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Artificial Neural Networks Application to Predict Type of Pregnancy in Women Equal or Greater Than 35 Years of Age

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Abstract— **Few studies focused on unwanted pregnancy and predictive factors in the late age of reproduction. This study applied feed-forward neural network algorithm with ten-sigmoid function in a hidden and an output layer with 150 neurons to develop a predictive model for type of pregnancy. Data of 1404 women in Khuzestan province of Iran in age 35 or more were collected and eight attributes were selected. The model was developed in MATLAB. The results of this classification task showed about 82 % accuracy, 76% specificity and 56% sensitivity. The model had an area under the curve of 0.67 (95% CI: 0.64–0.70) to predict unwanted pregnancy for the optimum cut point. The model creates an opportunity to discriminate type of pregnancy with 80% accuracy whether or not an individual is going to experience an unwanted pregnancy. This might be a criterion to find risky cases for unwanted pregnancy and then to select appropriate interventions for risky cases to prevent unwanted pregnancy occurrence.**

***Keywords*-artificial neural network*;* Iran*;* Prediction*; u*nwanted pregnancy**

I. INTRODUCTION

In spite of decrease the total fertility rate in Iran over the recent years, high prevalence of unwanted pregnancy have been yet reported [1]. Negative consequences of unwanted pregnancy, particularly affecting social, economic and health situations are well documented through various studies conducted in different places of the world [2].
Unhealthy behaviors are associated with unwanted pregnancy, particularly in countries such as Iran, where abortion is constricted except for therapeutic purposes during first four months of pregnancy if the fetus is physically or mentally handicapped or if the life of the mother is in danger [3].

More than 30% of the pregnancies in women aged 35 and older are unwanted. 29% of pregnancies were unintended among women aged 35 to 39 and this is 38% for women over age 40[4]. In another report, women ages greater than or equal 35 years were twice as likely to experience an unintended pregnancy in comparison with the younger age group who had an unwanted pregnancy resulting in birth [5].About 60% of unintended pregnancy in women ages 35-39 years ending in abortion [6]. Women ages 40 or older have higher rates of induced abortion [7].
Unwanted pregnancies are associated with increased maternal mortality and morbidity, particularly among women in developing countries.Women aged 35-39 in comparison to 25-29 age group have 2 times higher ratio of pregnancy–related mortality; this ratio increases for women aged 40 and older to five times[4].Older maternal age also is associated with increased risk of medical condition such as pregnancy induced hypertension and gestational diabetes [8].Higher risk of congenital abnormalities, spontaneous abortion and still birth is associated with advanced maternal age [7].Greater concern for health and doubts about risk of pregnancy is common in this age group[9]. Additionally, in this age group, in comparison to women aged 20-24,women are more than 3 times more likely to forget the use of contraception. Additionally, inonuse is report, d in about 15% of women aged 35-3, and 20% of women aged 40-44[4, 7].

There are different modeling techniques to predict an outcome through using historical data to estimate the parameters of a model; it then delivers the resulting exactly specified model to the new case for use in prediction and classification [10]. Having considered the strengths and limitations of each method, the one which outperforms other under the given conditions is chosen leading to a significant solution for a given application problem [11]. Artificial neural networks (ANN) are one of those methods newly formed from the interaction of computer science, information science and medicine. It has been applied in

medical sciences for prediction and classification of outcome, where regression models and other traditional statistical techniques have faced several limitations[12-14]. Because of the ANN intelligent structure and flexibility, they are competitors for traditional statistical modeling due to their power to "learn" mathematical relationships between a series of input (independent variable, predictor)and the corresponding output (dependent variable, outcome). This is achieved by "training" the network with a training dataset consisting of predictor variables and the known or associated outcomes. Therefore, they can implicitly detect complex nonlinear relationships between independent and dependent variables [10]. If significant amounts of nonlinearity exist between the predictor variables and the corresponding outcomes in a training dataset, then the network will automatically adjust the connection weights in its structure to reflect these nonlinearities. The predictor variables in a neural network, usually undergo a nonlinear transformation at each hidden and output node, and thus, a neural network can potentially model much more complex nonlinear relationships than a logistic regression model [15]. Hence, neural networks are advanced in theory and application able of transmitting information from the input to the output layer in a unidirectional manner and must be trained to make discriminate analyses.Having considered the high prevalence of unwanted pregnancy and its multifactornature along with complicated relationships, it requires a powerful technique to enable to tackle complex situations; neural network might handle this properly as an intelligent method.This study is aimed to develop a model to detect high risk cases for unwanted pregnancy leading to prevent its destructive consequences such as induced abortion and other threats for child and maternal health.

II. RESEARCH METHODOLOGY

A. Subjects and Data

We analyzed the data from1404 married women (35 years or older) attending health centers of 4 cities of Khuzestan province, Iran within 2010-2011. Required data were collected. Table1.Presents incorporated variations in more details as well as every of selected attributes' correlation status with the dependent variable (unwanted pregnancy). In order to avoid the problems related to missing values, subjects with missing elements in their variables were ignored.

Table1.Variables based on type of pregnancy

Variable	Type	Description	Type of pregnancy		P value
			*W N (%)	**UW N (%)	
Female	Predictors	Level of education including: illiterate Primary school Guidance School High School University	132(75.4%) 215(76.8%) 215(75.2%) 304 (80%) 224(87.5%)	43(24.6%) 65 (23.2%) 71(24.8%) 76(20.0%) 32(12.5)	0.0003
marriage age		The women`s age of getting married: <18 18-24 =>25	227 (68.4%) 535 (80.1%) 292 (91.3%)	129 (31.6%) 133 (19.9%) 28 (8.8%)	<0.001
abortion		The history of abortion: Yes No	178(66.4%) 912(82.8%)	90(33.6%) 197(17.8)	<0.001
obesity		BMI equal or more than 30: Yes No	261(73.1%) 829(81.3%0	96(26.9%) 191(18.7%)	0.001
gravid		Number of pregnancy: 1 2 3 4 5 ≥6	91(96.8%) 301(27.6%) 297(86.6%) 189(75%) 95(57.6%) 117(58.5%)	3(3.2%) 22(6.8%) 46(13.4%) 63(25.0%) 70(42.4%) 83(41.5%)	<0.001
city		City that under studied women lived: Dezful Khoramshahr Izeh Ahvaz	416(81.4%) 149(75.3%) 271(93.4%) 254(62.7%)	95(18.6%) 49(24.7%) 19(6.6%) 124(32.8%)	<0.001
method		Type of contraception the woman has used: Less effective method (Natural, Rhythm and condom) Effective methods(hormonal, IUD and surgery)	467(82.9) 623(76.5)	96(17.1) 191(23.5)	0.004
Unwanted Pregnancy	response	Intend to pregnancy			

*W= Wanted pregnancy, **UW= Unwanted pregnancy

	Number of instances	Sensitivity (%)	Specificity (%)	Model accuracy (%)	Area Under Curve (95% CI)
Training set	984 (70%)	50.6%	77.1%	82.7%	0.64
Testing set	210 (15%)	52.2%	75.0%	77.3%	0.59
Validation set	210 (15%)	62.2%	72%	81%	0.63
Total model	1404 (100%)	53.6%	76%	81.6%	0.67

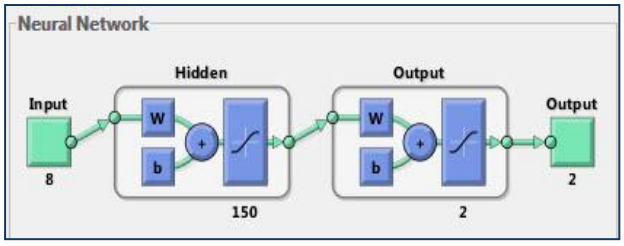
Table 2.Number of instances, value of model accuracy, sensitivity and specificity using training, testing and validation sets

B.Artificial Neural Networks

Artificial Neural Network (ANN) is biologically inspired analytical approach which is able of modeling complex nonlinear functions. It is a set of connected input/output units where every connection has a weight related with it. A neural network includes an input layer, an output layer, and one or more hidden layers. Neural networks have hidden layers with arbitrary number of nodes, which ease regulating the weight of each node to satisfy the input and output relationship.Adjusting the weights is the core phase of learning for predicting the correct class label of available input tuples through iterative learning [10].
Suppose we intend to classify an individual as being wanted or unwanted pregnancy on the selected features (predictors of table 1.) After correlation analysis, we have used 1404 examples for which we have 8 items of variables and the correct classification as being unwontedly pregnant or not.
To create the network, we used a pattern recognition network, which is a feed-forward network with tan-sigmoid transfer functions in both the hidden layer and the output layer. 150 neurons in one hidden layer were applied and the network has two output neurons, which represent a category of unwanted pregnancy occurrence. Figure1 shows the structure of the developed neural network with eight inputs, one hidden layer with 150 neurons, one output layer and finally the outputs which could be either 0 or 1 presenting not unwanted pregnancy or its occurrence respectively.

Figure 1: The schematic view of constructing neural network with 8 inputs, a hidden layer with 150 neurons and two outputs.

To train the network, the pattern recognition uses scaled conjugate Gradient algorithm for training. The application is randomly divided the input vectors and target vectors into three sets: 70% is used for training, 15% is used to validate that the network is generalizing and to stop training before overheating, and 15% is used as a completely independent test of network generalization.



C.Performance Evaluation

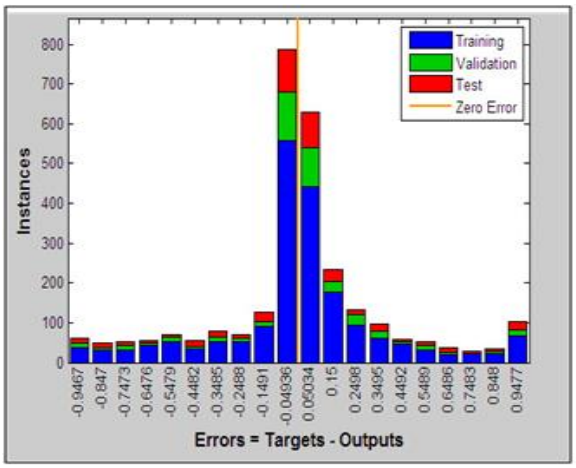
To calculated model fitness, model accuracy, and overall accuracy the confusion matrices can help. Values of sensitivity and specificity for unwanted pregnancy:
Sensitivity = (predicted as unwanted|unwanted)
Specificity = (predicted as wanted |wanted)
Overall accuracy = correctly classified cases/ total
Model fitness is calculated by using a training set while model accuracy is calculated though applying a testing set. Model accuracy is much more important to check the model quality as it is calculated by using totally independent data which have not been used to develop the model.
Area under the curve is the plotted values of probability of true positive and probability of false positive as the decision threshold is varied is called a Receiver Operating Characteristic (ROC) curve. The mean of squared error which is the error of the real target vector

III. RESULTS

in our data set and the predicted outcome defined by developed model has been also considered in this study.

Table 2 presents considered measurements to assess the model accuracy and reliability. Sensitivity and specificity in addition to model accuracy percentage for train, test and validation set have been addressed separately. Model fitness which is the model accuracy through applying a training set is 82.7%. Value of model accuracy which is obtained through applying independent dataset not have been used to build the model is 77.3%. 81% model accuracy through using a validation set proves no overfeeding occurrence as it is close with total accuracy (81.6%). Total model accuracy of 82% shows the ability of our model to classify the cases relatively accurate. There is such a midway level of

sensitivity (53%) addressing the model`s ability to find cases who at the risk of unwanted pregnancy; however, the model performs better to detect women who intend to become pregnant as the level of specificity is about 76%. The value of AUC also proves the middling performance of the model with 0.67 (95%CI: 0.64–0.70). The result of the Means of squared error shows the lower error value for test set which is an independent external data set. The distribution for this error has been shown in figure 3. It has almost a normal distribution mainly close to zero for three sets including training, testing and validations.



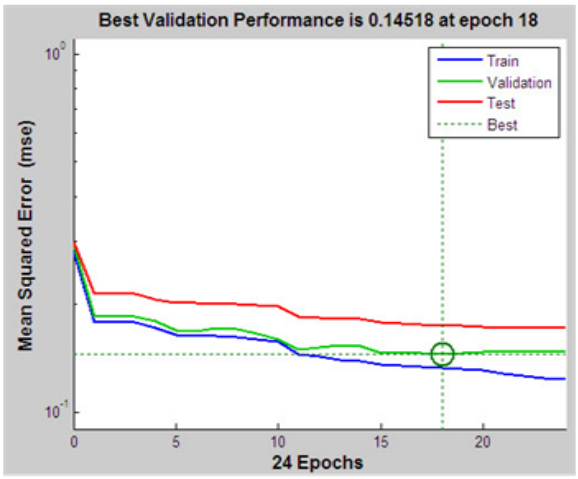
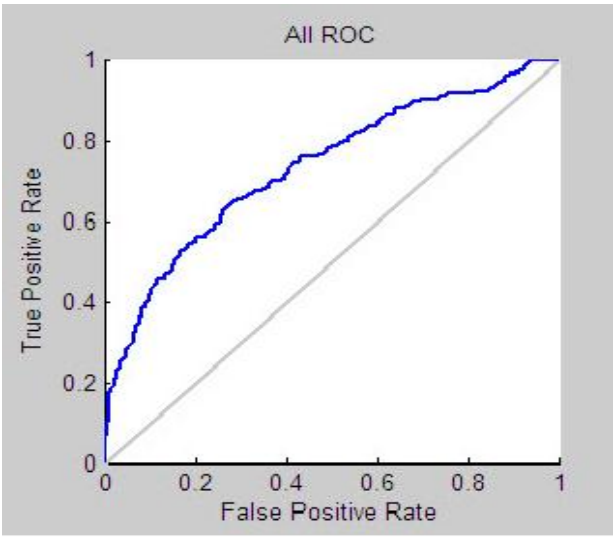
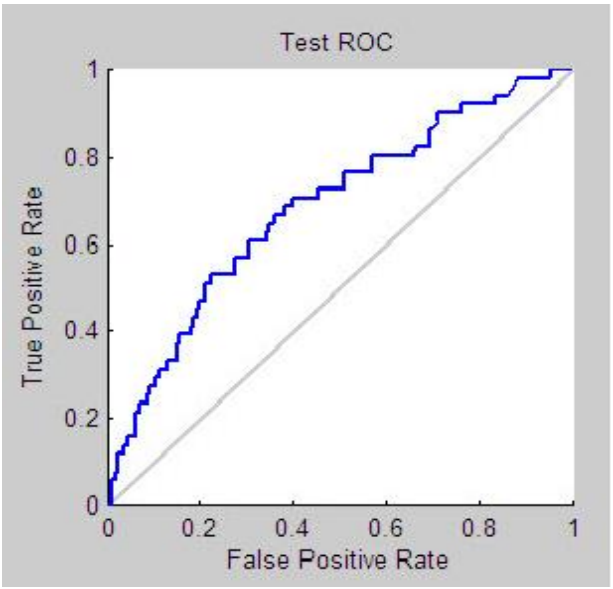


Fig2. Receiver operating characteristic (ROC) curves of model developed by testing set (down) and training set (up) plotted sensitivities and (1- specificity) to predict unwanted pregnancy.sets where the best performance with the lowest level of error is happened at 18th epochs.

Meanwhile, the three model behavior over the training process toward error reduction has been depicted in figure3 approve the crucial success to develop an accurate model without everfittingoccurred in the optimum epoch of 18. Furthermore, decreasing trend of errors over the epochs for three





Applied sets verifies no overfeeding case for this model (figure 3).

Fig3. Mean Squared Error which is calculated through target subtracted outputs predicted by model ranging from -1 to 1. As shown main value of instances have error close to zero and the distribution of error looks normal for all their sets: training, testing and validation set (up). The figure on the right point out the decreasing trend of errors for models developed through all tree set including training, testing and validation sets where the best performance with the lowest level of error is happening in 18th epochs**.**

IV. DISSCUSSION

In spite of the reduction of fecundity in the later years of reproduction, rate of unwanted pregnancy among women aged 35 or older is high [16] .About thirty percent of the pregnancies in women equal or greater than 35 years are unwanted [17]. Relationship between increasing maternal age and poor pregnancy outcomes including spontaneous abortion, prenatal mortality, chromosomal abnormalities and stillbirth is reported in several studies [18-20].In Iran, there are big populations of women, who are equal or greater than 35 years of age using unsafe contraception methods and might be under the exposure of unintended pregnancy. Because of the rapidly increasing prevalence of unwanted pregnancy, detecting risky women for this condition is very important [2,3]. However, they are distributed in Iran as a huge country and spotting those risky cases for unwanted pregnancy in order to give them proper supervision and support is very difficult; thus, we need a screening tool to find high risk cases.

NNs can be used as a high-sensitive and non-invasive initial screening and educational tool for control of unwanted pregnancy. This assessment tool can efficiently discriminate wanted and unwanted pregnancies which significantly improve the level of women's health. Neural network's ability of detecting underlying interactions between independent and dependent variables, as well as the nonlinear relationship among applied attributions has made an opportunity to develop a predictive model which classifies wanted and unwanted pregnancy.

Although ANN has been explored in many areas of medicine, including Nephrology, microbiology, radiology and neurology [14-21];we are unaware of their use in predicting the risk of unwanted pregnancy in women aged greater than 35. In the only study conducted by Saadathashemiand colleagues (2005) pregnancy type has been predicted for 4000 women in all fertility ages; the sensitivity and specificity of developmental model by applying ANN are reported as %87 and %92 respectively [13]. This high level sensitivity might be due to more samples and more unwanted cases in response variable. However, our work is the first study, which has focused on unwanted pregnancy in women aged 35 years or more along with exploiting the capability of neural network rather than common statistical modeling approaches simultaneously.

The valid ANN predictive model may play a crucial role in public health point of view as it can be embedded in computerized medical decision support systems in which, through simple yes or no questions provides a feasible approach to screen risky women for unwanted pregnancy after being fed by demographic, clinical and lifestyle data as system inputs. Final results which are system outputs will help healthcare practitioners to quickly determine the individual's risk of unwanted pregnancy.

Furthermore, this study examined the feasibility of the predictors in forecasting unwanted pregnancy among women aged greater than 35. The findings, based on the training dataset revealed seven common parameters significantly associated with unwanted pregnancy, including marriage age, contraception method, educational level, abortion history, obesity, gravid, city of residency. These predictors are readily accessible through routinely collected data in general practice or from general survey.

Although, this is the first study to develop and evaluate the feasibility of the ANN model to predict individual's risk of unwanted pregnancy in women (age equal or more than 35), study limitations should be noted. This work came across with a midway sensitivity, which might be because of a limited number of records; nonetheless, still such a model may be suitable for selecting high risk individuals in research studies, or increasing the pretest probability for other screening strategies. To achieve greater value of sensitivity and much more accurate model, more records of historical data related to unwanted pregnant cases are needed. Moreover, evaluations of the driving models were based on a cross-sectional survey without a longer follow-up period. The samples were restricted geographically and ethnically, consisting of women who attended at public health centers during the study period and may not be the genuine representative of the women population in this age group. Last but not least, the number of unwanted pregnancy cases was limited in comparison to wanting cases; this made our data base imbalanced which was because of limited samples in total.

Despite of these limitations, the results, combine multiple risk factors, and the prediction approach was reliable and effective to screen unwanted pregnancy event in women ($age \geq 35$) and this model can be used to screen unwanted pregnancy using routinely collected data in general practice. This will help healthcare practitioners to evaluate the risks of their patients quickly, inexpensively, and noninvasively through allowing targeted screening to take health interventions such as follow up and education more precisely.

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