MACHINE LEARNING SOLUTIONS TO POLYCYSTIC OVARY SYNDROME: A REVIEW

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***Abstract*— Polycystic Ovary Syndrome (PCOS) is one of the most popular endocrine disorders. It isa kind of disorder which generally occurs in women when they are in their reproductive age. Women who suffer from PCOS can experience totally absence of menses, unstable menstrual cycles and as well as the rise in androgens or sex hormones. The ovaries will have many follicles at a time and they fail to ovulate an egg every month and may also lead to infertility. The major causes which lead to the syndrome are unclear till date. On the other hand, if the syndrome is not diagnosed early, it can lead to more serious diseases which include diabetes-2 and diseases related to the heart. The major objective of this paper is to review on the application of all the emerging technologies such as machine learning (ML), Artificial Intelligence (AI) in the detection of the PCOS. It will enable researcher to help in knowing what changes can be made in the technologies or what new technologies can be adopted to detect the PCOS. This research paper discussed the advantages, disadvantages and future direction of emerging technologies application in PCOS detection and prediction.**

***Keywords*— AI, androgen, follicle, ML, and PCOS**

I. INTRODUCTION

Polycystic ovary syndrome (PCOS) is an endocrine gland disorder which leads to the overproduction of the sex hormones which will eventually lead to infrequent menstrual cycles or the totally absence of the menses in the women. PCOS is basically directly connected with insulin resistance. A normal ovary has the ability to ovulate an egg every month while the ovary of a woman having the syndrome fails to ovulate an egg every month which will lead to the absence of menses and can also lead to infertility in the women who wishes to conceive. The syndrome can be detected by any clinical, biochemical criteria or through an ultrasound [1]. The underlying causes for the syndrome are unknown but it is observed that if a person has a certain genetic disorder then it will lead to the syndrome. When women having some specific genetic disorder are made available to some or few environmental conditions then the symptoms of the syndrome can come on surface [2]. A wide variety of clinical and biochemical criteria helps in the diagnosis of PCOS. The symptoms of high androgens may include acne, gain in weight, male pattern alopecia and the symptoms which helps in knowing thatovulation has not taken place [3]. Diagnosis is made when a woman has at least two of the following symptoms: polycystic ovaries (ovaries with many follicles), anovulation, and hyperandrogeneism (excess of sex hormones). If the syndrome is detected at the early stages then the long term effects of the syndrome can be prevented. According to the study, about 40-80% of patients suffering from PCOS are obese which increases the risk of diabetes-2 and as well as diseases related to heart metabolic syndrome and endometrial cancer[5-7]. PCOS is not diagnosed [8] easily though it is the most general endocrine disorder which is found in women [2]. Earlier studies related to PCOS come out with a lack in knowledge of the people about the syndrome and as well about its symptoms and the etiology [9]. Delays in the diagnosis of the syndrome may lead to the metabolic disorder [7]. Other studies regarding syndrome come out with that there was an increase in the symptoms and signs of the PCOS though there is no change in the awareness of the syndrome among the females, despite the fact that there was a continuous increase in the number of women suffering from PCOS. A lot of women even did not visit doctors suffering from PCOS[10]. Artificial intelligence and machine learning has been used to detect PCOS in the past.

Authors in [11] proposed an algorithm which was used for the optimal selection of the features and was known as the Binary Harris Hawk Optimization algorithm. The following methodology used by the Harris Hawk was the Harris Hawk Optimization. The selected features were evaluated with the help of the k-NN classifier.22 datasets were taken from the UCI-ML repository for the experiments out of which 5 datasets were clinical. The 5 clinical datasets were WDBC,and three more and the accuracy rates were 87.36%, 97.32%, 85.45%, 73.27% and 90.83% respectively. The presented work was also compared and found to be best in terms of various estimation values. Authors in [12] proposed the comparison of the five classifiers which were Naïve Bayes, logistic regression, and three more on the dataset of PCOS. The datasets were taken from different hospitals of Kerala, India and consist of different 23 features of almost 541 women. Feature extraction

was applied to the collected dataset with the help of principal component analysis. The random Forest algorithm was the best algorithm among all algorithms with an accuracy rate of 89.2%. Authors in [13] presented a classification framework for the detection of the PCOS using ultrasound images. The dataset consists of the 62 images from different women and 558 examples were collected out of which 9 were of great importance. The unwanted part from the images was removed with the help of histogram equalization. After removal of the noises the images were gone through feature selection which was performed with the help of firefly optimization algorithm. Feed forward neural network algorithm was used for the classification and the accuracy, precision and specificity rates were 98.63,100% respectively. This paper presents a review on technological advances to detect PCOS. A critical analysis of state of art approaches has been conducted.

Remaining part of the paper is organized as follows. Section 2 presents the state of art review of literatures, Section 3 of the paper gives the contribution to the literature and Section 4 concludes the work.

II. LITERATURE REVIEW

About 50-70% of women suffering from PCOS are also diagnosed with insulinresistance and as well hyperinsulinemia insulin which are considered to be the major symptoms of the PCOS[14,15]. About 65-80% of women suffering from PCOS are found with Oligomenorrhea or amenorrhea [16]. Low bone mineral density (BMD) contributes to the abnormal menstrual cycles which may also lead to low estrogen [17]. Few studies showed the protective effect of hyperinsulinemia which is mainly associated with PCOS [18,19]. Other studies suggested that lean women on which studies were carried out found to be have lower BMD relative to the controls, and on the other side obese women did not show any difference [20]. Moreover there was no difference in the BMD of the women with PCOS and the controls (healthy women)[21]. The very first treatment for the syndrome is the lifestyle change and as well as the weight management, it was observed that there were significant improvements when there was a decrease in 5-10% of the weight of the patient[22]. BMD is directly associated with the body weight of the patient [18]. Moreover, there was a lot of evidence to know the bone strength with the help of the bone geometry [23]. The important demonstration that is needed to be considered that a normal weight women with PCOS compromised BMD [20].

Authors in[24] introduced various image processing techniques which deal with the shape and features of an image including various morphological operations erosion, dilation, opening and closing and as well the two basic algorithms were also proposed using MATLAB programming with the interface [24]. The basic algorithms were boundary extraction and region filling. Authors in [25] compared various methodologies by histogram processing. The major importance of the various methods was to make changes in the contrast and brightness of an input image so that the image became more clear and vivid. While enhancing thebrightness and other important features of the image and the initial features and the real features of the image should be maintained [25]. Authors in[26] proposed a method for the ovarian classification on the basis of the number of follicles present and detection of the machine learning algorithms were introduced. Usage of various ML algorithms in the diagnosis and the classification of the ovaries made detection more precise. In the classification, a large number of features such as the ovary size, number of neurons, training functions were considered which helps in enhancing the performance of the algorithms for detection and classification to a large extent [26].

Authors in [27] proposed that for a large number of applications and in the image processing, enhancing the quality of the image feature extraction is an important methodology that can be used. Authors discussed various applications and the various types of feature extractions which help in knowing how a selected feature can be used in enhancing the performance of a particular model [27]. Authors in [28] proposed a novel hybrid structure for the early detection of the PCOS which basically was the combination of two algorithms used to find the result with high accuracy and precision. A real data set was used in the detection of the PCOS to produce the best model for the detection. The data was divided into training (70%) and testing (30%) [28]. Whale Optimization Algorithm (WOA) was a feature extraction technique which was proposed by authors in [29]. In WOA, 2 stages of feature extraction were basically modeled depending upon the kind of prey whale attack on and the kind of prey whales used in the search. For the evaluation of the subsets, k-NN as the fitness function wasused. Roulette wheel selectionprocess was basically used in WOA. UCI ML repository datasets were used for conducting the various experiments. A total of 18 datasets were taken for the evaluation and conducting the experiments. The accuracy rate for WDBC and Lymphography was 96.8% and 85% respectively. WOA outperformed the various other approaches and techniques that used various kinds of genetic algorithms and PSO. The changes made in the basic WOA algorithm helped in enhancing the quality and the performance of the result. A hybrid approach which uses common important data and the developed version of the Binary Cuckoo Search algorithm was used in the feature selection by authors in [30].To exclude the features which will not be used further were removed in the first filter stage using mutual information. In stage 2, the Binary Cuckoo Search algorithm along with the K-NN was used for the selection of attributes that are of importance and can be further used in the process. Six datasets were used here for the experiments. Accuracy rate of WDBC and SHD (Stat log Heart Disease) were 86.54% and 87.23% respectively their performance was superior to

the filter and wrapper approach. Data balanced and feature extraction was addressed by the framework proposed for the CDSS by the authors in [31]. For balancing all the datasets, SMOTE was used and Orchard's method was used for the enhancement of the balanced datasets. Wrapper approach was used for the feature extraction to select the featured subsets. Chaotic Multi-Verse Optimization algorithm was used and to measure the extent of goodness of the selected attributes Random Forest Classifier was used. Objective function used here was the Mathew's correlation coefficient (MCC) and the F-score. To classify the various clinical data RF classifiers were used and the criteria for the classification was the Information gain ratio and classification was done using 100 different kinds of decision trees. The proposed work is competitive with the other work which was shown using the statistical and empirical comparison.

A wrapper methodology was used for the selection of the attributes, Forest Optimization algorithm was used for subset attribute selection and measurement of goodness of the selected attributes are done by authors in [32]. 11 datasets were used for the UCI-ML repository to carry out the various experiments out of which four datasets were clinical. Accuracy rate of the clinical datasets (SHD, CHD, Dermatology and Hepatitis) were 85.15%, 55.55%, 96.99% and 86.45% respectively. The results of all the datasets excluding CDH were in competition with each other when a comparison was made on different kinds of algorithms with various wrapper methodologies. Since there was no satisfactory result for the CDH it was concluded that it was a multi-class dataset. The use of multiclass datasets was considered that their uses will be mentioned in the coming work. Authors in [33] proposed other filter-wrapper methodologies for selecting different estimation features of algorithms with the help of ACO algorithm. Heuristic desirability was calculated to evaluate the feature subset and to filter the features search procedure was used instead of the wrapper approach. Using the search procedure for selecting the important features reduces the complexity in the different calculations to a greatextent while the complexity in the calculations using wrapper approaches for the filtration of the attributes was very high. k-NN and Artificial Forward Neural network were the two classifiers which were used for the classification of the different datasetsused for the evaluation. 10 datasets of the UCI-ML were used out of which two were clinical. The accuracy rate of WDBC and Arrhythmia was 100% and 62.5% respectively. The results were compared with the other different wrapper methodologies or techniques and the result came out to be superior. Authors in [34] presented a framework which also consists of the wrapper approach supported by the three algorithms of feature selection. The three algorithms that were used for the selection of the feature subsets were Differential Evolution, LO and GSO. With the help of assembler optimal features were found. The selected dataset with the help of feature extraction is evaluated and tested further with the help of gradient descent BPNN. Datasets for conducting experiments were taken from UCI-ML repository out of which two datasets were of WDBC and hepatitis. The accuracy rate of hepatitis and WDBC were 93.3 %and 98.73% respectively. The proposed framework was also compared to the prior studies and found to be the best in terms of sensitivity, specificity and as well as the accuracy. Authors in [11] proposed an algorithm which was used for the optimal selection of the features and was known as the Binary Harris Hawk Optimization algorithm. The following methodology used by the Harris Hawk was the Harris Hawk Optimization. The selected features were evaluated with the help of the k-NN classifier. 22 datasets were taken from the UCI-ML repository for the experiments out of which 5 datasets were clinical. The 5 clinical datasets were WDBC, and three more and the accuracy rates were 87.36%, 97.32%, and 85.45%, 73.27% and 90.83% respectively. The presented work was also compared and found to be best in terms of various estimation values. Authors in [12]proposed the comparison of the five classifiers which were Naïve Bayes, logistic regression, and three more on the dataset of PCOS. The datasets were taken from different hospitals of Kerala and consist of different 23 features of almost 541 women. Feature extraction was applied to the collected dataset with the help of principal component analysis. The random Forest algorithm was the best algorithm among all algorithms with an accuracy rate of 89.2%. Authors in [13] presented a classification framework for the detection of the PCOS using ultrasound images. The dataset consists of the 62 images from different women and 558 examples were collected out of which 9 were of great importance. The unwanted part from the images was removed with the help of histogram equalization. After removal of the noises the images were gone through feature selection which was performed with the help of firefly optimization algorithm. Feed forward neural network algorithm was used for the classification and the accuracy, precision and specificity rates were 98.63, 100% respectively. Table 1 presents the state of art review on Polycystic Ovary Syndrome.

III. CONTRIBUTION TO THE LITERATURE

Out of 35 reviewed papers, it can be seen that clinical detection constitutes 50%, ML detection constitutes 29.4%, Deep learning based detection is 14.7% and statistical analysis is 5.9%. Hence there is a lot of scope to introduce new emerging technologies in the detection. We come out with new technologies added with the wrapper classes that help in increasing the performance of the classifier so that result can be obtained with maximum accuracy and high precision. To know the most suitable technology or the algorithm for feature subset selection is still an issue. An algorithm that works best on a selected database might not work in the similar way on the other datasets [35].

Table 1: State of art review on PCOS

S/N	Paper Title	Advantages/Disadvantages	Reference no
1.	Polycystic Ovarian Disease	The study helps in the awareness of PCOS among people so that people will be able to take necessary steps if detected. The main causes of PCOS are not detected.	2
2.	Clinical characteristics of polycystic ovary syndrome in Indian women.	All the clinical symptoms ofPCOS are discussed in the paper.	3
3.	Hyperandrogenism in polycystic ovarian syndrome and role of CYP gene variants.	This paper helps in the identification of the genes that alter the levels of androgen in women.	4
4.	Obesity and polycystic ovary syndrome	The paper gives the direct correlation of obesity and PCOS.It helps us in knowing obesity is the main cause of PCOS .	5
5.	Association between polycystic ovarian syndrome and endometrial, ovarian, and breast cancer	The paper basically deals with the correlation of endometrial and ovarian and breast cancer and how it leads to cancer.	7
6.	Exploration of lifestyle choices, reproductive health knowledge, and polycystic ovary syndrome (PCOS) awareness among female Emirati university students	It helps in spreading awareness of PCOS and what lifestyle changes needed to be adopted to overcome PCOS.	9
7.	Women with polycystic ovary syndrome have comparable hip bone geometry to age-matched control women	The paper comes out with the result that SPW might be changed but oligomenorrhea does not have any effect on the bone density of women.	15
8.	Bone mineral density is unaltered in women with polycystic ovary syndrome.	This study helps in knowing that there was no effect on bone density of women with PCOS .	18
9.	International PCOS Network. Recommendations from the international evidence-based guideline for the assessment and management of polycystic ovary syndrome	It basically helps in making awareness of PCOS and their symptoms internationally.	19
10.	Image Enhancement using Histogram Equalization	It basically used the histogram equalization method to identify the ovaries of women with PCOS with great accuracy and precision.	21

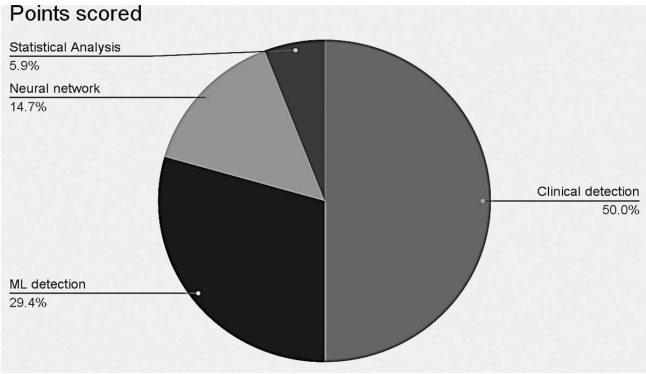

Figure 1: Percentage of various methods used in detection of PCOS

IV. CONCLUSION

It is found that various methods have been used in the detection of the PCOS out of which clinical detection constitutes 50%, ML detection constitutes 29.4%, deep learning based constitutes 14.7% and statistical analysis is 5.7%.

The limitations of the research are as:-There was no control group in the experiment to make the difference between exercise and various effects of diet, the studies even did not mention the effect of exercise can prevent loss of neck femoral in women with PCOS. Future studies should implement project that can decrease the computational time of the k-NN classifier. The further scope is also to determine whether exercise can help in maintaining femoral BMD in women with PCOS and can reduce the dangerous effect on the bone. Analyzing the datasets with other algorithms can be done since we know that a dataset providing good results with an optimization algorithm might not provide the same results with other datasets.

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