Evaluation of COVID-19 Vaccine Refusal among AOU Students in Kuwait and their Families and their Expected Inclination Towards the Acceptance or Refusal of the Vaccine

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Abstract: The purpose of this research was to determine the factors influencing the refusal of a coronavirus disease (COVID-19) vaccine among adult students from Arab Open University in Kuwait (AOU) and their families and to study the trends of reluctant participants. A questionnaire was conducted (n = 691; aged 12 and older). Significant factors and the tendency of hesitant participants to accept or reject the vaccine were explored by applying a cleaning and coding process, a rough set theory (RS), a decision tree (DT) classifier, and a p-value. Overall, 18.4% of the participants reported refusing to receive a COVID-19 vaccine, while 17.2% were uncertain. The study shows that hesitant subjects represent a tendency to accept vaccination. Of the vaccine-refusal participants, subjects aged 18-29, suffer from chronic disease, were infected with COVID-19, were vaccinated against seasonal flu, and had concerns about receiving a COVID-19, representing 44.1%, 21.05%, 16.76%, 54.33%, and 70.08%, respectively. Overall, 18.4% of the participants demonstrated a refusal to receive a COVID-19 vaccine and 17.2% are hesitant. Factors influencing the level of acceptance/rejection of the vaccine were determined. The results showed that hesitant participants have a strong tendency to accept the vaccine (81.82%). Since vaccination is an important strategy to reduce the spread of the COVID-19 pandemic, the ministry of public health must immediately address the significant factors for the acceptance/rejection of the vaccine, as well as the trend of hesitant participants toward the acceptance of the vaccine.

Keywords: Coronavirus disease 2019, vaccine acceptance, vaccine hesitancy, reduction, rough set, decision tree.

1. INTRODUCTION

Acute respiratory syndrome coronavirus 2 known as SARS-CoV-2 [1]. It seems to cause various symptoms such as mild upper respiratory tract infections, asymptomatic infections, respiratory failure, multiple organ failure, severe viral pneumonia, and death [2]. Due to concerns about the worldwide increase in infected cases and the difficulty of the infection itself, the World Health Organization, known as WHO, officially announced in March 2020 that COVID-19 is a serious pandemic [3]. This made the global organization implement several control measures to prevent virus distribution. Some of these measures include reducing social gatherings, forcing the wearing of facial masks, implementing suitable social distancing, and implementing partial and complete lockdowns. Reducing COVID-19 death and disease is always dependent on the suitability of vaccines in terms of safety and effectiveness. Moreover, vaccines must be accepted by the public and available once needed considering their immunologic protection [4]. The emergency use of the Pfizer-BioNTech COVID-19 vaccine was agreed upon by theWHO on 31 December 2020. AstraZeneca-SKBio (Korea) and the Serum Institute of India produced AstraZeneca/Oxford COVID-19 vaccines on February 15, 2021. The other COVID-19 vaccine (Ad26.COV2.S) was developed on 12 March 2020 by Johnson & Johnson, while the Moderna vaccine was developed on 31 April 2021. On 7 May 2021, Sinovac/China National Pharmaceutical Group developed the Sinopharm COVID-19 vaccine [5]. In Kuwait, there are two types of COVID-19 vaccines available: Pfizer-BioNTech and AstraZeneca-Oxford. Despite the advantages of the vaccine on health outcomes and its vast positive impact on immunization against infectious diseases, we still find numerous sounds from the public against vaccination. The refusal of vaccines shows a great danger to a healthy community, as it weakens the protection of society against vaccine-preventable infections [6]. Vaccine hesitancy is another challenge that controls the success or failure of global vaccine programs. This term refers to people who may be doubtful or unwilling to accept a vaccine [7]. Parents usually influence their children. In this manner, many of the previous studies showed that vaccine hesitancy among parents hurts children's vaccination, ranging from 7.7% to 34.7% [8]. Some of the previous studies assessed that vaccine hesitancy was found to be more significant among those who received information from the media rather than the official websites, were concerned about vaccine safety, and did not have enough knowledge about children's vaccinations from pediatricians [8]. In 2019, vaccine hesitancy was listed by the WHO as one of the ten threats to global health [9]. Understanding the reasons behind the hesitancy of vaccines is important for governments and the public community to be able

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to introduce solutions. Therefore, several surveys have been published concerning the intention to obtain the COVID-19 vaccine among the public [10-18]. A study conducted in the USA revealed that vaccine hesitancy among the public was 46% in October 2020 whereas it becomes 35.2% in March 2021, such a significant decline represents a regression figure of 10.8% in vaccine hesitancy [19]. Limited studies were carried out in the Middle Eastern region [10-14]. A study was carried out in Kuwait during the period from May to August 2020 (the entire lockdown period). The results showed that 67% of the sample (aged 18-74 years) agreed to be vaccinated.

After COVID-19-related restrictions were decreased, vaccination acceptance also decreased significantly to approximately 53.5% [10]. Another study was conducted between August and September 2020 among people aged >=18 years. The results showed that 53.1% of the samples are willing to be vaccinated [11]. A study conducted in December 2020 among 771 samples aged >=16 years revealed that 23.6% of them showed their intention to be vaccinated against COVID-19 infection [12]. A study was conducted in Kuwait from 16 to 18 January 2021. Participants aged >=18 years who live in Kuwait were included in this study. Their hesitancy to take a COVID-19 vaccine was 74.3% divided between participants who do not plan to take it (50.8%) and those who are not sure about taking it (23.5%) [24].

A study was conducted in Kuwait during the period from 26 March to 26 April 2021 to explore the frequency of hesitancy in the COVID-19 vaccine. The results showed that 73.8% of the participants expressed that they were vaccinated or intended to be vaccinated, while 26.2% of them stated their reluctance to receive vaccines [21].

In many cases, people with some chronic diseases are not willing to be vaccinated because they are concerned about it and may think that vaccination will contradict their disease. Shehab *et al*. investigated such a case by collecting data from patients with inflammatory bowel disease (IBD). During the period from 1 June 2021 until 31 October 2021. The overall frequency of COVID-19 vaccination among patients was lower than that of the general population and the WHO recommendation [22].

Limited studies have been conducted in Kuwait to study vaccine hesitancy among specific sectors. One of these studies was conducted by Bitar *et al*. who measured the acceptance of the COVID-19 vaccine among the division of the oil company population in Kuwait. The results showed that 92.5% of the participants were willing to be vaccinated [23].

Another study was conducted by Al-Sanafi (2021). Their study was intended to evaluate the acceptance of the COVID-19 vaccine among healthcare workers (HCWs) in Kuwait. The study was carried out during the period of 18 March 2021 to 29 March 2021. The acceptance rate for the COVID-19 vaccine was 83.3%. 9.0% of the participants were not willing to receive vaccination and 7.7% were unsure [20].

To avoid the spreading of COVID-19, it is important to know the opinions of the public on the acceptance of COVID-19 vaccines. This research study aimed to understand and evaluate the willingness of the Kuwaiti population to receive COVID-19 vaccines. The main goal was to assess the acceptance, rejection, and hesitation of adults in Kuwait to receive the COVID-19 vaccines and to expect the inclination of the hesitant adults toward the acceptance or refusal of the vaccine. To do so, two models have been constructed: one single-reduction method where rough set theory is used to choose the most significant factors and one hybrid-reduction method where rough set and t-test are used to determine the most significant factors. Moreover, each of the two models constructs three scenarios for hesitant adults to deal with. Then, an evaluation study assessed the performance of each scenario in each model. The study provides the official sectors (governments and privates) of public health in Kuwait with useful information/data to build or improve a suitable strategy that could support the vaccination process and extend the immunization plans against COVID-19.

2. SUBJECTS AND METHODS

2.1. Initial Setting and Design

In this research, data were collected using an observational study conducted in Kuwait from April 6 to 7 May 2022, using an online survey. Adults residing in Kuwait at the time of the survey and aged 18 years or older were eligible to be included in the study. Participants who violated the two conditions mentioned were excluded from the study. The questionnaire, which required 10-12 minutes to be filled out, was prepared to match the purpose of the study and was reviewed by several health professionals. The instrument consisted of 30 questions on the

Table 1: The Characteristics of the Participants (n=691)

Participants Characteristics	Frequency (%) Rounded to one digit
Age (in years)	
12–17	37(5.4)
18–29	326(47.2)
30–39	137(19.8)
40-49	106(15.3)
50-59	62(9)
60-69	19(2.7)
70-79	4(0.6)
>=80	0(0)
Gender	
Male	344(49.8)
Female	347(50.2)
Nationality	
Kuwaiti	175(25.3)
Without	97(14)
Other nationalities	419(60.6)
Educational Level	
Not educated	2(0.3)
School Level	265(38.4)
University Level	388(56.2)
Postgraduate Level	36(5.2)
Arab Open University members (Staff or students)	
Yes	386(55.9)
No	305(44.1)
Employment	
Unemployed (not student)	344(49.8)
Student	263(38)
Employed (not student)	84(12.2)
Smoking	
Yes	117(16.9)
No	574(83.1)
Chronic Disease(s)	
Heart disease	20(2.9)
hypertension	38(5.5)
respiratory diseases	40(5.8)
diabetes	29(4.2)
vaccine allergy	7(1)
Nothing	557(80.6)
Abide by the guidelines of the Ministry of Health	
Yes	632(91.5)
No	59(8.5)
vaccinated against the seasonal flu	
Yes	388(56.2)
No	303(43.8)
Infected with COVID-19	321(46.5)
Yes	370(53.5)
No	

(Table 1). Continued.

Participants Characteristics	Frequency (%) Rounded to one digit
Stress that you feel about this epidemic	
High	62(9)
Medium	263(38)
Low	145(21)
No stress	221(32)
In contact with COVID-19 patients	
Yes	237(34.3)
No	454(65.7)
Did you receive or plan to receive a COVID-19 vaccine?	
Yes (received)	445(64.4)
No (not received, no plan to receive)	127(18.4)
Not sure if to receive	119(17.2)
Concerns do you have, if any, about receiving a COVID-19 vaccine?	
The COVID-19 vaccine is not safe	113(16.3)
COVID-19 vaccine may be harmful or have side effects	194(28.1)
Worried that the location of the COVID-19 vaccine will be not safe	24(3.5)
I am concerned about knowing which vaccine is best for me	58(8.4)
No concerns about getting the COVID-19 vaccine	302(43.7)
Obtain reliable information on vaccination against COVID-19 from:	
Ministry of Health	495(71.6)
Social media	110(15.9)
People around me	36(5.2)
Other means	50(7.2)
Information about COVID-19 Infection published by the Ministry of Health is sufficient	
Yes	305(44.1)
No	148(21.4)
To some extent	238(34.4)
Anxiety about catching the disease if you do not get vaccinated	
Yes	308(44.6)
No	383(55.4)
Trust the effectiveness of the vaccine to reduce the disease	
Yes	339(49.1)
No	352(50.9)
Not taking the vaccine will increase the incidence of the disease.	
Yes	373(54)
No	318(46)
The vaccine is effective against the new strain of coronavirus (omicron)	
Yes	176(25.5)
No	185(26.8)
Not sure	330(47.8)
The wave (omicron) is targeting people who have not received the vaccine more than others.	
Yes	192(27.8)
No	216(31.3)
Not sure	283(41)
Forcing people to take the vaccine is a positive step toward controlling the disease	
Yes	319(46.2)
No	372(53.8)

(Table 1). Continued.

Participants Characteristics	Frequency (%) Rounded to one digit
Reasons behind the high volume of registering in the Ministry of Health to receive the COVID-19 vaccine	
To enter clubs, restaurants, and markets.	268(38.8)
Afraid of Omicron	9(1.3)
Satisfied with the effectiveness of the vaccine	139(20.1)
Because employers force them.	129(18.7)
To travel.	82(11.9)
Other reasons	64(9.3)
The increase in the rate of injuries and the number of deaths makes individuals rush totake the vaccination	
Yes	316(45.7)
No	168(24.3)
Not sure	207(30)
Accept to be vaccinated if your first dose of one vaccine and the second dose of another vaccine	
Yes	177(25.6)
No	381(55.1)
Not sure	133(19.3)
Banning unvaccinated people from entering public places	
Yes	223(32.3)
No	371(53.7)
Not sure	97(14)
Plan to get the third dose of COVID-19	
Yes	267(38.6)
No	279(40.4)
Not sure	145(21)
COVID-19 is a global hoax	
Yes	221(32)
No	200(28.9)
Not sure	270(39.1)

sociodemographic characteristics of the participants, their knowledge and experience with COVID-19, and their beliefs.

2.2. The Questionnaire and its Variables

The questionnaire was developed using online Google forms. The snowball sampling method was used for the data collection on social media such as WhatsApp and discussion groups. All data collected by the questionnaire were cleaned. Rows with missing data were deleted to not affect the accuracy of the results. The data were then coded to be easily analyzed. The variables of the participants (characteristics) with their frequencies are shown in Table **1**.

2.3. Clean and Code the Dataset

During this stage, the collected data (from the questionnaire) was cleaned and then coded to suit the analysis process. A dataset consisting of 697 rows representing the participants who responded to the questionnaire was generated. The dataset was cleaned of noise before being used and analyzed. The noise was seen in the dataset by one or missing values. Some participants did not answer all the questions on the questionnaire. There are different methods to treat missing values. One of them is by removing all rows that have missing values. This method is accepted if the number of rows that have missing values is low. In this case, the removal of these rows will not affect the analysis process. Of the 697 participants who responded to the questionnaire, 6 participants were

excluded. The final dataset included a total of 691 participants. Coding is a creative process where an infinite number of different codes can be generated for the potential patterns that we would like to find. For example, the date of birth can be changed to age, income can be divided by a value, say, 1000, and purchase date can be converted to month numbers [25]. All 691 rows were coded to simplify and accelerate the analysis process.

2.4. The Rough Set Theory

There are many feature selection algorithms used in the field of data science, data mining, machinelearning, and others. The reader may refer to [26,27] for some details. The rough set theory (RS) is one of these algorithms. The discernibility matrix for feature selection and partition properties is used by rough set theory to develop knowledge discovery algorithms [28]. The reduce (the list of the most significant features) R of the attributes (features) A generated by rough set theory gives the same classification quality as the original dataset (ODS) of the conditional attributes C. This classification quality is represented by γ. Therefore, a good reduct is defined as a subset of attributes (A) such that $\gamma_A(R(ODS)) = \gamma_C(ODS)$ and $A \in C$. This theory will be used in this study to find the most significant attributes for the given COVID-19 dataset regarding the three classification values (Accept the vaccine,Reject the vaccine, and hesitate).

The independent variables (factors) of the COVID-19 dataset are shown by all the questions in the questionnaire, except the one that asks the participants if they are willing to receive the COVID-19 vaccination. This question is called the dependent factor or the classification factor. By applying the rough set method to this dataset, the reduct of 10 independent factors was generated plus the dependent factor itself. These factors are shown in Table **2**.

2.5. T-Test

The t-test is a statistical test that compares the means of two groups (in this case, the dependent and independent groups). It is used to determine whether a process influences the group of interest or whether two groups are different. The p-value that represents the result of the t-test shows the probability that the results of the dataset appeared by chance. Its value will range from zero to 100%. A high p-value indicates that the data occur by chance. If the p-value<0.05 then the data are statistically significant. In this manner, the t-test ensures the significance of the reduct generated by the rough set theory.

2.6. Decision Tree Classifier

A Decision Tree, which is a supervised learning method, is one of the important classification methods used in machine learning to test the performance of data systems. The input is the dataset records, and the output is the classification. It consists of nodes and leaves. Each node represents an attribute, whereas the leaves represent a prediction of a model (the classification). The branches of the tree represent the chances that the attribute values eventually go to classes [29]. This classifier will be used here to make decisions similar to how humans make decisions. The objective is to produce a modelthat predicts the value of a target variable by learning some decision rules inferred from the data variables. The decision will be based on the significant variables generated by the

Table 2: The Significant Factors

Question #	The question
Q1	What is your age?
Q2	Do you suffer from chronic Disease(s)?
Q3	Did you vaccinate against the seasonal flu?
Q4	Did you infect with COVID-19?
Q5	What are your concerns about receiving a COVID-19 vaccine?
Q6	Where do you obtain reliable information on vaccination against COVID-19 from?
Q7	Do you think the wave (omicron) targets people who have not received the vaccine?
Q8	Do you agree to ban unvaccinated people from entering public places?
Q9	Do you think that COVID-19 is a global hoax?
Q10	Are you one of the Arab Open University members (Staff or students)?

rough set theory. The generated model with decision rules will be used to classify any new participant and will be able to predict his acceptance, rejection, or hesitation of the vaccine without any bias. In this way, we can easily analyze each group of participants based on their classification value. More focus can be placed on those who are hesitant and then it will be easier to ethically deal with them to show them the importance of the vaccine.

2.7. The Evaluation Metrics

The performance of the proposed models was evaluated using a decision tree classification algorithm. In addition to the accuracy metric, they were evaluated concerning their reduction rate, precision, recall, and F-measure. The accuracy is calculated using formula 1:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

where TP and TN are the true positives and the true negatives, respectively, and FP and FN are the false positives and the false negatives, respectively.

The precision metric determines the number of positive classifications that belong to the positive class, and it is calculated using formula 2:

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

The recall metric determines the percentage of the number of positive classifications to all predicted results, and it is calculated using formula 3:

$$Recall = \frac{TP}{TP + FP} \quad (3)$$

F-Measure uses both recall and precision to capture all of their properties and it is calculated using formula 4:

$$F - measure = 2\left(\frac{precision * recall}{precision + recall}\right) \quad (4)$$

2.8. The Proposed Models and the Best Scenario

In this section, two models will be considered, one of them being an extension of the other. The first model is based on rough set theory as a reduction method, whereas the extended model uses the p-value of the attributes forming the reduced dataset generated by rough set theory. The first model is shown in Figure **1** and is described in the following steps:

1. Collect the COVID-19 dataset via a questionnaire that is called the original dataset (ODS).
2. Clean the COVID-19 dataset by removing duplicate rows and rows with missing values.
3. Code all categorical attributes of the ODS.
4. Apply the rough set theory to the coded dataset to generate the best reduct (BR).
5. Create three scenarios to find the best trend for reluctant participants to accept or reject the vaccine.
6. Find the performance of each scenario (accuracy, precision, recall, and F-measure) by applying the decision tree classifier.
7. Compare the performance results.
8. Choose the scenario with the highest performance.

The second model is the extension of model 1 and is shown in Figure **2**. The following steps describe this model:

1. Collect the COVID-19 dataset via a questionnaire that is called the original dataset (ODS).
2. Clean the COVID-19 dataset by removing duplicate rows and rows with missing values.
3. Code all categorical attributes of the ODS.
4. Apply the rough set theory to the coded dataset to generate the best reduct (BR).
5. Find the p-value of each attribute in the reduced dataset. Remove attributes with a p-value<0.05. In this case, an attribute was deleted. The best reduct is now called (BR').
6. Create three scenarios to find the best trend for the hesitant participants to accept or refuse the vaccine.
7. Find the performance of each scenario (accuracy, precision, recall, and F-measure) by applying the decision tree classifier.
8. Compare the performance results of these scenarios and the performance of the scenarios tested by the first approach.

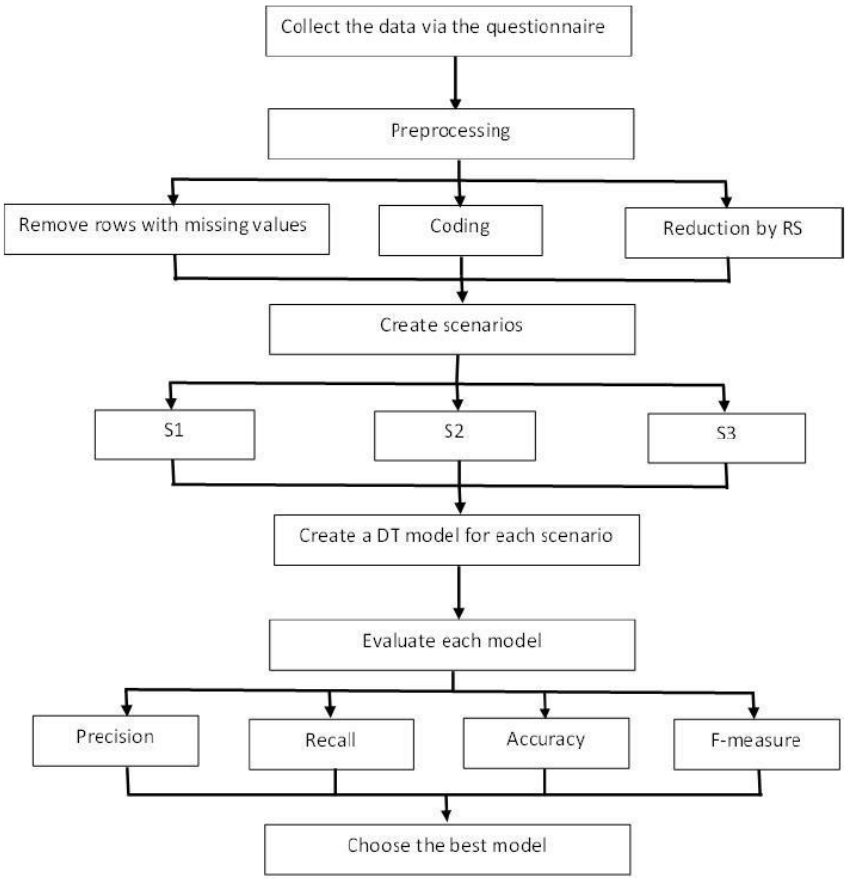

Figure 1: Model 1.

9. Choose the scenario with the highest performance.

To find the best scenario, three experiments were conducted:

1. In experiment 1, the original information system (COVID-19 dataset) generated by the questionnairewas used after it was cleaned. This experiment uses the entire information system (691 rows and 30attributes).

2. In experiment 2, the reduced information system generated by the rough set theory was used (reduced COVID-19 dataset). This experiment uses the entire information system (691 rows and 10attributes).

3. In experiment 3, the reduced information system generated by the rough set and then tested for p-value was used (the extra reduced COVID-19 dataset). This experiment uses the entire informationsystem (691 rows and 9 attributes).

For each experiment, the three different scenarios are explained below:

1. Scenario 1 (reveals model 1): The dataset with the three classes (accept the vaccination (A), rejectthe vaccination (B), and hesitate (C)).

2. Scenario 2 (reveals model 2): The dataset after replacing class C with class A.

3. Scenario 3 (reveals model 3): The dataset after replacing class C with class B.

Most of the descriptive statistics in the field of medicine were performed using standard deviationsand means which are usually one-to-one comparisons by finding the relationship between two variables. In this study, the analysis was conducted using machine learning methods (rough set theory and decision tree classifier) and the statistical t-test. The generated factors are the key players that have an impact on the acceptance or rejection of COVID-19 vaccination. These factors need to be further analyzed to understand the reasons behind the rejection and hesitation of the vaccine. If so, we simply work on the obstacles to resolve them. Such work will have a high impact on the safety of society against COVID- 19.

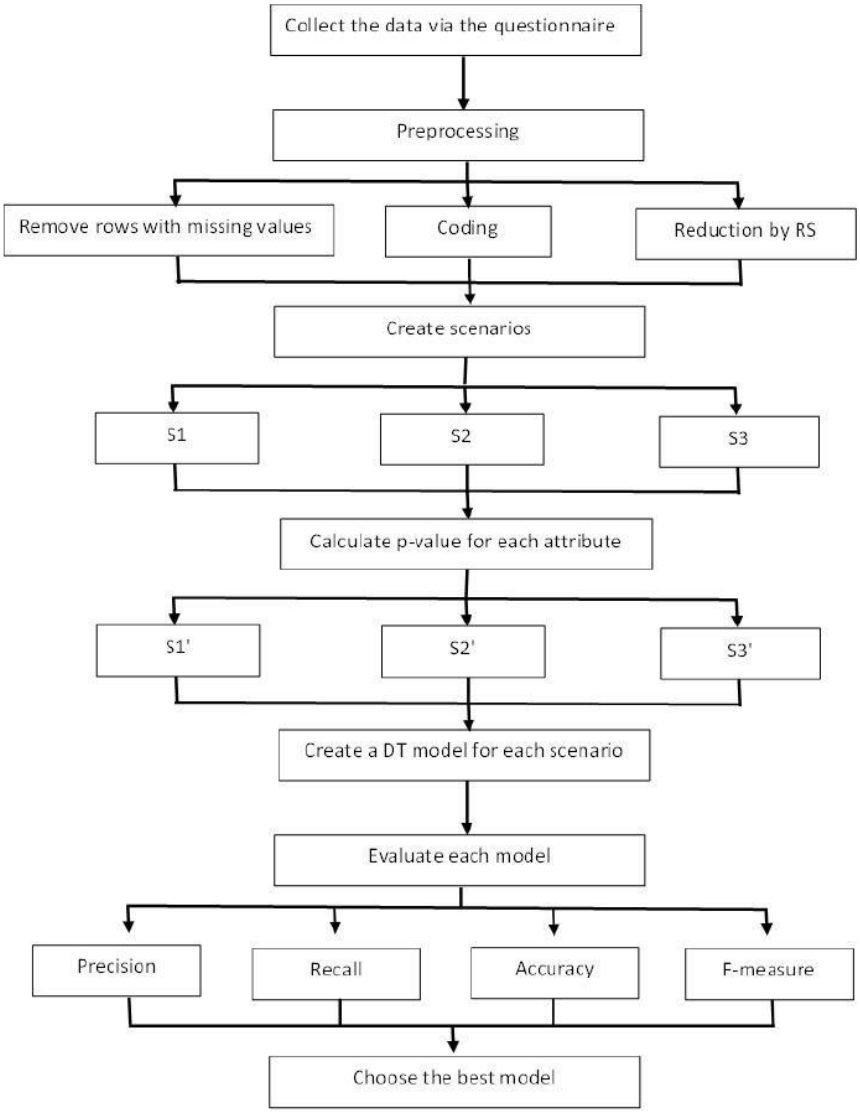

Figure 2: Model 2.

4. RESULTS

4.1. Distribution of Characteristics

Most of the participants were residents (60.64%) aged 12 and older. Around 55.86% are members of the AOU (students and staff), whereas 44.14% are their relatives who are not members of the AOU. The participants were fairly distributed according to their sex with (50.22%) females. Most of the participants were between 18 and 29 years old (47.18%). More than half of the participants (56.15%) are undergraduate students, 5.2% have post-graduate education and 38.35% are at the school level. Themost frequently informed comorbidities (considering that the participant may have more than one comorbidity) were hypertension (5.5%) and diabetes (4.2%), followed by respiratory diseases (5.79%), heart disease (2.89%), and vaccine allergy (1.01%). Meanwhile, (80.61%) reported that they do not suffer from any comorbidities. Only 16.93% reported being smokers. Of the 691 participants, 370 reported having been infected with COVID-19 (53.55%). Most of the participants adhered to the guidelines of the Ministry of Health (91.46%). When participants were asked about the level of stress they feel about this epidemic, most reported having a medium level of stress (~38.06%), followed by those who did not have stress (31.98%), low level (20.98%) and high level (8.97%). Approximately 34.3% of the participants were in contact with COVID-19 patients. Among 691 participants, 194 (28.08%) were concerned that the COVID-19 vaccine could be harmful or have side effects, 113 said that the vaccine is not saved (16.35%), 24 were concerned about the safety of the vaccination site (3.47%), 58 of them do not know which

type of vaccine is suitable for them (8.39%), and 302 (43.7%) said that they are not concerned. Most of the participants reported that they obtain reliable information on COVID-19 vaccination from the Ministry of Health (~71.64%), social media (~15.92%), people around (5.21%), and others (7.24%). Only 19.25% of the participants reported that they are in a high-risk category to easily catch COVID-19 as they are old or work in the health sector. Approximately (56.15%) of the participants reported having previously received the Influenza vaccine. Only 25.47% of the responders believe that vaccination is effective against omicron, whereas 47.76% were not sure about that. About 53.84% of the participants were against forcing people to take the vaccination. Almost 32.27% agreed to prevent people who did not take the vaccine from entering public areas. Approximately 40.1% of the respondents said they had no plan to take the third dose of vaccination, whereas 38.8% of them were registered with the ministry to take it. The rest of the respondents are not sure whether to take it or leave it. Around 44.6% of the respondents expressed their anxiety about not being vaccinated. In general, around 50.9% of participants do not trust the COVID-19 vaccination.

4.2. Acceptance and Refusal of a COVID-19 Vaccine: Motivations and Obstacles

More than half of the participants (65.7%) reported their acceptance to receive COVID-19 vaccines, while 18.4% of the participants reported their refusal to receive COVID-19 vaccines and 17.2% were uncertain. Of the vaccine refusal participants, subjects aged 18-29 represent 44.1%, subjects who suffer from chronic disease represent 21.05%, around 16.76% of the subjects were infected with COVID-19, 54.33% were previously vaccinated against the seasonal flu, almost 70.08% have concerns about receiving a COVID-19, most of them (50.39%) obtained information about COVID-19 from the Ministry of Health (this may need a deep investigation of the quality of information published by the ministry), about 55.12% of them thought that the omicron wave is not targeting people who did not receive the vaccine (this makes them think that they are safe from the infection of omicron), the majority of them (74.02%) were not agreed to forbid them from entering public places, and 47.24% of them thought that COVID-19 is a global hoax. Almost 43.31% of the participants who refused to receive a COVID-19 vaccine are members of AOU (students and staff), but not their families. Participants reported that the most difficult thing they could face if they did not get vaccinated was constant anxiety about catching the disease (40%) while (60%) reported that they do not have any fears. More than half of the participants (55%) trust the effectiveness of the vaccine to reduce the disease. Of the participants, 50.2% reported that not taking the vaccine will increase the incidence of the disease. Almost half of the participants (47%) stated that the vaccine is effective against the new strain of coronavirus (omicron), while 30.5% reported that it is not and 22.3% were not sure. Around 40% of the participants reported that the wave (omicron) targets people who have not received the vaccine more aggressively than the recipients, while 36% reported that it is not and 23% were not sure. Most of the participants (61%) did not agree to force people to take the vaccine because it is against their freedom. The survey showed thatcitizens and residents have recently resorted to registering to receive the COVID-19 vaccine. The main reasons behind that were to travel (61%), to enter clubs, restaurants, and markets (60%), and because their employers force them (57%). Most of the participants (41%) reported that the increase in the rate of injuries and the number of deaths makes them rush to take the vaccination, while 25% reported that this reason is not important to rush them to receive the vaccine, and 34% were not sure if this reason is significant. Most of the participants (56%) reported that they are not willing to be vaccinated if your first dose of one vaccine and the second dose of another vaccine, while 23% reported that they accept it and 20% were not sure. Around half of the participants (55%) reported that they support disallowing unvaccinated people from entering public places, while 29% reported that this is against their freedom and 16% were not sure. Unfortunately, only 39% of the participants reported that they plan to receive the third dose of COVID-19, while 42% reported that they will not and 21% were uncertain. Around 30% of the participants think that COVID-19 is a global hoax, while 31% of the participants reported that it is not and 40% were unsure. Most of the participants (65%) belong to the Arab Open University. Figure **3** represents the significant factors related to being reluctant to receive a COVID-19 vaccine withtheir percentages.

4.3. The Trend of Hesitant Participants

In this manner, the goal is to find the best scenario (model) that determines the most probable preferences of the reluctant participants. The one with higher accuracy represents such cases' inclinations to closely accept or reject the vaccination.

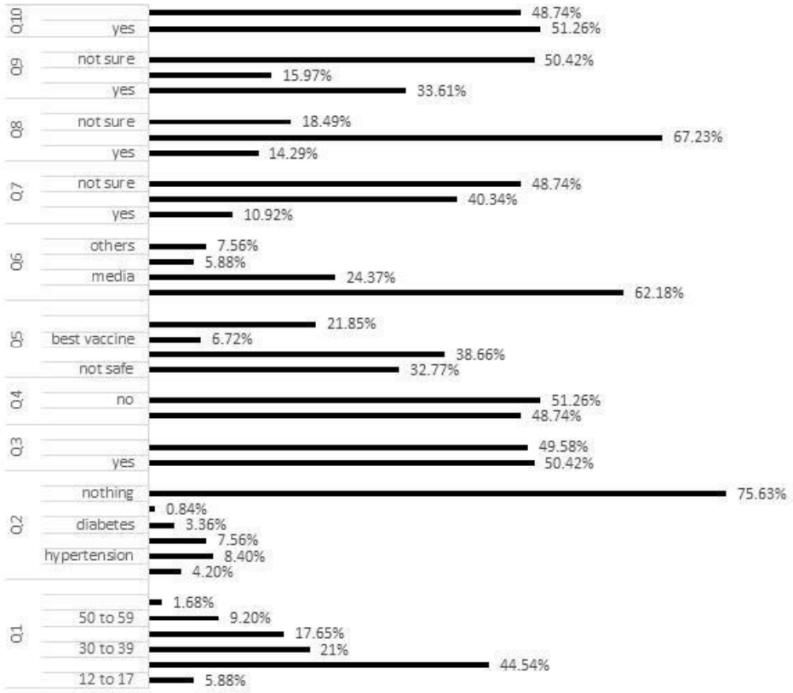

Figure 3: Factors related to the hesitates to receive a COVID-19 vaccine (the percentages refer to thehesitant participants in each bin out of the total of all reluctant subjects).

For experiment 1, the results are shown in Tables **3** and **4**. Table **3** shows the best accuracy for scenario 2 with 81.6%. The accuracy of scenario 1 is 68%, while it was 69.2 for scenario 3. For a more comprehensive image, precision, recall, and F-measure show an obvious preference for scenario 2 ratherthan scenario 3. This gives another indication that scenario 2 is better than scenario 3. Table **3** shows the accuracy of the three scenarios, whereas Table **4** shows that precision, recall, and the F-measure provide high rates for the best scenario (scenario 2).

Table 3: The Accuracy of each Scenario of Experiment 1

The Scenario	The accuracy %
Scenario 1	68
Scenario 2	81.6
Scenario 3	69.2

Table 4: Precision, Recall, and F-Measure of Scenario 2 and Scenario 3 of Experiment 1.

Performance Metric	Scenario 2	Scenario 3
Precision	81.6	68.8
Recall	100	96.1
F-measure	89.9	78.4

For experiment 2 and by viewing the analysis results, one can conclude that scenario 2 proved to be very efficient and outperformed the other analyzed scenarios and it is the best. Table **5** shows the accuracy of the three scenarios, whereas Table **6** shows that precision, recall, and the F-measure provide high rates for the best scenario. The best scenario is the proposed scenario for this research problem (scenario 2).

Table 5: The Accuracy of each Scenario of Experiment 2

The Scenario	The accuracy %
Scenario 1	64.47
Scenario 2	81.82
Scenario 3	64.47

Table 6: Precision, Recall, and F-Measure of Scenario 2 and Scenario 3 of Experiment 2

Performance Metric	Scenario 2	Scenario 3
Precision	81.82	64.47
Recall	100	100
F-measure	90	78.4

The classification accuracy obtained by the decision tree classifier for scenario 1 was 64.47%. Under the

Table 7: The p-Value of each Question Concerning each Scenario

Question #	P-value (scenario 1)	P-value (scenario 2)	P-value (scenario 3)
Q1	< 0.05	< 0.05	< 0.05
Q2	< 0.05	< 0.05	< 0.05
Q3	< 0.05	< 0.05	< 0.05
Q4	0.388	< 0.05	< 0.05
Q5	< 0.05	< 0.05	< 0.05
Q6	< 0.05	< 0.05	< 0.05
Q7	< 0.05	< 0.05	< 0.05
Q8	< 0.05	< 0.05	< 0.05
Q9	< 0.05	< 0.05	< 0.05
Q10	< 0.05	< 0.05	< 0.05

same experimental conditions and concerning scenario 2, the prediction rate was 81.82%, whereas,in scenario 3, the prediction rate was 64.47%. Thus, scenario 2 resulted in an obvious improvement. Formore accurate decisions, precision, recall, and F-measures were also examined as performance metrics. Precision and F-measure show an obvious preference for scenario 2 rather than scenario 3 whereas recall is the same for both. This gives another indication that scenario 2 is better than scenario 3.

For experiment 3, to give another picture of the work and the importance of the generated attributes, a t-test measure was used to ensure the importance of these attributes generated by the rough set theory. The p-value was calculated for each attribute (question) concerning the classification attribute that represents the accept, refuse, or hesitate values. Table **7** represents the results.

Table **7** shows that question 4 (in bold) is not significant for scenario 1, whereas it is significant for other scenarios. As is shown earlier (in Tables **5** and **6**), the best scenario is scenario 2 and consequently the importance of the fourth question is not significant and will not affect the best scenario (scenario 2). For more details, the accuracy and other performance metrics were calculated for the three new scenarios after this question (the fourth question) is removed from the reduced dataset generated by the rough settheory. The results are shown in Tables **8** and **9**.

Table **8** shows that the best accuracy is still given for the best scenario (scenario 2) with an accuracyvalue of 81.80% which is less than that of scenario 2 of experiment 2 by only 0.02%. As shown in Table **9**, the recall and F-measure of scenario 2 and scenario 3 are the same as in scenario 2 and scenario 3 ofexperiment 2, while the precision values of scenario 2 and scenario 3 are less than those of scenario 2 and scenario 3 of experiment 2 by 0.02% and 0.03% respectively. Such analysis improves the acceptance of scenario 2 of experiment 2 which has higher performance than scenario 2 of experiment 3 shown by its accuracy and precision values. Also, scenario 2 of experiment 2 has a higher performance than scenario 2 of experiment 1 shown by its accuracy, precision, and F-measure values, whereas it is the same for recall value.

Table 8: The Accuracy of each Scenario of Experiment 3

The Scenario	The accuracy %
Scenario 1	64.50
Scenario 2	81.80
Scenario 3	64.50

Table 9: Precision, Recall, and F-Measure of Scenario 2 and Scenario 3 of Experiment 3

Performance Metric	Scenario 2	Scenario 3
Precision	81.82	64.47
Recall	100	100
F-measure	90	78.4

In conclusion, scenario 2 of experiment 2 is the best followed by scenario 2 of experiment 3 with little difference in accuracy value, and then scenario 2 of experiment 1 (shown in Figure **4**). But there is an advantage for scenario 2 of experiment 3 that it uses a smaller number of attributes (factors). These results

revealed that the data of the subjects who are reluctant to take the vaccine are compatible with the data of the subjects who accept the vaccine. From this conclusion, the golden behavior of hesitant participants says that they tend to accept the vaccine rather than reject it.

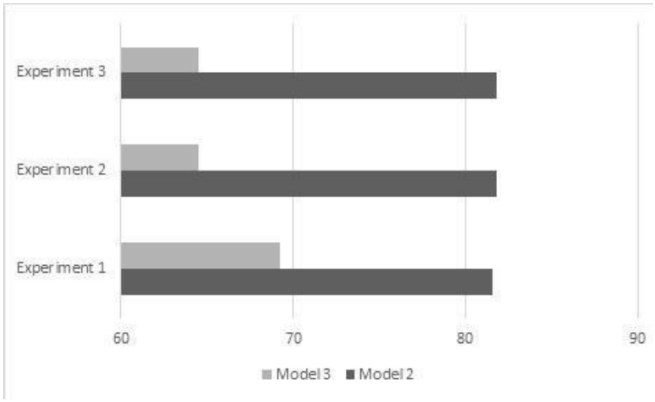

Figure 4: The accuracy of models 2 and 3.

5. DISCUSSION

This is the first study in Kuwait to assess the acceptance and rejection/hesitancy of the COVID-19 vaccine against Arab Open University students and their families. The results demonstrated that the rejection/hesitation of the vaccine (~34.5%) was rated moderate to high among the survey subjects. The results show that participants with high knowledge of the vaccine received from the Ministry of Health (51.8%), had hypertension (60.5%), heart disease (61.9%), diabetes (66.7%), respiratory diseases (57.5%), Allergies (50%), also fear of the COVID-19 infection are more significant to accept the vaccine. Out of 126 participants who refused the vaccination, 55 are between the ages of 18 and 29 years (43.7%), and of 119 participants who are not sure they will accept the vaccine, 53 are between the ages of 18 and 29 years (44.5%). On the other hand, low vaccine rejection is predicted by ages greater than or equal to 50 with 15.9%. Vaccination against seasonal flu plays an important role as an indicator of high vaccine acceptance (69.8%). Around 29.2% of the respondents refused the vaccination because they believe that vaccination centers are not safe, 28.3% say that the vaccination itself is not safe, and 20.5% believe that the vaccine has side effects. Almost 61.9% of the participants who had previously been infected with COVID-19 accepted the vaccine, while 20.3% refused. The acceptance rate in this the study was compatible with other results reported by different studies such as that in Lebanon (63.4%) [30] compared to a lower rate reported in Kuwait (53.1%) [10]. The results of this study are also compatible with similar studies conducted in the UK (64–71.7%) [16], the US (69%) [13], and Japan (65.7%) [14].

To my knowledge, this is the first study to evaluate the acceptance/rejection of COVID-19 vaccines and their determinants based on the rough set method. Furthermore, it is the first study to propose a trending scenario for participants who are not sure about receiving the vaccine. The results of the analysis cannot be generalized to the entire Kuwait Community, since the sample dataset consisted of only AOU members and their home relatives. Finally, to minimize the risk of misunderstanding the questions, reviewing them for content and clarity was an important task before distributing the final form.

6. CONCLUSION

This study revealed moderately high acceptance of the COVID-19 vaccines (65.5%) among studentsin AOU and their families. Several significant factors were discovered that influence the acceptance level of vaccination including chronic disease, flu vaccine receipt, fear of some concerns (vaccine is not safe, harmful with side effects, type of vaccine, location safety), source of information on the vaccine, the thought of hoax and fear spread of omicron. The Ministry of Health should deal with the significantfactors associated with vaccine acceptance/refusal to increase the vaccination rate to achieve herd immunity. They must stand on the reasons for vaccine refusal, which represented 18.4%, and tackle thereasons for vaccine hesitation (17.2%) and overcome them. This study also revealed that hesitant participants tend to accept vaccination over rejection with a high accuracy value (81.82%). The findingsof this study offer a guide on the categories that must be addressed to increase vaccine rates by increasing the trust in the vaccine in all available ways, such as official information from the Ministry of Health, educational sectors (schools and universities), advertisements, media, and others.

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STATEMENT OF ETHICS

Ethical issues including confidentiality, voluntariness, and anonymity of the participants were considered. The study was approved by the

Information Technology and Computing program at AOU (No. 22007). Completing the questionnaire the participants was an indication of consent to participate.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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SUPPLEMENTARY DATA

The data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants but are available from the corresponding author [Al-Shalabi, L.]

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