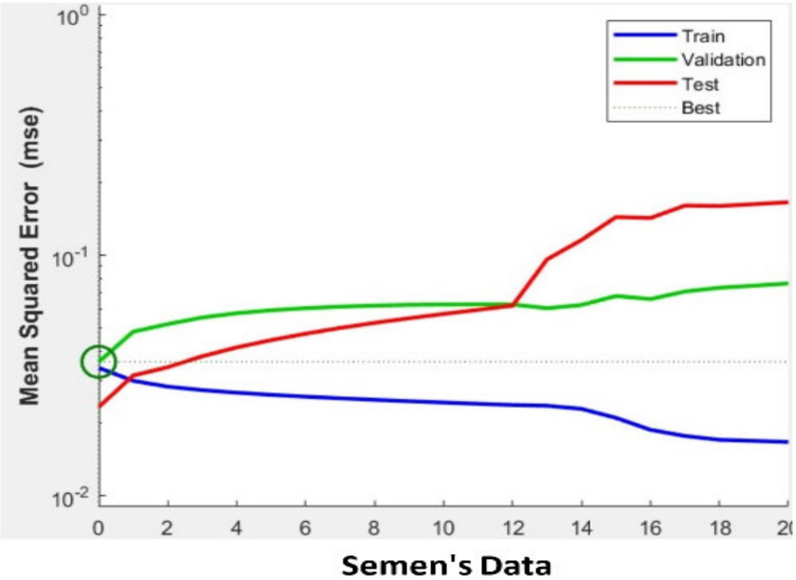

FIGURE 8. The figure illustrates performance validation.

to predict it with significant accuracy as shown in Table 8

$$\text{Sperm Concentration Classification accuracy}$$
$$= 84 + 6/(84 + 4 + 6 + 5) \times 100$$
$$= 90/101 \times 100$$
$$= 89.10$$
$$\text{Sperm motility Classification accuracy}$$
$$= 75 + 7/(75 + 9 + 7 + 9) \times 100$$
$$= 82/100 \times 100$$
$$= 82.0$$

The proposed architecture based on ANN and DL has been defined in this study since ANN significantly impacts its optimal performance. One of the most crucial steps in ANN is figuring out how many neurons should be in the hidden layer; if there aren't enough neurons there, the neural network won't be able to solve a particular problem. The ANN is overly complex. It becomes too tightly related to the data set and loses its generalizability. 11 input neurons, along with a layer of hidden neurons and two output neurons (normal, altered). A deep learning algorithm uses a back-propagation algorithm to train the network. The learning process will end when the network's error value is at its lowest during the optimal cycle. The Table 9 provides a comparison between different machine learning techniques for semen prediction and sperm concentration. After comparison, we have found that DLNN provides more accurate results of semen prediction and sperm concentration than already used machine learning techniques.

TABLE 11. Performance validation.

	Results
Performance	Best Validation Performance 0.036054 (at epoch 0)
Train State	Gradient = 0.008001 (at epoch 20)
Train State	Mu = 0.0001 (at epoch 20)
Train State	Validation Check = 20 (at epoch 20)
Regression	Train = 0.91695 , Validation = 0.91052 , Test = 0.94455 , All = 0.92021

IV. SIMULATION RESULTS

Table 10 and Figure 8 show the simulation results of the system after training the neurons in the input and output layers are shown in the figure below, which also contains the performance, training state, and regression plot respectively.

Table 11 shows that the DLNN algorithm is suggested in this study to classify the fertility dataset successfully. Deep learning is utilized to build a feed-forward neural network for the simulation. There are numerous attempts to choose the various control parameters for the DLNN. After that, the output layer is subjected to sigmoid logistic regression using four hidden layers, each containing 48, 3612, and six neurons. The proposed model is optimized using the RMSP technique. The performance of the semen rate prediction system can be optimized with the combination of a training set for the hidden layer of the neural network, a transfer function used to transfer data from one layer to another layer. The structure of the neural network to achieve minimum root square mean error (RMSE) of the system as shown in equation Eq. 12.

$$RMSE = \sqrt{\sum_{i=1}^{N} (Conc_{i,predict} - Conc_{i,experiment})^2 / N} \quad (12)$$

where Conc_i is a semen meditation for sample i, a purlin (linear, P), Logsig (log-sigmoid, L), and Tansing (Hyperbolic tangent sigmoid, T) are all the factors used as relocation functions and the deep learning algorithm is used for training the system. In neural networks, weights between 1 to 20 are assigned to achieve the lowest root mean square error for predicting the semen rate more accurately and to avoid the local minimum [46].

V. CONCLUSION

In this research, we aimed to review the role of myoinositol, a natural insulin sensitizer, on menstrual cycle disorder, ovulation induction, and in vitro fertilization sperm injection in women with PCOS. Polycystic ovary syndrome (PCOS) is the most common cause of ovulation disorders and infertility in women due to ovulatory dysfunction. Untreated chronic dysfunction may cause female infertility and induce hypo-estrogenism; therefore, Deep learning AI models assist physicians in managing this condition to account for specific patient characteristics [17]. In this research, we have presented the functionality of a newly developed system. In this study for the prediction of men's semen data between the ages of 18-50, we have used mainly three parameters: progressive, non-progressive, and immotile. The semen data is classified into four categories: true positive, true negative, false positive, and false negative, to predict the semen rate more accurately. Besides that, we have discussed different factors like human habits, including coffee, alcohol, and smoking per day, and environmental factors that might affect the fertility rate of semen in men. If you use some more factors rather than the existing ones, the prediction of the semen data using DLNN will become complex and time-consuming. It is observed that the deployment of the DLNN system in health centers is an interesting approach for semen fertility rate prediction. In the reproductive process of men's fertility, DLNN is used to predict the sperm injection of men and the presence of sperm with non-obstructive azoospermia in human health tests. In the future, the proposed system will be used to validate the human sperm head morphology dataset.

CONFLICT OF INTEREST

The authors declare that they have no Conflict of interest.

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