A Predictive Model for the Risk of Infertility in Men using Fuzzy Logic

[1]TEMITAYO OYEGOKE, [1]ADEKEMI AMOO, [1]JEREMIAH BALOGUN, [2]TOLULOPE ALO, [1]PETER IDOWU
[1]Department of Computer Science and Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, NIGERIA
[2]Department of Computer Science and Engineering, Tai Solarin University of Education, Ogun State, NIGERIA
temitayooyegoke@yahoo.com, olawunmikemi@yahoo.com, jeremiahbalogun@gmail.com, paidowu@oauife.edu.ng

Abstract: - Infertility in women has been the general trend because people do not believe that men too can be infertile, but nowadays it is has been verified that male as a role to play in infertility as well as the female. This study developed a fuzzy logic model for the prediction of risk of infertility in men. The work identified the non-invasive risk factors and their associated relationship with the risk of male infertility from medical experts; and collected relevant data from 28 males. The model using was formulated using triangular membership functions equal to the number of risk factor labels and adopted the relationship for creating 4374 IF-THEN rules. The model was simulated using Fuzzy Logic Toolbox of the MATLAB software and was validated using the 28 male records collected. The result of the model showed an accuracy of 100% owing to the capacity to map underlying rules to every data record applied. The study concluded that the model will provide effective decision-support required for mitigating the related effects of male infertility in Nigeria.

Key-Words: - prediction model, infertility in men, fuzzy logic

1 Introduction

Infertility can be defined as the failure of a couple to conceive within a certain period of time, usually 12 months or more of regular unprotected sexual intercourse despite sexual intercourse [1], [26]. According to International Committee for Monitoring Assisted Reproductive Technology (ICMART), it is also a reproductive system disease defined by the failure to achieve pregnancy after a year of regular unprotected sexual intercourse [9] Infertility can be said to be of many types, such as resolved infertility which is pregnancy occurring after one year of trying without medical intervention and primary infertility which is never pregnant or secondary infertility which is the failure to conceive after having previously delivered an infant without medical intervention [3].

Male infertility can be defined as the inability of a male to achieve pregnancy in a fertile female [4]. In about 60% of all couples experiencing infertility, male factor is responsible in about 40% of the couples. It is discovered that the male factor is associated with a greater percentage of cases of primary rather than secondary infertility [5]. Male factor infertility is now generally accepted and important as the female factor. In men, infertility risk factors, such as Sexually Transmitted Diseases (STDs), smoking, environment and drugs, male accessory gland infection, mumps orchitis, varicocele, cryptorchidism and other infectious diseases are well documented. Environmental factors such as toxic materials, pesticides, and radiation, also have effect on male infertility.

Infertility is primary if the couples are unable to get pregnant, while secondary infertility is the inability to get pregnant after an earlier pregnancy. Infertility is generally quoted as occurring in 8-12% of couples. It is estimated that approximately one-third of cases of infertility are due to male factors, one third to female, and the remaining third to a combination of both male and female factors. In approximately 20% of the cases, the origin of the condition is never identified and the cause is labeled as unexplained. Infertility has been said to be highest in countries with high fertility rates [6]. According to [7], it states that infertility is estimated to affect between 8 to 12% of reproductive-aged couples worldwide.

In southwest Nigeria, male factor was reported to be responsible for 42.4% infertility cases [8], while in Maiduguri, North Eastern Nigeria, infertility is the reason for about 40% of all gynecological consultations [9]. In Kano, 40.8% prevalence of infertility were reported [10], 46% in Ile-Ife [11]. According to [12], he states that in Sub-Sahara Africa which Nigeria is part of, pelvic infections largely constitute the cause of infertility in several place [13], [14], [15]. These stem from

sexually transmitted diseases, post-abortal and post-delivery complications. Comparative studies from Ile-Ife, Nigeria showed a positive contribution between secondary infertility and induced abortion, post-abortal sepsis, manual removal of placenta as well as previous prolonged unsupervised labor [17]. Both the males and females are said to contribute equally to infertility [15].

Men's fertility generally relies on the quantity and quality of his sperm. If the number of sperm a man ejaculates is low or if the sperm are of a poor quality, it will be difficult and sometimes impossible for him to cause a pregnancy. It is estimated that one in 20 men has some of fertility problems with a low numbers of sperm to ejaculate. However, only about one in every men has no sperm to ejaculate. Infertility causes personal and social problems for couples and it is noteworthy that, even today, recognizable causes of male infertility are present in only 40% of cases [18].

Toxic materials and pesticides causes a decrease in sperm concentration [19], [20]. Oxidative stress has been recognized as one of the main causes of male infertility and impaired stress [21]. It is commonly known that health is an important aspect of man's existence and health is wealth. Technology has improved the availability of information in the hands of people generally. Although it may not be totally accessible by all, some information can still be gotten. Every day, scientists make research on things that surrounds human and this has helped because it has brought out a lot of diseases to limelight of which infertility is one of it. It is germane to be informed about one's health condition because health is a very important aspect.

Predictive modelling is the process of estimating, predicting or stratifying members according to their relative risk. In this study, the predictive task to be performed is a classification [22]. There is need for the prediction of infertility in men so that men will be conscious that infertility affects both male and female and not the female only, so that men will be aware of the disease and may be able to take appropriate measures in curing themselves of the disease, also to reduce the rate of broken homes among couples. This project will help men to be informed about their current state as per predicting likelihood of infertility so that if such need treatment, it will be done on time before the situation gets out of hand.

Fuzzy logic is a multi-valued logic obtained from fuzzy set theory deals with the human reasoning that ranges from 'almost certain' to 'very unlikely'. In contrast to classical propositional logic (true/false), the membership value of fuzzy logic variables are not only 0 and 1 but it can b range between 0 and 1 [23]. It is essential to realize that fuzzy logic uses truth degrees as a mathematical model of the vagueness phenomenon while probability is a mathematical model of randomness. In this study, a predictive model was formulated to determine the risk of infertility in men which is inspired by fuzzy logic.

2 Related Works

There are lot of diseases that has been predicted using various data mining techniques. Some of the techniques has predicted the diseases at the early stage while some has helped in curing the diseases

[24] in their paper performed a comparative analysis of machine learning techniques for predicting infertility in women. Naïve Bayes, C4.5 decision trees algorithm and multi-layer perceptron algorithms were used to formulate the predictive model for infertility in women. C4.5 decision trees algorithm revealed the most important risk factors and used these variables to develop model with an accuracy of 74.3%. The study was limited to infertility in women.

[25] developed a predictive model using multi-layer perceptron with three sets of clinical variables: personal profiles, medical and surgical history and gynecological history. Using a filter-based feature selection algorithm (consistency subset evaluator), six relevant features were identified out of fourteen variables selected for the study. A comparison of the performance of the predictive model developed was done using all fourteen variables and the selected six relevant variables via the use of three different training methods; full dataset, percentage proportion (60% for training and 40% for testing) and 10-fold cross validation. The study showed that feature selection of relevant variables improved the performance of infertility prediction from 69.23% before feature selection to 76.92% after feature selection.

[26] developed a predictive model for the classification of women's health disease (fibroid) using decision trees algorithm. Data was collected from three classes of people (no fibroid, mild condition and severe condition) and eight features were used in developing the proposed predictive model. The results showed that the decision trees algorithm was able to select two important features as predictive for fibroid in women; the features selected were: the age of the patient and signs of heavy bleeding. The evaluation of the performance of the predictive model was observed to give a value

of 56%. The study was limited to the use of decision trees algorithm in predicting the likelihood of fibroid in women and there exist other supervised machine learning algorithms which were not considered.

[27] applied artificial intelligence using multi-layer perceptron (an artificial neural network architecture) algorithm to predict semen characteristics resulting from environmental factors, life habits and health status in order to develop a decision support system that can help in the study of male fertility potential. Semen samples collected from 123 young, healthy volunteers were analyzed and information regarding their life habits and health status was collected using questionnaire. Sperm concentration and percentage of motile sperm were related to socio-demographic data, environmental factors, health status, and life habits in order to determine the predictive accuracy of the multi-layer perceptron network model developed. The results showed that the most important semen parameter is the sperm concentration with an accuracy of 90%, sensitivity of 95.45% and specificity of 50%. This study was limited to the prediction of infertility in men using only a single supervised machine learning algorithm unlike the proposed study which compares the performance of three machine learning algorithms used for predicting infertility in women.

Most of the existing models focused on infertility of men which may not be the case among couples. The focus of this research is to develop a predictive model for infertility in women.

3 Methods

This section presents the material and methods that were adopted in this study for the development of the fuzzy logic model for assessing the risk of infertility in male patients.

3.1 Data Identification and Collection

For the purpose of this research, data variables about infertility were identified from the health organizations' expert following the review of related works using interviews. The risk factors that were identified to be associated with the risk of infertility in men were also identified to be non-invasive since they did not require the use of invasive means for assessing the values of risk factors thus reducing associated costs and time spent in assessing variables from patients. Following the identification of the risk factors that are associated with the risk of infertility in men, relevant data was collected using questionnaires to assess the values of the identified variables from patients of the Obafemi Awolowo University Teaching Hospital Complex Ile-Ife, Osun state. The risk factors associated with the risk of infertility are presented as follows:

a. **Smoking history** which was classified as either never, previous and yes. The risk of infertility is highest for present smokers followed by previous smokers and least for non-smokers.
b. **Alcohol history** which was classified as either never, previous and yes. The risk of infertility is highest for present alcohol consumers followed by previous consumers and least for non-consumers.
c. **Age** which was classified as teens for those under 20 years, adult for those between 20 years and 60 years and aged for those above 60 years. The risk of infertility is highest for aged followed by adults and least for teens.
d. **Occupation hazard** which was classified as either never for those not exposed, sometimes and yes for those exposed. The risk of infertility is highest for those who are exposed to hazards but least for those who are not exposed to hazards.
e. **Toxic exposure** was classified as never for those who are exposed to toxic chemicals, sometimes and yes for those who are exposed to toxic waste. The risk of infertility is highest for those who are exposed to toxics and least for those who are not exposed to toxic waste.
f. **Body Mass Index (BMI)** was classified as normal for those with BMI less than 25, overweight for those with BMI less than 30 and obese for those whose BMI is above 30. The risk of infertility is higher for those who are obese followed by those who are overweight and least for those who are normal.
g. **Illicit drug use** was classified as never for those who have never indulged in drug use while previous and yes were used to identify those who indulge in drug use. The risk of infertility is highest for present drug users followed by previous users and least for non-users.
h. **History of pelvic surgery** was classified as no for those whom have never had surgery and yes for those who have had the surgery. The risk of infertility is highest for those whom have had surgery in the past and least for those whom have never had surgery.
i. **Risk of Infertility** was classified as Low risk, Moderate risk and High risk based on the values of the risk factors assessed from the individuals.

3.2 Formulation of a Fuzzy Logic Model for Prediction of Risk of Infertility in Men

The formulation of the predictive model for the risk of infertility in men in Nigeria was done using the MATLAB fuzzy logic toolbox. The membership function of each input variable of the fuzzy logic model was formulated alongside the membership function of the output target variable. In a membership function (MF), the input space is sometimes referred to as the universe of discourse. The only condition a membership function must really satisfy is that it must vary between 0 and 1. The mathematical model of the triangular membership function had base points a on the left and c on the right and with an apex b at the center thus creating an interval of [a, c] such that b lies in the center and a, b and c are real numbers. The triangular membership function was used to formulate the predictive model for the risk of infertility in men based on an interval [a, b, c] of crisp values according to equation (1).

$$f(x;a,b,c)=\begin{cases} 0 & ,x<a \\ \dfrac{x-a}{b-a} & ,a\le x\le b \\ \dfrac{c-x}{c-b} & ,b<x\le c \\ 0 & ,c>x \end{cases} \qquad (1)$$

The fuzzy logic model for the risk of infertility in men was formulated based on the eight (8) identified risk factors alongside the target risk of infertility. Figure 1 shows the fuzzy logic model formulated for the risk of infertility based on the identified eight (8) risk factors. The Fuzzy Logic model was required to accept inputs from users which include the factors affecting the risk of infertility in men in Nigeria.

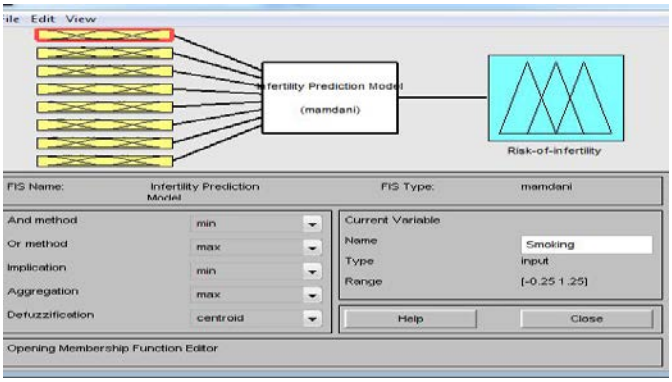

Fig.1: Fuzzy Logic Model for Male Infertility

3.3 Fuzzification of Identified Variables of the Fuzzy Logic Model

Fuzzification is the first process in modelling a fuzzy logic system. The first step in the modelling of the controller is data fragmentation (Fuzzification) into input that can be accepted by fuzzy logic. The fuzzification process was used to map the values of the crisp interval [a, c] onto a fuzzified value according to equation (1). In order to create discrete labels for each identified variable, unique crisp intervals were created for each variable such that an interval corresponded to a triangular membership function which was used to define a label. Therefore, the number of triangular membership function formulated for a variable was proportional to the number of labels.

This study provided center values of 0, 1 and 2 to define the level of severity and association of each label with the variables that had three (3) labels while the centers 0 and 1 was adopted for variables with two (2) labels. Therefore, seven (7) out of the eight (8) identified risk factors were fuzzified using 3 triangular membership functions while the last variable was formulated using 2 triangular membership function while the target class was formulated using 3 triangular membership functions. Table 1 shows the fuzzification of the variables identified for assessing the risk of infertility in male patients.

The fuzzification of the labels of each variable identified in this study were formulated based on equation (1) for each identified interval provided. Therefore, a variable with 3 labels adopted the use of 3 triangular membership functions with centers 0, 1 and 2 while the variables with 2 labels adopted the use of 2 triangular membership functions with centers 0 and 1. Equation (2) presents the triangular membership function adopted for the interval [-0.5, 0.0, 0.5] with center 0. The fuzzified value μ(x) of the interval has a value of 0 for values less than -0.5 and greater than 0.5 but with a fuzzified value μ(x) of 1 if the crisp value entered is 0. Equation (3) presents the triangular membership function adopted for the interval [0.5, 1.0, 1.5] with center 1. The fuzzified value μ(x) of the interval has a value of 0 for values less than 0.5 and greater than 1.5 but with a fuzzified value μ(x) of 1 if the crisp value entered is 1. Equation (4) presents the triangular membership function adopted for the interval [1.5, 2, 2.5] with center 2. The fuzzified value μ(x) of the interval has a value of 0 for values less than 1.5 and greater than 2.5 but with a fuzzified value μ(x) of 1 if the crisp value entered is 2.

Label_1 (x; -0.5, 0, 0.5) =

$$\begin{cases} 0, & x \le -0.5 \\ \frac{x+0.5}{0.5}, & -0.5 < x \le 0 \\ \frac{0.5-x}{0.5}, & 0 < x \le 0.5 \\ 0, & x > 0.5 \end{cases} \quad (2)$$

Label_2 (x; 0.5, 1.0, 1.5) =

$$\begin{cases} 0, & x \le 0.5 \\ \frac{x-0.5}{0.5}, & 0.5 < x \le 1.0 \\ \frac{1.5-x}{0.5}, & 1.0 < x \le 1.5 \\ 0, & x > 1.5 \end{cases} \quad (3)$$

Label_3 (x; 1.5, 2.0, 2.5) =

$$\begin{cases} 0, & x \le 1.5 \\ \frac{x-1.5}{0.5}, & 1.5 < x \le 2.0 \\ \frac{2.5-x}{0.5}, & 2.0 < x \le 2.5 \\ 0, & x > 2.5 \end{cases} \quad (4)$$

4 Results and Discussions

This section presents the results of the methods adopted in this study for the development of the fuzzy logic model for assessing the risk of infertility in male patients. This section presents the graphical plot of the triangular membership functions that were formulated for each risk factor alongside the target class variable for assessing the risk of infertility in mal patients. Using a structured questionnaire, the results of the data identified and collected showed that a total of 28 questionnaires were filled by respondents selected from OAUTHC, Ile-Ife, Osun State. Table 2 presents the results of the distribution of the data collected from the patients selected for this study.

4.1 Results of Data Identification and Collection

The results showed that among the respondents selected for this study, majority of the patients selected had low risk of infertility with a proportion of 67.9% followed by those with moderate risk of infertility with a proportion of 25% of patients selected. The results further showed that majority of the patients never had a history of smoking and alcohol consumption with a proportion of 78.6% and 50% respectively whom were adults owing for a proportion of 82.1%. The results showed that majority of the patients had never been exposed to occupational hazards and toxics with proportion of 53.6% and 64.3% respectively. Also, the results showed that majority of the patients selected had a normal BMI with a proportion of 67.9% and had never indulged in illicit drug use nor any history of pelvic surgery with a proportion of 75% and 89.3%.

4.2 Results of the Formulation and Simulation of Fuzzy Model for Male Infertility Risk

Following the description of the distribution of risk factors and risk class of male infertility for this study, the results of the formulation of the triangular membership functions of the Fuzzy Logic model is presented. As earlier stated, the first seven (7) risk factors were formulated using three (3) triangular membership functions with centers 0, 1 and 2 based on increasing severity of the risk of infertility in male patients while the last risk factor was formulated using two (2) triangular membership functions.

Figure 2 shows the fuzzification of 3 triangular membership functions for Smoking using the interval [-0.5 0 0.5] for Never, [0.5 1 1.5] for Previous and [1.5 2 2.5] for Yes for increasing severity of infertility in male patients.

Fig.2: Fuzzification of Smoking

Figure 3 shows the fuzzification of 3 triangular membership functions for Alcohol Consumption using the interval [-0.5 0 0.5] for Never, [0.5 1 1.5] for Previous and [1.5 2 2.5] for Yes for increasing severity of infertility in male patients.

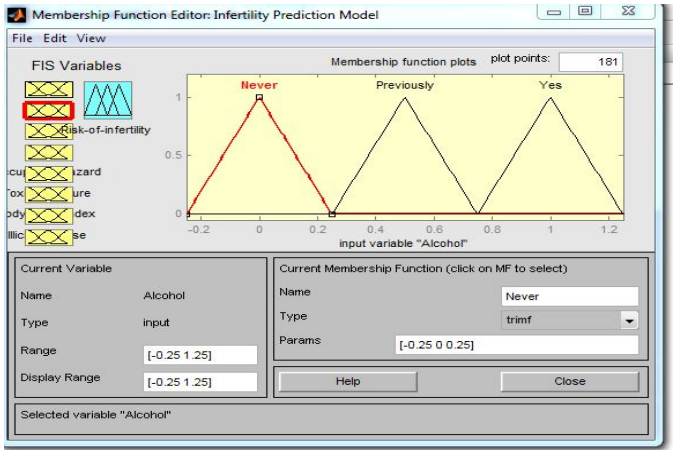

Fig. 3: Fuzzification of Alcohol Consumption

Table 1: Fuzzification of Variables identified for Male Infertility Risk

Variable Name	Fuzzy Linguistic Variable	Crisp Interval	Crisp Input
Smoking	**Never**	[-0.5, 0.0, 0.5]	0
	Previous	[0.5, 1.0, 1.5]	1
	Yes	[1.5, 2.0, 2.5]	2
Alcohol Consumption	**Never**	[-0.5, 0.0, 0.5]	0
	Previous	[0.5, 1.0, 1.5]	1
	Yes	[1.5, 2.0, 2.5]	2
Age	**Teen**	[-0.5, 0.0, 0.5]	0
	Adult	[0.5, 1.0, 1.5]	1
	Aged	[1.5, 2.0, 2.5]	2
Occupation Hazard	**Never**	[-0.5, 0.0, 0.5]	0
	Sometimes	[0.5, 1.0, 1.5]	1
	Yes	[1.5, 2.0, 2.5]	2
Toxic Exposure	**Never**	[-0.5, 0.0, 0.5]	0
	Sometimes	[0.5, 1.0, 1.5]	1
	Yes	[1.5, 2.0, 2.5]	2
Body Mass Index	**Normal**	[-0.5, 0.0, 0.5]	0
	Overweight	[0.5, 1.0, 1.5]	1
	Obese	[1.5, 2.0, 2.5]	2
Illicit Drug Use	**Never**	[-0.5, 0.0, 0.5]	0
	Previous	[0.5, 1.0, 1.5]	1
	Yes	[1.5, 2.0, 2.5]	2
History of Pelvic Surgery	**No**	[-0.5, 0.0, 0.5]	0
	Yes	[0.5, 1.0, 1.5]	1
Risk of Infertility in Male	**Low Risk**	[-0.5, 0.0, 0.5]	
	Moderate Risk	[0.5, 1.0, 1.5]	
	High Risk	[1.5, 2.0, 2.5]	

Table 2: Results of the Distribution of the variables identified and collected

Variable Name	Labels	Frequency	Percentage (%)
Smoking	**Never**	22	78.58
	Previously	3	10.71
	Yes	3	10.71
Alcohol	**Never**	14	50.00
	Previously	9	32.14
	Yes	5	17.86
Age	**Teen**	4	14.29
	Adult	23	82.14
	Aged	1	3.57
Occupational Hazard	**Never**	15	53.57
	Sometimes	11	39.29
	Yes	2	7.14
Exposure to Toxics	**Never**	18	64.28
	Sometimes	5	17.86
	Yes	5	17.86
Body Mass Index (BMI)	**Normal**	19	67.86
	Overweight	3	10.71
	Obese	6	21.42
Illicit Drug use	**Never**	21	75.00
	Previously	6	21.42
	Yes	1	3.58
History of Pelvic Surgery	**No**	25	89.29
	Yes	3	10.71
Male Infertility	**Low Risk**	19	67.86
	Moderate Risk	7	25.00
	High Risk	2	7.14

Figure 4 shows the fuzzification of 3 triangular membership functions for Age using the interval [-0.5 0 0.5] for Teens, [0.5 1 1.5] for Adult and [1.5 2 2.5] for Aged for increasing severity of infertility in male patients.

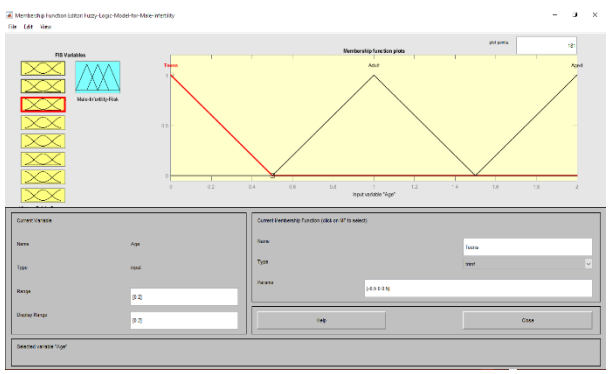

Fig.4: Fuzzification of Age

Figure 5 shows the fuzzification of 3 triangular membership functions for Occupational Hazard using the interval [-0.5 0 0.5] for Never, [0.5 1 1.5] for Sometimes and [1.5 2 2.5] for Yes for increasing severity of infertility in male patients.

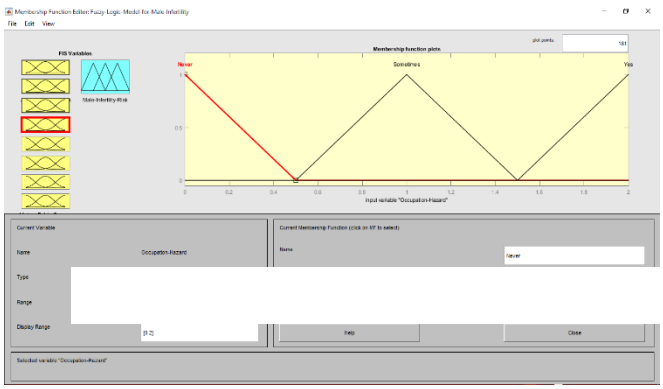

Fig.5: Fuzzification of Occupational Hazard

Figure 6 shows the fuzzification of 3 triangular membership functions for Toxic Exposure using the interval [-0.5 0 0.5] for Never, [0.5 1 1.5] for

Sometimes and [1.5 2 2.5] for Yes for increasing severity of infertility in male patient.

Fig.6: Fuzzification of Toxic Exposure

Figure 7 shows the fuzzification of 3 triangular membership functions for BMI using the interval [-0.5 0 0.5] for Normal, [0.5 1 1.5] for Overweight and [1.5 2 2.5] for Obese for increasing severity of infertility in male patients.

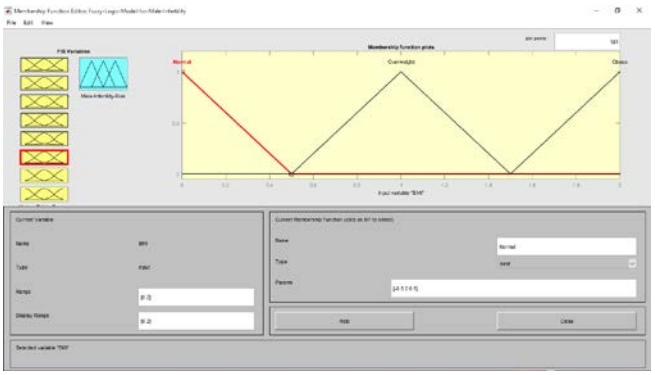

Fig.7: Fuzzification of Body Mass Index (BMI)

Figure 8 shows the fuzzification of 3 triangular membership functions for Illicit Drug Use using the interval [-0.5 0 0.5] for Never, [0.5 1 1.5] for Previous and [1.5 2 2.5] for Yes for increasing severity of infertility in male patients.

Fig.8: Fuzzification of Illicit Drug Use

Figure 9 shows the fuzzification of 2 triangular membership functions for History of Pelvic Surgery using the interval [-0.5 0 0.5] for No and [0.5 1 1.5] for Yes for increasing severity of infertility in male patients.

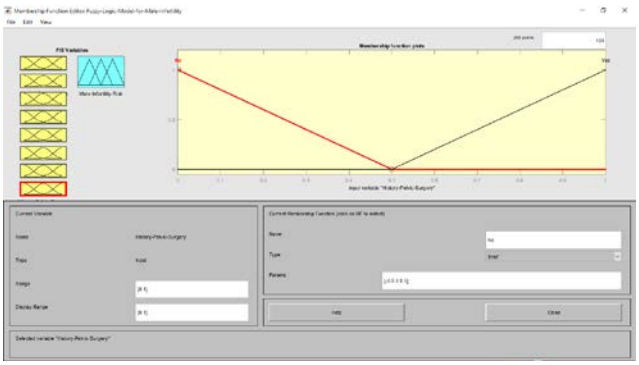

Fig.9: Fuzzification of History of Pelvic Surgery

Figure 10 shows the fuzzification of 3 triangular membership functions for Risk of Male Infertility using the interval [-0.5 0 0.5] for Low Risk, [0.5 1 1.5] for Moderate Risk and [1.5 2 2.5] for High Risk for increasing severity of infertility in male patients.

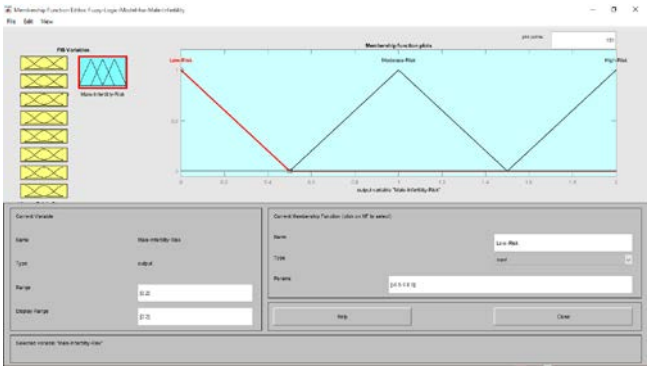

Fig.10: Fuzzification of Risk of Male Infertility

4.3 Results of the validation of fuzzy model

Following the formulation of the triangular membership functions proposed for this study, the dataset collected for this study was adopted for the validation of the fuzzy logic model for infertility in male. The modeling behaviour of the fuzzy logic model for the risk of infertility in male patients was done using IF-THEN statements by combining the risk factor values as the antecedent while the target risk of male infertility was adopted as the consequent of each antecedent rules. Figure 11 shows the interface of the rule base that was generated for the fuzzy logic model or the risk of infertility in male.

The number of rules was formulated as a permutation of all the variables present in the fuzzy logic model. The total number of rules formulated

for the fuzzy logic model were 4374 ($= 3^7 \times 2$) rules since 7 variables have 3 labels while 1 variable has 2 labels. The rules were created from the variables and combined based on the respective points for each label as: 0, 1 or 2 which provided a total score of 15 owing to a maximum score of 2 for 7. Following this, the results of the validation of the rule-base of the fuzzy logic model using the dataset collected showed that all 28 records were correctly classified such that all 19 low risk cases were correctly classified, all 7 moderate risk cases were correctly classified and the 2 high risk cases were also correctly classified by the fuzzy logic model based on the rule base constructed for the fuzzy logic model proposed in this study.

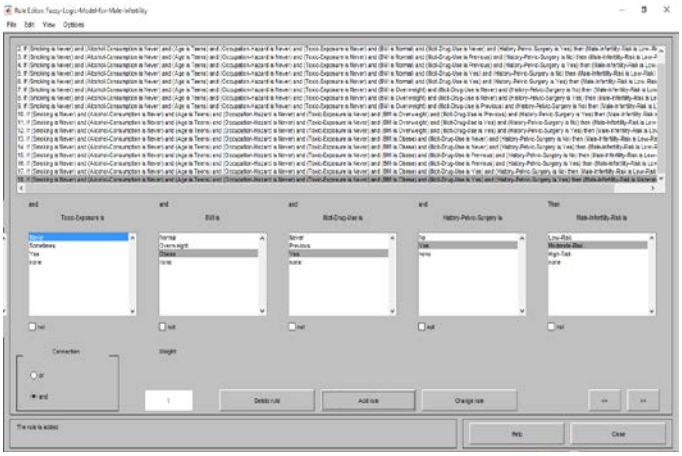

Fig.11: Rule Base of the Inference Engine of Fuzzy Model

4.4 Discussion

From the results of the data identified and collected for this study, the identified risk factors considered in this study were all non-invasive and thus did not require the use of invasive techniques for the assessment of the risk of infertility in male unlike in other studies which required the collection and analysis of male sperm cells which required very expensive and laborious hours of analysis. The risk factors identified in this study can be easily assessed from a patients thus facilitating the effective and efficient assessment of infertility in male patients. The results of the data collected for this study revealed that majority of individuals were likely to have low risk of male infertility. The results of the fuzzy logic model formulated revealed that using the triangular membership function the variables which were numerical in nature could be easily converted to discrete variables which were adopted as the linguistic variables of the triangular membership functions adopted for this study using appropriate intervals with centers of 0, 1 and 2. Also, using the rule-base proposed in this study for the formulation of the inference engine, the relationship between the values of the 8 risk factors associated with infertility risk revealed that a total of 4374 IF-THEN rules were inferred for the Fuzzy Logic model for assessing the risk of infertility in male patients. The model validation using the dataset collected for the study revealed that the fuzzy logic model for the risk of infertility was able to correctly determine the risk of infertility in male patients based on the values of the 8 risk factors provided.

5 Conclusion

This study developed a fuzzy logic-based model for the assessment of the risk of infertility among male patients in Nigeria based on the values of 8 non-invasive risk factors identified by experts. The risk factors identified were formulated using the triangular membership function based on center values of 0, 1 and 2 with respect to the severity of the risk of infertility among male patients. The number of triangular membership functions formulated for each risk factor was proportional to the number of labels that were identified for each risk factor such that risk factors with 3 labels had 3 membership functions while those with 2 labels had 2 membership functions. The study however proposes for future work the need of adopting the use of machine learning algorithms for the formulation of the predictive model for the risk of infertility in male patients. This will be based on the collected dataset rather than on the information provided by experts which may likely be affected by human biasness. The study also proposes that the fuzzy logic model developed be integrated into existing health information system for the prompt assessment of the risk of infertility among male patients thus facilitating effective decision support at public health centers.

Table 3: Classification of male Infertility Risk using Score

Target Class	Labels	Score Interval	Fuzzy Crisp Interval
Risk of Infertility in Male	**Low Risk**	**0 – 4**	**[-0.5 0.0 0.5]**
	Moderate Risk	**5 – 10**	**[0.5 1.0 1.5]**
	High Risk	**11 – 15**	**[1.5 2.0 2.5]**

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