# A Neural Network-based Approach to Prediction of Preterm Birth using Non-invasive Tests

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## ABSTRACT

**Background:** One of the main reasons for neonatal deaths is preterm delivery, and infants who have survived preterm birth (PB) are at risk of significant health complications. However, an effective method for reliable and accurate prediction of preterm labor has yet to be proposed.

**Objective:** This study proposes an artificial neural network (ANN)-based approach for early prediction of PB, and consequently can hint physicians to start the treatment earlier, reducing the chance of morbidity and mortality in the infant.

**Material and Methods:** This historical cohort study proposes a feed-forward ANN with 7 hidden neurons to predict PB. Thirteen risk factors of PB were collected from 300 pregnant women (150 with preterm delivery and 150 normal) as the ANN inputs from 2018 to 2019. From each group, 70%, 15%, and 15% of the subjects were randomly selected for training, validation, and testing of the model, respectively.

**Results:** The ANN achieved an accuracy of 79.03% for the classification of the subjects into two classes normal and PB. Moreover, a sensitivity of 73.45% and specificity of 84.62% were obtained. The advantage of this approach is that the risk factors used for prediction did not require any lab test and were collected in a questionnaire.

**Conclusion:** The efficacy of the proposed approach for the early identification of pregnant women, who are at high risk of preterm delivery, leads to necessary care and clinical interventions, applied during the pregnancy.

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## Keywords

Premature Birth; Artificial Neural Network; Machine Learning; Preterm Delivery; Preterm Labor; Pregnancy

## Introduction

The World Health Organization (WHO) defines preterm labor as deliveries before 37 weeks of gestation. Premature birth (PB) is one of the most common causes of infant mortality and morbidity [1], leading to a high mortality rate, and in those who survived acts as one of the most important causes of neurological complications in the infant [2,3]. The majority of infants born with PB would require extensive care from specialists in the early years of life, imposing substantial costs on families and the health care system [3,4]. An estimated 15 million infants are born preterm every year which accounts for more than 10% of the total deliveries [5].

Various methods were investigated to predict PB in women with

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symptoms of preterm labor, such as measurement of cervical length and fetal fibronectin [6] and measurement of cervical length and cervicovaginal fluid cytokine levels [7]. For instance, high levels of maternal salivary cortisol in women with a threatening episode of preterm labor between 24$^{th}$ to 31$^{st}$ weeks of gestation can be a predictor of preterm delivery [8]. However, none of these techniques can objectively and accurately predict the timing of labor and prematurity of an infant, mainly due to their low positive predictive power [9].

Prevention of PB before the onset of preterm labor symptoms can reduce morbidity and mortality as well as the cost of treatment in this group of infants [10]. Several methods were introduced, such as the use of progesterone or cervical cerclage [11,12] to prevent PB. However, it is essential to first identify high-risk individuals to apply these methods.

Prediction of the onset of preterm labor is challenging due to affection by many parameters. Previous work employed machine learning (ML) to predict preterm labor. For example, Catley et al. predicted PB based on eight risk factors using an artificial neural network (ANN), but the results were not promising (sensitivity=55%) [13]. Mas-Cabo et al. conducted an ANN-based prediction of PB using electrogastrographic records. However, this approach may not be practical due to the high expenses of electrogastrography tests [14]. Moreover, Wlodarczyk et al. applied a convolutional neural network (CNN) on ultrasound images to predict PB, but this method required a sonography procedure that may not be available [15]. Among studies [13-15] on an ML based prediction of PB, either their performance was not promising [13], or they have applied expensive procedures that are not available in many medical centers, reducing substantially their usability [14,15]. This study aimed to propose an ML-based method based on routine tests and procedures for PB prediction. Efficient prediction of PB causes physicians to apply necessary treatments for the prevention of this condition, thereby greatly reducing mortality and morbidity.

## Material and Methods

### Population study

For this historical cohort study, data were collected from pregnant women admitted to Mahdieh Obstetrics and Gynecology Hospital in Tehran from 2018 to 2019. During the two years, 150 women who had a preterm delivery (delivery before the 37$^{th}$ week of gestation) with complete data were selected as the case group, and 150 women with natural delivery were randomly selected as the control group.

Data from pregnant women, including baseline demographic data and all information about previous pregnancies, were collected through interviews and questionnaires, physical examinations, and laboratory measurements. A total of 13 parameters, affecting the success of intrauterine insemination (IUI), including occupation, age, education, race, weight at the first trimester of pregnancy, body mass index (BMI), order of menses, parity, multi-parity, history of preterm labor in previous pregnancies, the interval between pregnancies, gestational diabetes, and blood type, were collected and selected as the ANN's inputs. The current study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences in Iran and all patients' data were kept confidential. This was a historical cohort study and previously collected data (from routine medical tests for pregnant women) were obtained from patients' files. Accordingly, no new procedure or test was conducted for this study.

### ANN

An ANN classifier was designed with one hidden layer with 7 neurons, in which sigmoid activation functions were used in the input and hidden layer. However, a linear activation function was applied to the output layer. Pilot studies showed that the ANN outperformed

linear and statistical classifiers, such as linear discriminant analysis (LDA) and Bayesian, respectively. The ANN was trained using the Levenberg-Marquardt algorithm. From the case and control groups, randomly, 15% of the subjects were selected for testing, 15% for validation, and 70% for training the ANN. The cross-entropy between the actual response and the ANN output was employed as the loss function. The ANN structure and training parameters were empirical (Figure 1).

### Evaluation of the ANN performance

Training and testing of the model were repeated 100 times, and the average results were reported. The ANN performance was assessed using three parameters: classification accuracy, sensitivity, and specificity.

## Results

The classification accuracy, sensitivity, and specificity of the test data were 79.03%, 73.45%, and 84.62%, respectively. Figure 2

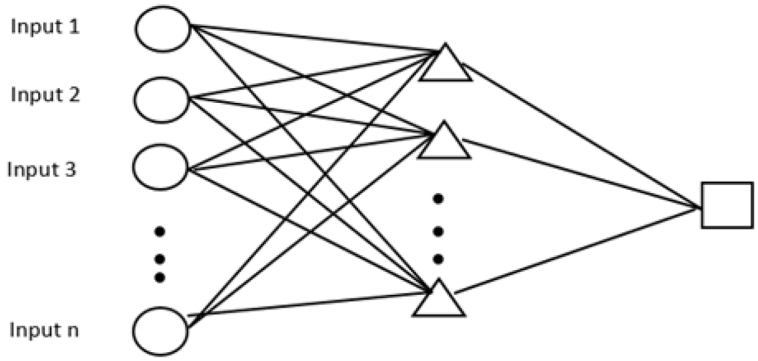


**Figure 1:** The structure of the proposed artificial neural network (ANN) for premature birth (PB) prediction; the number of inputs is n=13 risk factors, the number of hidden neurons (triangular nodes) is 7, and the output node outputs the predicted class: normal (0) or PB (1).

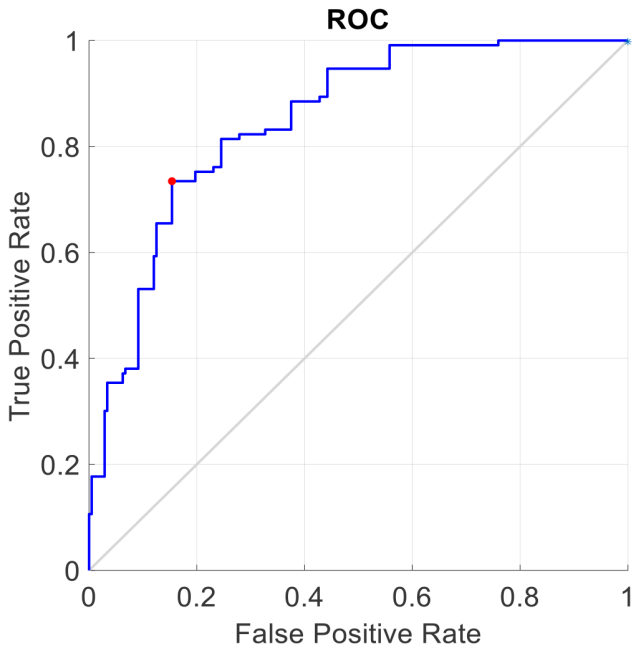


**Figure 2:** The receiver operating characteristics (ROC) curve of the proposed artificial neural network (ANN) for the test data

shows the receiver operating characteristics (ROC) curve.

In the case and control groups, the majority of the subjects were housewives (about 94.3%). Moreover, 95.4% of the subjects in the case group and 74.3% in the control group were Iranian (the rest were Afghans). The mean weight at the first trimester of pregnancy in the case and control groups was 60.26±13.3 and 65.58±10.63, respectively. Menses was regular in 83% and 79.8% of the subjects in the case and control groups, respectively. In addition, 11.3%, 60.4%, and 28.3% of the subjects in the case group and 3.8%, 60.6%, and 34.9% in the control group were in the age ranges of under 18, 18-30, and above 30, respectively. In addition, 45.3%, 41.5%, and 13.2% of the subjects in the case group had their first to third pregnancies, respectively. However, in the control group, 34.9%, 33.9%, 16.5%, and 14.7% of the subjects gave birth for the first to the fourth time, respectively. Moreover, 94.3% and 97.2% of pregnancies in the case and control groups were single, and the rest were twins. Furthermore, 7.5% and 1% of the subjects in the case and control groups, respectively, had suffered from preterm delivery complications in their previous pregnancy. The mean distance between pregnancies in the case and control groups was 1.8 and 2.5 years, respectively. Gestational diabetes was not significantly different between the two groups (the difference was approximately 3.3%).

## Discussion

In this study, an ANN was proposed to predict preterm delivery based on 13 risk factors. Several studies have previously investigated the prognosis of this complication. The advantage of the proposed approach is that it is non-invasive. In addition, the proposed method is very economical since no laboratory information was used. The classification accuracy of this study was 79.03%. However, increasing the number of subjects can significantly increase the performance of ML and therefore will be investigated in our future research. Moreover, the performance may improve by adding other risk factors as the ANN inputs, such as those suggested in [3,16], which will be also investigated in our future studies.

There is limited literature on the application of ML for the prediction of preterm delivery. Elaveyini et al. [17] achieved a classification accuracy of 70% for an ML-based prediction of PB, in which the low performance might be attributed to the small number of samples in their study (50 subjects). In 2019, Kwang-Sig Lee et al. [18] studied 504 pregnant women for ML-based prediction of preterm delivery with promising results, which were higher than that of the current study. However, as opposed to the current method, some of the risk factors [18] were noninvasive. Perhaps a larger statistical population and the involvement of additional risk factors as the ANN inputs, such as cervical length (which may have useful information for PB prediction) was the reason for the higher performance of the method in [18]. In addition to parameters, such as cervical length, some researchers have investigated the role of laboratory biomarkers in predicting preterm delivery [19-24]. The results of these studies indicate that their performance is not superior to the method presented in this research despite the imposition of cost and aggressive method.

The obtained results substantially outperformed those of Catley et al., in which 8 risk factors were used [13], due to the limited number of risk factors as well as the choice of risk factors. Mas-Cabo et al. used electrogastrographic records for PB prediction and achieved promising performance [14]. However, this approach is not practical, as it requires expensive lab tests, without any availability in many hospitals. Wlodarczyk et al. proposed using ultrasound images for CNN-based PB prediction [15], but despite the high computational complexity of this approach and the need for a sonography test, this method [15] achieved a lower sensitivity than that of the proposed

approach.

## Conclusion

This work proposed an ML-based approach for automated prediction of PB with the advantage of high practicality due to only 13 risk factors (as the model inputs) collected in a questionnaire, without the need for any lab tests. The proposed method can help physicians in the early prediction of PB and consequently may increase thinfant's survival chance.

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## Authors' Contribution

M. Mirzamoradi conceived the idea and supervised the project. H. Mokhtari Torshizi analyzed the data and drafted the manuscript. M. Abaspour and A. Ebrahimi conducted data collection. A. Ameri supervised the project and edited the manuscript. All the authors read, modified, and approved the final version of the manuscript.

## Ethical Approval

This research was approved by the ethics committee of Shahid Beheshti University of Medical Sciences in Iran (IR.SBMU.MSP.REC.1397.568).

## Informed Consent

This was a historical cohort study and previously collected data (from routine medical tests for pregnant women) were obtained from patients' files were used, and all patients' data were kept confidential. Hence no new procedure or test was conducted for this study.

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## Conflict of Interest

None

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