Research Paper
Academic Platform Journal of Engineering and Smart Systems (APJESS) 11(1), 19-26, 2023
ISSN: 2822-2385
Received: 24-Jul-2022 Accepted: 05-Dec-2022
https://doi.org/10.21541/apjess.1137177

Forecasting the Impact of Vaccination on Daily Cases in Türkiye for Covid-19

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Abstract

In this study, it is aimed to investigate the effect of the vaccine on the cases in the fight against Covid-19, which threatens the whole world. The number of Covid-19 cases, which were tried to be reduced with various precautions all over the world and in Türkiye, has become a new hope with the start of vaccination. The increase in the effect of the vaccination, which started in January 2021, brought the need to examine the vaccination rate in three groups as slow, medium and fast. In this study, different scenarios were tried in the number of vaccinations applied in Türkiye, and the daily number of cases until December 2021 was forecasted by Artificial Neural Networks (ANN). The effect of restrictions and vaccination on the number of Covid-19 cases was investigated. Different training algorithms were used and the best success rate was found with the comparison method. Accurate forecasting of cases will let policy makers to take precautions on time. Moreover, the effect of vaccination on cases should be investigated.

Keywords: Covid-19, Forecasting, Artificial Intelligence, Artificial Neural Networks (ANN), Daily Case.

1. INTRODUCTION

New studies and developments are constantly being carried out in the fight against the coronavirus (Covid-19) pandemic, which has been affecting worldwide for about two years. The Covid-19 epidemic, which emerged in Wuhan, on December 1, 2019, has spread worldwide over time. When the disease was seen in other countries, the World Health Organization (WHO) declared a pandemic on January 30, 2020 [1,2]. A new state of panic has occurred in the world with the confirmation of Italy's first case on January 31, 2020. WHO declared that Europe is the epicenter of the Covid-19 crisis on March 13, 2020. The deaths in Italy on March 19, 2020, leaving behind China, where the disease started, brought about the danger of the disease and the need to find treatment as soon as possible.

The precautions at the beginning of the pandemic are mostly mask, distance and cleanliness. In addition, various restrictions have been introduced. Human mobility was reduced with various restrictions to prevent the spread of the pandemic. Thus, it aimed to increase the protection of people with weakened immunity against the possibility of contamination. Although the restrictions seem to be beneficial in reducing the risk of transmission, they affected negatively in many areas such as the country's economy, people's lifestyles, education systems, etc. The states applied some restrictions against the possibility of the collapse of the health systems when the number of seriously ill patients increased. The first Covid-19 case was detected in a Turkish citizen who returned from a European trip in Türkiye on the night of 10 March 2020. The first Covid-19 case seen in Türkiye has brought some restrictions. Serious restrictions have been started to be considered due to reasons such as lack of information about the virus, the health infrastructure not being ready for Covid-19, and the lack of certain treatment methods. Most of the countries tried to prevent the epidemic by restricting mobility at the beginning of the pandemic. Restrictions slowed the pace of the epidemic and reduced the number of daily cases. Although restrictions reduce the risk of transmission, they cannot eliminate the disease. Thus, some vaccine studies developed for the treatment of the disease. Vaccine studies, which have been actively implemented, are becoming widespread day by day. It has been observed that some precautions such as the obligation to wear masks in the open air have been removed in some countries where vaccination is sufficient. Looking at this information, it is understood that the vaccine is the most important factor in the fight against Covid-19.

In this study, the effect of vaccination and restriction on the number of daily cases was investigated. The daily number of cases was forecasted by considering the weekend & evening curfews, partial & full closure, and controlled normalization periods applied from March 2020 to July 2021. The success rates obtained using different training functions were

compared for these estimations. The effect of Covid-19 vaccination was included in the study with the start of vaccination in Türkiye on January 13, 2021. The purpose of this study; is by determining the number of cases for the future, reduce the hospital density, and direct the restrictions to be taken according to the number of cases. In addition, it is to raise people's awareness by explaining the effect of vaccination on the number of cases.

2. LITERATURE REVIEW

The lack of information about the Covid-19 allowed many studies. As a result of each research, new various findings were obtained. Daniel mentions the damage of Covid-19 to education. He aimed to minimize these damages caused by Covid-19 and ensure the education sector's continuity with his proposal [3]. When Covid-19 first appeared in Wuhan, it could not determine the diagnosis of Covid-19 quickly due to reasons such as the world was not ready for such an epidemic, the necessary precautions were not taken, and the epidemic spread rapidly. Alazab et al. diagnosed Covid-19 disease using Deep Convolution Neural Network (CNN). They completed the detection process by obtaining an F-score between 95-99% in their data consisting of 1000 chest X-rays. In addition, using 3 different forecasting algorithms, they estimated the number of patients who will get Covid-19 disease in 7 days [4,5].

Najmul Hasan used a hybrid structure consisting of Ensemble Empirical Mode Decomposition (EEMD) and ANN for Covid-19 case detection. He examined the period between 22 January and 18 May 2020. In his examination, he decomposed the signals with EEMD and separated them from their noise. After this process, he trained with ANN. The result of his training gave better results than traditional methods [6]. Ardabili et al. estimate the number of Covid-19 cases globally with the Grey Wolf Optimizer based ANN. They used the cases for training between January 22 and September 15, 2020, and the number of cases between September 16 and October 15, 2020, for testing. They obtained 6.23 Mean Absolute Percentage Error (MAPE) in their training and 13.15 MAPE results in the test process [7].

Ozen et al. estimated the number of cases for the USA using the Python and R programming languages. They compared the error rates of algorithms such as polynomial regression and linear regression. As a result, they suggested that the estimations should be made with polynomial regression since the error rate of the linear regression algorithm was low [8]. Ankaralı et al. forecasted the number of intensive care beds and respiratory devices for April 2020 with Gompertz and Time-series models. They made an estimation of the number of intensive care patients per day for a month [9]. Rustam and friends forecast the number of Covid-19 cases using the MLS model in their study named Covid-19 Future Forecasting Using Supervised Machine Learning Models. Standard estimation methods such as Linear Regression (LR), Support Vector Machine (SVM), and Exponential Smoothing (ES) were also used in their estimations [10].

Sahai et al. made predictions for some countries such as the USA, Brazil, India, Russia, and Spain. They used the ARIMA model and the Hannan and Rissanen algorithm [11].

The IHME Covid-19 health service utilization forecasting team estimated the number of beds, the number of intensive care unit's beds, and the number of intubated devices in the health infrastructure depending on the Covid-19 disease using a statistical method [12]. Turan et al., In their study, estimated the 5-day COVID-19 Death Numbers in Turkey with ANN. Their study using the ANFIS model predicted the number of deaths in the next 5 days with a 96% accuracy rate [13]. Selvi and Başer, in their study, tried to predict the weekly death numbers for the future by using Facebook's Prophet model. They made their predictions for 15 different periods [14]. Namusudra at al. in their study proposes a novel Nonlinear Autoregressive (NAR) Neural Network Time Series (NAR-NNTS) model for forecasting COVID-19 cases. The results showed that NAR-NNTS model trained with LM training algorithm performs better than other models for COVID-19 epidemiological data prediction [15]. Eroğlu uses artificial neural network (ANN) and deep learning models to predict Covid-19 cases 7 days in advance. It was also found that ANN was successful in Covid-19 case prediction [16]. Fanelli and Piazza analyze the temporal dynamics of the coronavirus disease 2019 outbreak in China, Italy, and France in the time window. Their study's first aim is to provide officials with realistic estimates for the time and magnitude of the epidemic peak, i.e., the maximum number of infected individuals [17].

3. MATERIALS AND METHODS

3.1. Artificial Neural Network Model

Artificial Neural Networks (ANN) is a system that imitates the working structure of the human brain and is inspired by the nervous system [18,19, 20]. The ANN is the definition of functions such as thinking like a human, making decisions, analyzing, and comparing to machines. The machines also enter the learning phase like humans and gain experience with the help of ANN [21, 22, 23]. The multi-layered ANN structure is given in Figure 1.

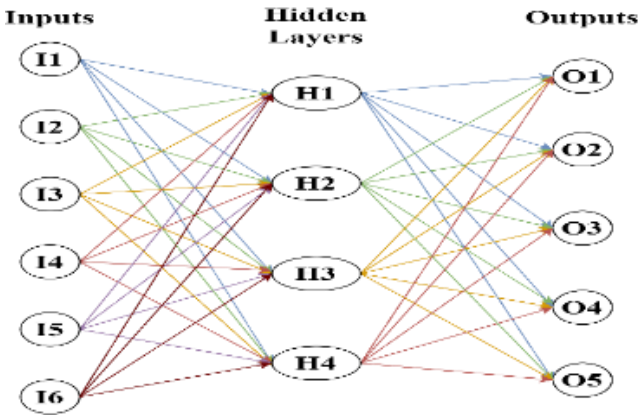

Figure 1. Multi-layer ANN network structure

Various activation functions are used in ANN to teach complex data better. Logarithmic-Sigmoid (Logsig), Tangent-Sigmoid (Tansig), and Purelin are the most basic three activation functions in ANN. Logsig function is the most used activation function. The definition range of this function is in the range [0 1] and exhibits a non-linear variation in this range. The definition range of the Tansig is

[-1 1]. The most important difference between the Tansig and the Logsig function is that it is also defined in negative regions. Purelin is the activation function in which the output value changes linearly according to the input values. The definition range is [-1 1]. The input and output curves of the activation functions are given in Figure 2 [24].

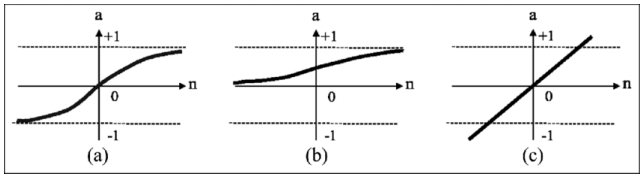

Figure 2. Input-output curves of activation functions (a: tansig b: logsig c: purelin)

It is aimed to reduce training time and increase training performance by using more than one training function. Thus, Levenberg-Marquardt Backpropagation (Trainlm), Gradient Descent with Momentum and Adaptive Learning rate Backpropagation (Traingdx), Conjugate Gradient Backpropagation (Traincgb), and Resilient Backpropagation (Trainrp) were used as training functions in the study [25].

Trainlm: It is known as Luvenberg-Marquardt backpropagation, which is frequently encountered in ANN applications. It works with the principle of updating the bias and weights according to the Luvenberg-Marquardt optimization. Although it needs more memory, it is one of the most preferred training functions.

Traingdx: It is a training function with variable learning rate and backpropagation. It is advantageous in terms of variable learning speed.

Traincgb: Powell/Beale is a training function which has restart backpropagation. weights and biases are updated according to the Powell/Beale spread.

Trainrp: It is a network training function that updates the weight and bias values according to the flexible backpropagation algorithm (Rprop). The soft backpropagation training algorithm is a successful function in eliminating the detrimental effects of the sizes of the partial derivatives [25].

3.2. Data

The data used in this study were taken from the official data announced by the Ministry of Health of the Republic of Türkiye [26]. All symptomatic and non-symptomatic case numbers were used in this study. At the beginning of the epidemic, the Ministry of Health announced the number of patients showing the symptoms of the disease until November 2020 in Türkiye. Therefore, the estimated case numbers were used for the number of asymptomatic patients between March 2020 and November 2020.

4. EXPERIMENTAL STUDY AND DISCUSSION

To examine the effect of vaccination on daily cases a neural network model was built. The model has six inputs, four hidden layers and just output. The factors that trigger the daily number of cases were chosen as input data. These factors were the restriction factor, the total number of tests, the number of daily applied tests, daily applied number of first-dose and second-dose vaccines, the total number of vaccines applied. It is expected that the number of daily cases will decrease when the restrictions or the number of vaccinations is intense. In addition, the need for Covid-19 testing was used as an input with the thought that contact with positive cases could be high. The output data of the designed algorithm were the number of daily cases. The estimated number of immunized people may be far from the real values since the protection of the applied vaccines, how many antibodies the recovered cases have, or the duration of immunity against the disease are not known exactly. The immunity period of those who had the disease was accepted as about three months. The mean time between the first dose and the second dose of vaccine was assumed as 14 days and all vaccines were choosing one type. Considering that the first dose of the vaccines provides 70% and the second dose 80% antibodies, the case of lasting three months of immunity was examined.

It was carried out with the Feed-Forward Backprop Network type in ANN for prediction and training. The data announced until 29 July 2021 were used for training and the period until between August and December 2021 was used for testing. Data from 30 July to 24 August were used for testing. The daily case numbers were estimated in the Network Toolbox interface in the MATLAB. The purpose of using more than one training function algorithm is to shorten the training time and to increase the performance. The validation values of the training functions of ANN were given in Table 1.

Table 1. Training functions and their performance used in ANN

Function Name	Validation: R	All: R
Trainlm	0.8781	0.8737
Traingdx	0.9957	0.9943
Traincgb	0.9981	0.9975
Trainrp	0.9946	0.9943

Feed-Forward Backpropagation network type and Mean Square Error (MSE) were used for all training functions [24]. Test results are given in Table 2.

Table 2. Test results in ANN

Function Name	MSE (Normalized Value)
Trainlm	0.8781
Traingdx	0.9957
Traincgb	0.9981
Trainrp	0.9946

Traincgb training function has the most successful validation rate. In addition, the validation values of Gradient Descent with Momentum and Adaptive Learning rate Backpropagation (Traingdx) and Levenberg-Marquardt Backpropagation (Trainrp) training functions were close to

Traincgb. The data were normalized and trained. The comparison of daily case numbers with estimated and actual data with the Trainlm function as shown Figure 3. As a result of the training, the validation value of the Trainlm function was calculated as 87.81%.

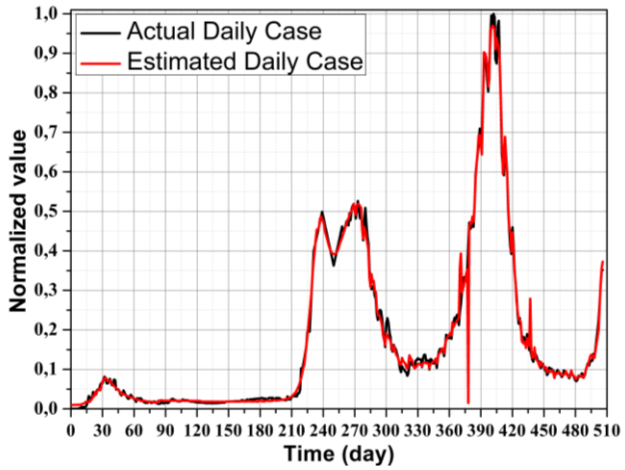

Figure 3. The comparison of daily case numbers with estimated and actual data with the Trainlm.

The vaccination process started on January 13, 2021, while it aimed to reduce the risk of transmission with various restrictions in the early days of the epidemic. After that, it is expected that herd immunity will increase rapidly and the number of cases will decrease. It was observed that there was a decrease in the vaccination rate due to some reasons. The algorithm was trained with the help of the training functions of the data announced until July 29, 2021. The daily number of cases was estimated according to the high, normal and low vaccination rate until November 2021.

The high vaccination status has been compared to the period when the number of vaccines applied from the past to the present is the highest. It also indicates that more and more vaccines will be made every day in the future. The normal vaccination status is the continuation of vaccination close to the rates that have occurred in the last weeks. Low vaccination status is the gradual decrease in the number of vaccinations. The numbers of high, normal, and low vaccination status used in the estimates are shown in Figure 4.

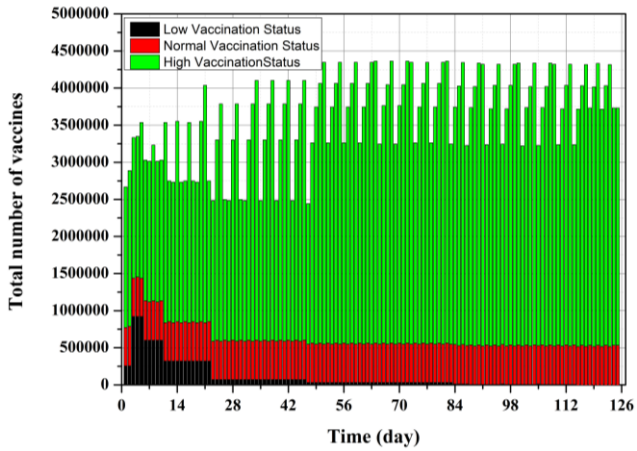

Figure 4. The total number of vaccines

The total number of vaccinations between August and December is given in Figure 4. The daily case numbers were estimated according to the vaccine amounts indicated in Figure 4. The vaccination status was estimated until November 2021 according to the application of low, normal and high vaccines. The daily case numbers were estimated with different training functions and the vaccination status was assumed as between 20 July and 29 July. The estimated number of daily cases by four different functions was given in Figure 5.

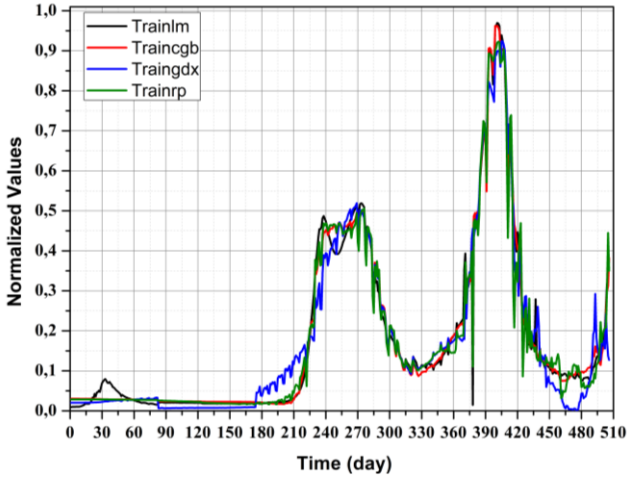

Figure 5. The estimated number of daily cases by four different functions.

The potential number of daily cases was estimated with the Traincgb function according to the low and high vaccination status, and it shown in Figure 6.

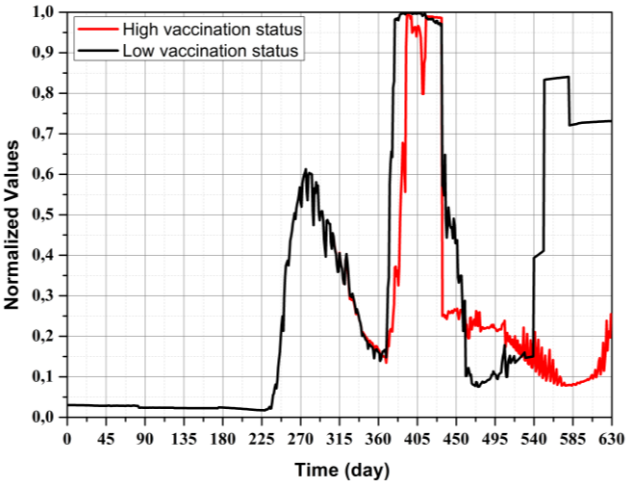

Figure 6. Daily case number estimation by low and high vaccination status of Traincgb function.

It is expected that the immunity will be directly proportional with the increase in the number of vaccinations. It is thought that the number of daily cases will decrease with the increase of immunity. Other input data were kept constant to display the effect of the vaccine in the estimates clearly. The estimation of the change in the number of daily cases of the Traingdx training function when vaccination status is high is shown in Figure 7.

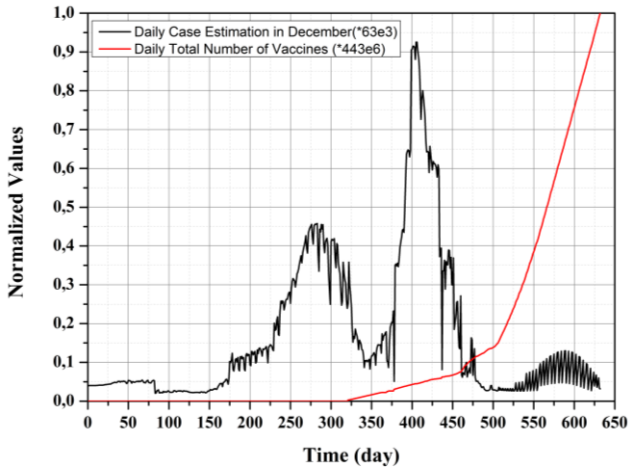

Figure 7. The estimation number of daily cases of the Traingdx training function

There were serious decreases in the number of daily cases, when vaccination was high. The reason for the sudden increase in the number of cases in late November and early December (between 500 and 625 units on the chart) is that the immunity period in vaccination is considered to be three months and the third dose of vaccines is not taken into account. It is expected that the daily number of cases will be around 2000 – 3000 if the total amount of first and second dose vaccination at the beginning of December is 440 million. The number of 3000 cases in December is estimated in the chart, since the third dose of vaccines is not taken into account and the immunity period is accepted as 3 months. Thus, the importance of the 3rd dose vaccine is also revealed. It is thought that the number of daily cases will decrease without the need for restrictions when enough vaccination is done. The effect of the restriction when the vaccination status is normal with the Traincgb training function is given in Figure 8. The use of different training algorithms allows the training functions to be compared with each other. The number of cases announced by the Ministry of Health in July and the daily number of cases estimated by the designed algorithms were given in Table 3.

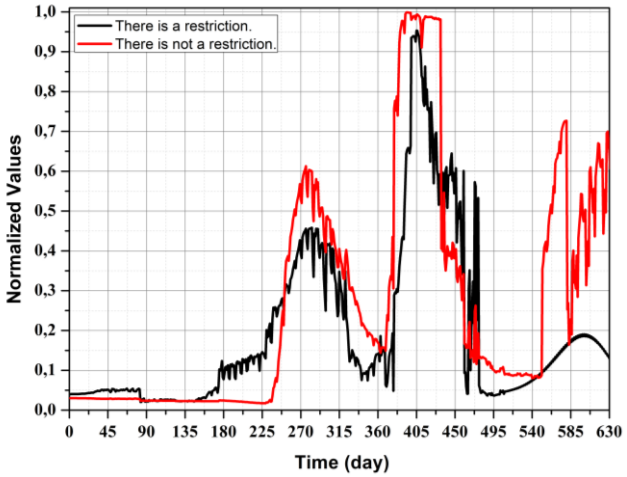

Figure 8. Estimation of the number of daily cases by Restriction Status with Traincgb Training Function.

Table 3. The estimated and announced daily number of cases in July

Date	The Announced Number of Cases	Estimated Number of Cases			
		Trainlm	Traingdx	Traincgb	Trainrp
10.07.2021	5530	5419	3681	6807	3984
11.07.2021	5261	5434	4353	6822	3722
12.07.2021	5404	5994	4608	7162	3902
13.07.2021	6285	6665	5609	7714	4548
14.07.2021	6907	8089	7653	8690	4696
15.07.2021	7304	7344	13614	8592	4414
16.07.2021	6918	10608	13864	10179	5861
17.07.2021	7666	8481	23387	9315	5112
28.07.2021	7680	8769	12828	9262	7164
19.07.2021	7667	8757	10750	8888	7481
20.07.2021	8780	7167	9837	7484	7816
21.07.2021	8151	7054	7758	7214	9993
22.07.2021	9586	9217	7772	8909	14009
23.07.2021	11094	10219	11426	9711	10830
24.07.2021	12381	10985	12609	10080	12005
25.07.2021	14230	11791	11942	10437	12660
26.07.2021	16809	16255	11189	15894	13082
27.07.2021	19761	19129	20833	18763	13123
28.07.2021	22291	22312	15194	19700	19021
29.07.2021	22161	22498	11618	24113	28060

Table 4. Daily case number estimates with training functions for November and December

Date	Daily Number of Case Estimates											
	Vaccination status: High				Vaccination status: Low				Vaccination status: Normal			
	Trainlm	Traingdx	Traincgb	Trainrp	Trainlm	Traingdx	Traincgb	Trainrp	Trainlm	Traingdx	Traincgb	Trainrp
09.11.2021	7623	4878	6645	5286	23958	59212	45998	12084	12022	11317	8024	28414
10.11.2021	4605	6655	7402	5391	23251	59140	46006	12058	12263	11475	8179	29488
11.11.2021	4512	2149	6240	8701	22476	58813	45992	7509	12462	11133	8223	28071
12.11.2021	6141	3396	6730	5526	21929	58980	46024	7509	12717	11261	8392	29103
13.11.2021	5258	4451	7346	5091	21291	58896	46031	5677	12919	10914	8441	27633
14.11.2021	3994	6102	8718	4960	20676	58807	46038	11961	13189	11013	8625	28623
15.11.2021	3955	5947	9227	4853	20083	58715	46046	18247	13393	10662	8680	27111
16.11.2021	4652	1904	6683	8946	19511	58618	46053	11916	13678	10734	8880	28060
17.11.2021	6474	3002	7681	5931	18961	58516	46059	11894	13883	10380	8940	26516
18.11.2021	9340	3912	8902	5014	18431	58409	46066	11872	14180	10425	9159	27425
19.11.2021	4543	5338	11610	4540	17922	58296	46073	11851	14387	10070	9226	25859
20.11.2021	4669	1717	7251	8954	17432	58179	46080	18139	14697	10089	9465	26730
21.11.2021	6463	2698	8932	6351	17022	58225	46095	11826	14904	9734	9538	25152
22.11.2021	9600	3499	10923	5086	16556	58106	46100	11806	15225	9729	9799	25985
23.11.2021	4019	4714	15057	4318	16109	57982	46104	11787	15431	9375	9879	24406
24.11.2021	6366	2475	10406	6723	15679	57852	46109	11768	15763	9348	10164	25203
25.11.2021	9590	3196	13194	5219	15266	57716	46113	11749	15969	8997	10252	23633
26.11.2021	4649	4237	13409	4207	14870	57574	46118	11731	16310	8951	10564	24395
27.11.2021	6186	2263	12421	7108	14489	57426	46122	11713	16513	8603	10659	22842
28.11.2021	9356	2908	16070	5419	14123	57272	46126	11696	16864	8539	10999	23569
29.11.2021	4642	3777	15834	4153	13772	57110	46130	11679	17064	8197	11103	22042
30.11.2021	5955	2064	15016	7482	13447	56940	46133	11664	17423	8119	11474	22737
01.12.2021	5866	2003	15918	7591	13122	56765	46137	11648	17714	7904	11731	22317
02.12.2021	7623	4878	6645	5286	23958	59212	45998	12084	12022	11317	8024	28414

The correlation coefficients between the obtained estimation results and the announced number of daily cases are Trainlm: 97.23%, Traingdx: 46.42%, Traincgb: 94.26% and Trainrp: 89.61%. As can be seen from the correlation coefficients, the best estimation results for July were obtained with the Trainlm Function. Since the beginning of the pandemic, the best accuracy rate from March 2020 to July 2021 has been achieved with the Traincgb training function, at approximately 98% access rate. Estimates for November and December 2021, taking into account different vaccination status and there is no restriction, were given in Table 4.

As can be seen in Table 4, it is seen that there is a serious increase in the number of cases when vaccination status is low and a decrease in the number of daily cases when the vaccination status is high. The input values such as the number of tests performed per day and the restriction factor were kept constant and the effect of the vaccine on the daily number of cases were only changed while estimating the daily number of cases. It is seen that the number of cases will decrease without any restrictions during periods of high vaccination status. The effect of the restrictions for the two situations where the vaccination status was normal and low were examined and the results were given in Table 5.

Table 5. The effect of restriction on estimated daily case numbers with the Trainrp function

Date	Vaccination Status High	Vaccination Status Normal
09.11.2021	5776	4850
10.11.2021	5750	4733
11.11.2021	5698	4770
12.11.2021	5701	4556
13.11.2021	5677	4845
14.11.2021	5653	4923
15.11.2021	5630	4995
16.11.2021	5608	5291
17.11.2021	5586	5229
18.11.2021	5564	4912
19.11.2021	5543	4860
20.11.2021	5523	4871
21.11.2021	5518	4890
22.11.2021	5498	4738
23.11.2021	5479	4691
24.11.2021	5460	4732
25.11.2021	5441	4826
26.11.2021	5423	4872
27.11.2021	5405	4923
28.11.2021	5388	4850
29.11.2021	5371	4859
30.11.2021	5356	4805
01.12.2021	5340	4860
02.12.2021	5776	4850

Restrictions have had a significant impact during periods of low vaccination status. Estimation made in daily case numbers shows that vaccination has a significant effect on the number of cases. When the vaccination status is high, there is no need for restrictions. As a result of this study, the estimated number of people who became immune according to the amount of vaccination in December is shown in Table 6.

Table 6. Estimated number of immunized people

Date	Vaccination Status High	Vaccination Status Normal	Vaccination Status Low
02.12.2021	75582935	69429669	63154480

In this study, it is aimed to see the effect of the vaccine on the number of cases and the effect of restrictions. In addition, as a result of the training, it aims to guide socialization by estimating the number of cases in the coming months. When the tables are examined, intensive vaccination creates a serious decrease in the number of daily cases. Reducing vaccination has an adverse effect on the daily number of cases. When the estimations examined in Table 4 and Table 5, there is no need for restriction in case the vaccination is high. Thus, it shows the importance of vaccination.

5. CONCLUSION

In this study, it is aimed to predict the number of Covid-19 cases that may occur in the coming months and the effect of the vaccine on the number of cases. Considering the effect of vaccination and restrictions, daily case numbers were estimated with different training functions. The estimated and the actual number of daily cases may be different. This difference mostly coming from some reasons such as the impact of people's social lives, mutating the virus or people give up the necessary precautions. Restrictions may come or abrogate by estimating the number of cases in the coming months according to the status of the vaccination numbers. This will help countries to be more prepared for emergencies that may occur.

This study examined the success rates of the network created for estimation. It has been observed that the success rate of the network created with the "Traincgb" training function is higher than the others in both the training and testing stages.

This study has anticipated a reference for future studies, like the number of patients estimation, etc. In future studies using the same data, the ANN model can be compared with other algorithms, and the success rates of the algorithms on estimation can be compared. In addition, especially the effects of the mutation that the virus has undergone can be added to future studies.

Author contributions: In the study, Author 1 contributed to the creation and implementation of the model, Author 2 contributed to the design and literature review, Author 3 contributed to the evaluation of the results obtained, and Author 4 contributed to the writing, supervision and execution of the data.
Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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