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Predicting Odds of Antibiotic Resistance in Humans Based on Consumption Practices

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***Abstract*— With the finding of the first antibiotic - Penicillin in 1928, there has been a rapid increase in discovery of new antibiotics and their application to treat diseases, such as pneumonia and diarrhea, which would have otherwise led to multiple human deaths before the 20th century. However, the recent rise in cases of antibiotic resistance amongst humans, coupled with a significant lack of discovery of new antibiotics, has shaped up as an alarming global health crisis. The widespread increase in cases of antibiotic resistance can be attributed to mutation(s) in the gene(s) contained in bacterial loops of DNA, known as plasmids - however, practices by humans have a role to play too. Inappropriate and excessive consumption of antibiotics by humans imposes additive selection pressure on bacteria - accelerating the rate at which they evolve resistance. Therefore, in this study, we aim to propose appropriate models for certain antibiotics, in the form of multiple logistic regression equations, to predict the odds of antibiotic resistance as a result of consumption practices - data for which was gathered in a virtual cross-country survey, and provided by respondents. The predictive models devised in this study can be used to raise awareness in the public regarding detrimental impacts of unsuitable antibiotic consumption, and the investigation can be extended with implementation of more sophisticated research methodology in laboratories.**

***Keywords*—Antibiotics, Antimicrobial Resistance, Regression, Vertical Gene Transfer, dependent variable, binary variable**

I. INTRODUCTION

In April 2019, the Interagency Coordination Group on Antimicrobial Resistance (IACG), released a report stating that at least 700,000 people die globally per year due to antimicrobial resistance, with majority of the cases contributed by antibiotic resistance, and this statistic is expected to increase till 10 million deaths per annum by 2050. (1) Similarly, the Global Antimicrobial Surveillance System (GLASS), launched in October 2015 by the World Health Organization, revealed that antibiotic resistance was prevalent among 500,000 people, in the 22 countries where residents were exposed to bacterial infections, out of the 52 countries enrolled in GLASS.

This report also mentioned that *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Streptococcus pneumoniae*, and *Salmonella* were the most common antibiotic resistant strains of bacteria, excluding *Mycobacterium tuberculosis* and *Mycobacterium bovis* which are responsible for tuberculosis infection. (2) Even more alarming is the 'Discovery Void' which has been declared by the World Health Organisation in 2014 - which indicates how there are significant gaps in development of effective, and major antibiotics, over the past 30 years. (3) Certain ecological factors, such as the current rise in average global temperatures, are making the threats posed by antibiotic resistance increasingly aggressive. This idea was proposed by an article (4), which explored that an increase in local temperature and population density is associated proportionally with the rise in incidence of antibiotic resistance, in the United States. However, certain seasonal changes in drug resistance levels can be attributed to an increase in antibiotic consumption during that period, due to the incidence of specific ailments, such as respiratory diseases (5).

Originally, a bacterium becomes resistant to an antibiotic, by random mutation which changes the nucleotide base sequence of DNA on its plasmid. The plasmid with the resistant genes is then passed on by Horizontal or Vertical Transfer (6), to other bacteria which have infected the body, to eventually produce a colony of resistant bacteria, as they multiply in numbers by the process of binary fission. Horizontal Gene Transfer can possibly occur by three methods: conjugation, transformation, and transduction (7). The first process - conjugation - often occurs solely between bacterial cells, and is the most common form of Horizontal Gene Transfer. A conjugation tube is formed between the host and recipient, to facilitate the transfer of a single strand, in the 5' end-to-3' end direction (8), of the double-stranded DNA carried on the plasmid of the host cell.

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Secondly, in transformation, a single strand of exogenous DNA which originates from the external environment, is internalized by the bacterial cell, eventually leading to its homologous recombination (9), and consequently an increased genetic diversity - in this study, however, the antibiotic resistance is the main focus as a phenotypic characteristic in bacteria. Lastly, bacteriophages, viruses of bacteria, have a central role to play in transduction, as they carry out generalized transduction - incorporating random pieces of host DNA in the recipient cell, as well as specialised transduction - delivering a specific piece of the host genome to the recipient. While Horizontal Gene Transfer was originally attributed for transfer of antibiotic resistance genes to, and between bacteria, there is now significant evidence available that this process is also enabled by Vertical Gene Transfer (10). This process leads to an increased strain of antibiotic resistant bacteria, as the parent cell possessing the resistant gene on its plasmid, reproduces asexually (11), to produce genetically identical daughter cells, with the resistant genes too.

However, the recent worldwide increase in incidence of antimicrobial resistance cases, and its related deaths, can be attributed to decline in development of new antibiotics, but more importantly, coupled with inappropriate and extensive use of antibiotics, including but not limited to (12) : repetitive usage in multiple courses, of a single antibiotic to treat a bacterial infection; prescribing antibiotics when unnecessary, such as for viral infections; ignorance on the part of the consumer by not completing the entire course of duration of the antibiotic; undertaking self-medication of antibiotics, when a doctor's prescription can minimize chances of inappropriate usage; using antibiotics for accelerating growth in poultry and livestock, rather than treating infection; and lack of awareness in health-care settings and in consumers, regarding suitable use of antibiotics. These practices impose continued selection pressure on the bacteria, reducing their biological fitness, hence leading to selection of genes with antibiotic resistance traits, which possess a higher fitness (13).

In this study, we aim to establish a predictive model which relates the odds of antibiotic resistance in humans with variable consumer practices - intending to increase awareness in the public pertaining to antibiotic resistance, which has been recognised by the World Health Organisation as 'one of the top 10 global threats facing humanity' (14).

II. METHOD

Since, sufficient data regarding consumption of antibiotics by humans, and its negative repercussions leading to specific antibiotic resistance, was not available in online databases, we conducted a virtual survey. This form received responses from 116 consumers, and led to a cross-country survey, as respondents resided in countries including India, USA, Canada, and Indonesia. The survey prompted consumers to provide data pertaining to the following questions appropriately and accurately:

1. Provide information on their sex
2. Input their age
3. Mention their current country, state, and city of residence
4. Select all the antibiotics which they had consumed till the date of partaking in the survey (respondents were provided with the consequent options: Amoxicillin, Doxycycline, Cephalexin, Ciprofloxacin, Clindamycin, Metronidazole, Azithromycin, Sulfamethoxazole, Trimethoprim, Clavulanate, Ampicillin, Levoflaxin, None, and any other)
5. Consequently select the antibiotics to which their bodies had stopped responding
6. Mention the number of times they had undertaken course of all the antibiotics which they had consumed (respondents were provided with a scale of 0 to 5)
7. Mention the number of times they had not completed the entire prescribed course of all the consumed antibiotics (respondents were provided with a scale of 0 to 5)
8. Mention the number of times the consumers chose to undertake self-medication of antibiotics (respondents were provided with a scale of 0 to 5)

Once the intake of further responses to the survey halted, we used the software 'Graph Pad Prism' Version 9.0.0 to classify the answers from respondents under suitable headings of the different antibiotics.

This compiled data was analyzed with the medium of respective multiple logistic regression equations, in order to formulate a potential predictive model. We defined the response of the respondent's body to a consumed antibiotic as a binary and dependent variable - with '0' indicating that the consumer reported his/her body was not resistant to the specified antibiotic, and '1' indicating the opposite effect.

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III. RESULTS

Below, the responses of the consumers have been displayed in a tabular form, with one table designated to a particular antibiotic.

Statistical Analysis was done by adding the ROC curve and multiple logistic regression equation with binary output. The responses have been put in a tabular form from Table 1-12.

TABLE 1
Responses pertaining to the consumption of antibiotic Amoxicillin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	30	India	West Bengal	Kolkata	0	4	0	2
2	Male	40	India	Karnataka	Bangalore	0	5	1	1
3	Male	46	India	Telangana	Hyderabad	0	5	0	3
4	Female	62	USA	Maryland	Phoenix	0	4	0	0
5	Female	45	India	Telangana	Hyderabad	0	2	0	0
6	Male	55	India	Andhra Pradesh	Guntur	0	5	0	2
7	Female	39	India	West Bengal	Kolkata	0	5	0	0
8	Female	63	India	Delhi	New Delhi	0	2	0	1
9	Female	35	India	Delhi	New delhi	0	3	0	2
10	Female	43	India	Punjab	Jalandhar	0	1	0	0
11	Female	43	India	Telangana	Hyderabad	0	2	1	0
12	Male	36	Indonesia	Jakarta	South Jakarta	0	5	0	0
13	Female	36	India	Maharashtra	Mumbai	0	0	2	0
14	Female	32	India	Delhi	New Delhi	1	5	0	3

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
15	Female	66	India	Delhi	Delhi	0	3	1	2
16	Female	41	India	DELHI	New delhi	0	5	0	0
17	Female	46	India	New Delhi	New Delhi	0	5	0	0
18	Female	20	India	New Delhi	New Delhi	0	3	0	1
19	Female	54	India	Delhi	Delhi	0	0	0	0
20	Male	38	India	Telangana	Hyderabad	1	2	0	0
21	Female	34	India	Union territory	Chandigarh	0	1	0	0
22	Female	50	India	Haryana	Gurugram	0	3	1	1
23	Male	67	India	Punjab	Jalandhar	1	4	5	5
24	Female	17	India	Delhi	New delhi	0	2	1	0
25	Male	33	USA	PA	Philadelphia	1	5	0	0
26	Male	46	India	Delhi	Delhi	0	1	0	0
27	Male	33	India	Delhi	Delhi	0	4	2	0
28	Female	51	India	Maharashtra	Mumbai	0	2	0	0
29	Male	35	India	Delhi	New Delhi	0	1	0	1
30	Male	50	India	Uttar Pradesh	Ghaziabad	0	2	0	1

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
31	Male	40	Canada	PR	Surrey	0	2	0	4
32	Female	42	India	New Delhi	Delhi	0	0	0	0
33	Male	69	India	Delhi	Delhi	0	3	0	1
34	Female	37	Australia	Victoria	Melbourne	0	1	0	2
35	Male	41	Canada	ON	Oakville	1	5	0	5
36	Male	46	India	Uttar Pradesh	Ghaziabad	0	5	1	2
37	Male	46	Canada	Ontario	Mississauga	0	3	0	0
38	Female	41	India	Haryana	Haryana Gurgaon	0	5	2	2
39	Female	46	India	Karnataka	Bangalore	0	2	0	0
40	Male	56	India	Delhi	Delhi	0	1	0	0
41	Female	45	India	Delhi	Delhi	0	1	0	1
42	Female	41	India	Delhi	Delhi	0	5	1	2
43	Female	40	India	Delhi	Delhi	0	2	0	0
44	Female	43	India	Delhi	Delhi	0	2	0	0
45	Female	45	UAE	UAE	Dubai	0	5	0	3
46	Female	32	India	Maharashtra	Thane	0	2	0	0

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
47	Male	40	India	Maharashtra	Mumbai	0	0	0	0
48	Female	25	India	Maharashtra	Mumbai	0	5	2	0
49	Female	49	India	Delhi	Delhi	0	5	0	0
50	Male	41	India	Delhi	Delhi	0	2	0	0
51	Male	45	India	Haryana	Gurgaon	0	5	4	4
52	Male	46	India	Delhi	Delhi	0	2	0	0
53	Male	46	India	Delhi	New Delhi	0	5	0	3
54	Male	46	Canada	British Columbia	Surrey	0	0	0	0
55	Male	46	India	Gujarat	Ahmedabad	0	5	0	1
56	Female	45	USA	NY	New City	0	2	0	0
57	Male	47	India	Telangana	Hyderabad	0	2	0	0
58	Male	45	India	Haryana	Gurugram	0	5	1	0
59	Female	62	India	Delhi	South Delhi	0	1	0	0
60	Female	39	India	Gujarat	Ahmedabad	0	4	0	0
61	Female	35	India	Gujarat	Ahmedabad	0	4	0	0
62	Female	18	India	Delhi	New Delhi	0	2	1	0

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S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
63	Female	34	India	Gujarat	Ahmedabad	0	5	0	2
64	Female	34	India	Gujarat	Ahmedabad	0	2	0	0
65	Female	41	Canada	Ontario	Oakville	0	3	0	2
66	Female	53	India	Haryana	Gurgaon	1	2	2	0
67	Female	36	India	Delhi	New Delhi	1	3	0	1
68	Female	59	India	Haryana	Gurugram	0	2	0	0
69	Female	30	USA	Maryland	Washington DC	0	5	0	0

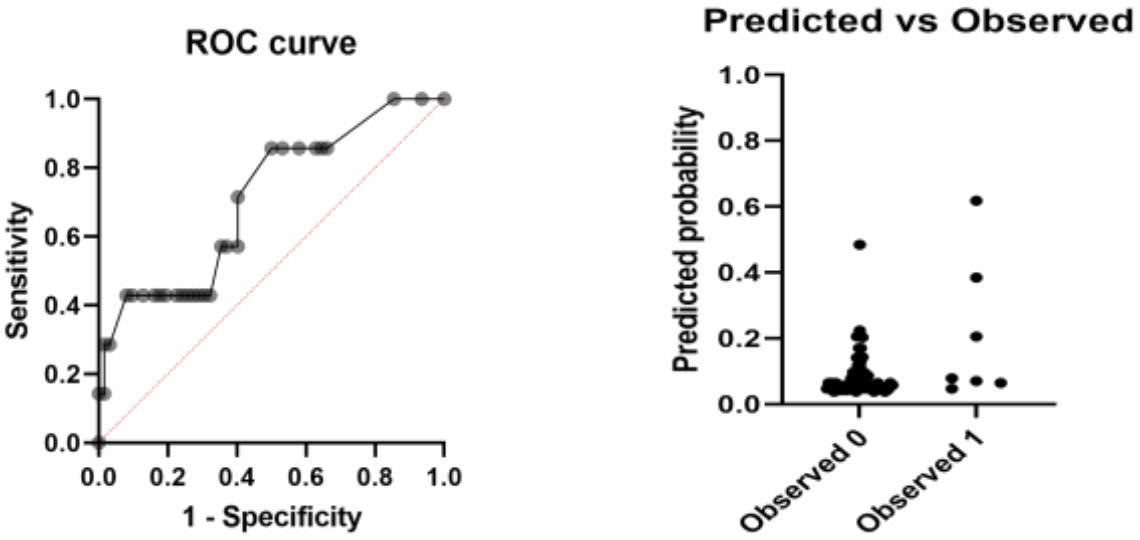

Figure 1. Graph based analysis with Antibiotic Amoxicillin

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TABLE 2
Responses pertaining to the consumption of antibiotic Doxicycline

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	40	India	Karnataka	Bangalore	0	1	1	0
2	Female	62	USA	Maryland	Phoenix	0	1	0	0
3	Female	39	India	West Bengal	Kolkata	0	1	0	0
4	Female	20	India	New Delhi	New Delhi	0	2	0	1
5	Male	33	USA	PA	Philadelphia	0	2	0	0
6	Female	41	India	Haryana	Gurgaon	0	2	0	0
7	Male	47	India	Telangana	Hyderabad	0	1	0	0
8	Female	41	Canada	Ontario	Oakville	0	3	0	2

TABLE 3
Responses pertaining to consumption of antibiotic Sulfamethoxazole

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	33	United States	PA	Philadelphia	0	1	0	0
2	Male	46	India	Delhi	Delhi	0	5	0	1

International Journal of Recent Development in Engineering and Technology
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TABLE 4
Responses pertaining to consumption of antibiotic Trimethoprim

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	33	United States	PA	Philadelphia	0	1	0	0

TABLE 5
Responses pertaining to consumption of antibiotic Ciprofloxacin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	30	India	West Bengal	Kolkata	0	1	0	1
2	Male	40	India	Karnataka	Bangalore	0	2	1	0
3	Female	42	Hyd	Telangana	India	0	2	0	1
4	Female	45	India	Telangana	Hyderabad	0	2	0	0
5	Female	65	India	Telangana	Hyd	0	5	0	0
6	Female	39	India	West Bengal	Kolkata	0	5	0	0
7	Male	51	india	Telangana	Hyderabad	0	5	1	0
8	Female	35	India	Delhi	New delhi	0	3	0	3
9	Male	36	Indonesia	Jakarta	South Jakarta	0	5	0	5

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
10	Female	32	India	Delhi	New Delhi	0	2	0	2
11	Male	18	India	Delhi	New Delhi	0	2	1	1
12	Female	66	India	Delhi	Delhi	0	4	2	2
13	Female	46	India	New Delhi	New Delhi	0	5	3	2
14	Female	20	India	New Delhi	New Delhi	0	1	0	0
15	Male	67	India	Punjab	Jalandhar	1	2	2	5
16	Female	17	India	Delhi	New delhi	1	2	3	0
17	Male	50	India	UTTAR PRADESH	Ghaziabad	0	1	0	0
18	Male	69	India	Delhi	Delhi	0	2	0	1
19	Male	41	Canada	ON	Oakville	1	5	0	5
20	Male	46	India	Delhi	Delhi	1	3	0	0
21	Female	41	India	Delhi	Delhi	0	2	0	0
22	Female	45	UAE	UAE	DUBAI	0	5	0	2
23	Female	49	India	Delhi	Delhi	0	1	0	0

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
24	Male	35	USA	California	Berkeley	0	1	0	0
25	Male	46	India	Delhi	Delhi	0	4	0	0
26	Male	46	India	Delhi	New Delhi	0	3	0	1
27	Male	46	India	Gujarat	Ahmedabad	0	1	0	0
28	Male	45	India	Haryana	Gurugram	0	5	0	0
29	Female	18	India	Delhi	New Delhi	0	1	1	0
30	Male	29	India	Haryana	Gurugram	0	1	0	1
31	Female	37	India	Telangana	Hyderabad	0	1	0	0
32	Female	59	India	Haryana	Gurugram	0	1	0	0

International Journal of Recent Development in Engineering and Technology
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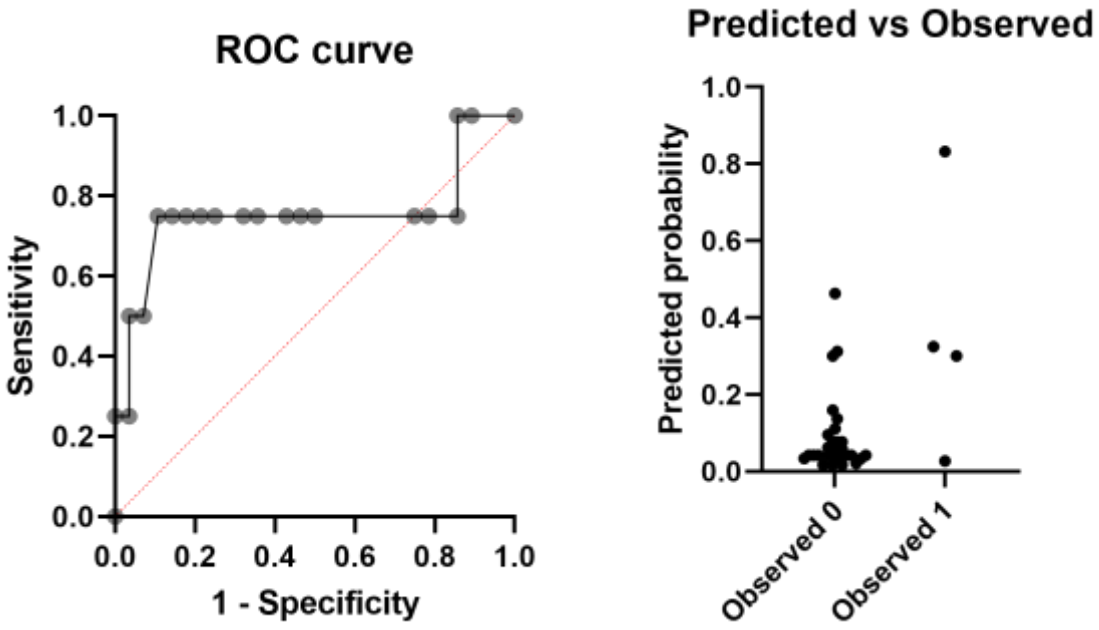

Figure 2. Graph based analysis with Antibiotic Ciprofloxacin

TABLE 6
Responses pertaining to consumption of antibiotic Cephalexin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Female	65	India	Telangana	Hyderabad	0	5	0	0
2	Female	39	India	West Bengal	Kolkata	0	1	0	0
3	Male	18	India	Delhi	New Delhi	0	1	1	1
4	Female	46	India	New Delhi	New Delhi	0	5	0	0
5	Male	38	India	Telengana	Hyderabad	1	1	0	0
6	Male	67	India	Punjab	Jalandhar	1	5	4	5

International Journal of Recent Development in Engineering and Technology
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S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
7	Female	41	India	Haryana	Gurgaon	0	2	0	1
8	Female	43	India	Delhi	Delhi	0	2	0	0
9	Female	49	India	Delhi	Delhi	0	1	0	0
10	Male	46	India	Delhi	Delhi	0	1	0	0
11	Male	46	India	Delhi	New Delhi	0	1	0	1
12	Female	62	India	Delhi	Delhi	0	2	0	1
13	Female	59	India	Haryana	Gurugram	0	1	0	0

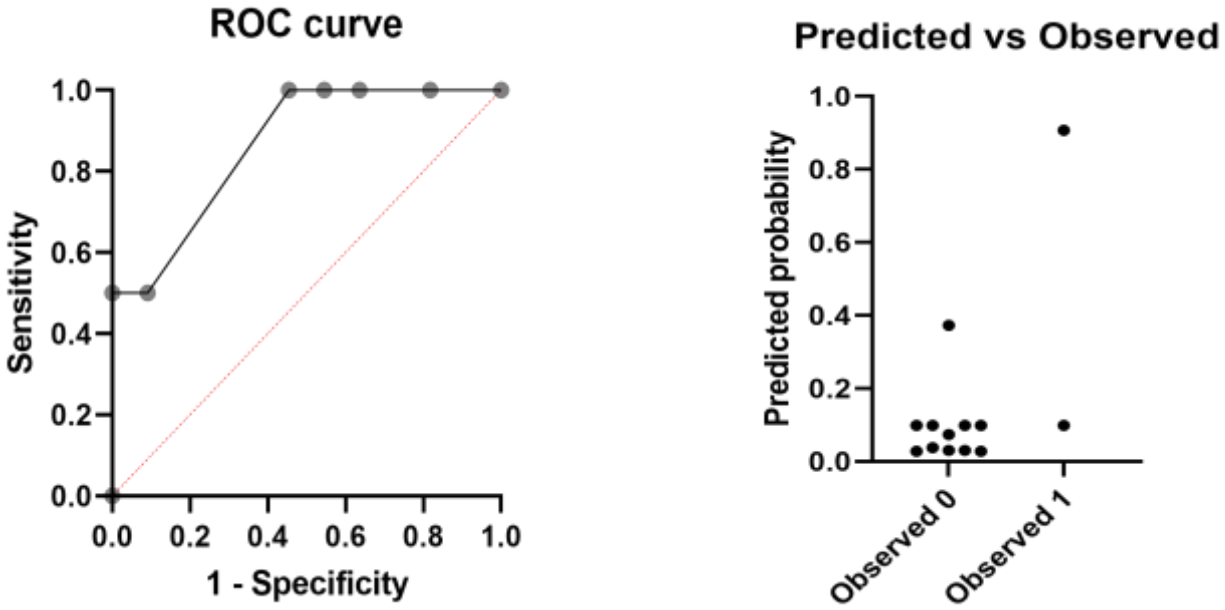

Figure 3. Graph based analysis with Antibiotic Cephalexin

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 9, Issue 12, December 2020)

TABLE 7
Responses pertaining to consumption of antibiotic Clindamycin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Female	62	USA	Maryland	Phoenix	0	1	0	
2	Female	46	India	New Delhi	New Delhi	0	2	0	
3	Female	34	India	Union territory	Chandigarh	0	4	0	
4	Male	33	United States	PA	Philadelphia	0	2	0	
5	Male	17	India	New Delhi	New Delhi	0	5	0	
6	Female	17	India	Delhi	Delhi	0	1	1	
7	Male	35	India	Delhi	New Delhi	0	1	0	
8	Male	46	India	Delhi	Delhi	0	1	0	

International Journal of Recent Development in Engineering and Technology
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TABLE 8
Responses pertaining to consumption of antibiotic Metronidazole

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	30	India	West Bengal	Kolkata	0	2	0	1
2	Female	39	India	West Bengal	Kolkata	0	5	0	0
3	Female	46	India	New Delhi	New Delhi	0	4	0	2
4	Male	33	United States	PA	Philadelphia	0	1	0	0
5	Male	33	India	Delhi	Delhi	0	2	0	0
6	Female	49	India	Delhi	Delhi	0	1	0	0
7	Male	35	USA	California	Berkeley	0	1	0	0
8	Male	46	India	Delhi	New Delhi	0	1	0	1
9	Male	46	India	Delhi	New Delhi	0	1	0	1

International Journal of Recent Development in Engineering and Technology
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TABLE 9
Responses pertaining to consumption of antibiotic Azithromycin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	40	India	Karnataka	Bangalore	0	5	1	0
2	Female	45	India	Telangana	Hyderabad	0	5	0	2
3	Female	65	India	Telangana	Hyd	0	5	0	0
4	Male	55	India	Andhra Pradesh	Guntur	0	5	0	0
5	Male	37	India	New Delhi	New Delhi	0	3	0	3
6	Female	43	India	Punjab	Jalandhar	0	2	0	0
7	Female	43	India	Telangana	Hyderabad	0	1	0	0
8	Male	36	Indonesia	JAKARTA	South Jakarta	0	5	0	5
9	Female	35	India	Uttar Pradesh	Noida	0	1	0	2
10	Female	72	India	Punjab	Japan	0	5	2	2
11	Female	36	India	Maharashtra	Mumbai	0	2	2	2
12	Female	32	India	Delhi	New Delhi	0	5	0	5
13	Female	36	India	Delhi	North Delhi	0	2	1	1
14	Female	66	India	Delhi	Delhi	0	5	1	5
15	Female	41	India	DELHI	New delhi	0	5	0	0

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
16	Female	46	India	New Delhi	New Delhi	0	5	0	5
17	Female	20	India	New Delhi	New Delhi	0	2	0	1
18	Male	38	India	Telengana	Hyderabad	1	2	0	0
19	Female	46	INDIA	DELHI	NEW DELHI	0	1	0	0
20	Male	35	India	Delhi	Delhi	0	1	0	0
21	Female	32	India	Delhi	Delhi	0	2	0	0
22	Female	17	India	Delhi	New delhi	0	4	0	1
23	Female	34	India	Union territory	Chandigarh	0	5	0	3
24	Male	33	United States	PA	Philadelphia	0	5	0	0
25	Male	33	India	Delhi	Delhi	0	5	2	3
26	Male	32	India	Telangana	Hyderabad	1	3	0	3
27	Male	35	India	Delhi	New Delhi	0	1	0	1
28	Male	40	Canada	PR	Surrey	0	5	0	5
29	Female	42	India	New Delhi	Delhi	0	5	2	2
30	Male	69	India	Delhi	Delhi	0	4	0	2
31	Female	37	Australia	Victoria	Melbourne	0	1	0	0

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
32	Male	41	Canada	ON	Oakville	1	5	0	5
33	Female	41	India	Haryana	Haryana Gurgaon	0	4	1	2
34	Female	46	India	Karnataka	Bangalore	0	2	0	0
35	Female	45	India	Delhi	Delhi	0	1	0	1
36	Male	46	India	Delhi	Delhi	0	3	0	0
37	Female	59	India	Haryana	Gurugram	0	1	0	0
38	Female	41	India	Delhi	Delhi	0	5	2	0
39	Female	43	India	Delhi	Delhi	0	2	0	0
40	Female	45	UAE	UAE	DUBAI	0	5	0	2
41	Female	47	India	Maharashtra	Mumbai	0	3	0	0
42	Male	17	India	New Delhi	New Delhi	0	2	0	0
43	Female	49	India	Delhi	Delhi	0	5	0	5
44	Male	41	India	Delhi	Delhi	0	2	0	0
45	Male	46	India	Delhi	Delhi	0	1	0	0
46	Male	46	India	Delhi	Delhi	0	5	0	1
47	Male	46	India	Delhi	New Delhi	0	3	0	1

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
48	Male	46	India	Gujarat	Ahmedabad	0	1	0	0
49	Male	45	India	Delhi	Delhi	0	4	4	0
50	Male	47	India	Telangana	Hyderabad	0	4	0	2
51	Female	46	India	Delhi	New Delhi	0	3	0	0
52	Male	45	India	Haryana	Gurugram	0	5	1	0
53	Female	62	India	Delhi	South Delhi	0	2	0	1
54	Female	38	India	Uttarakhand	Dehradun	0	5	0	2
55	Female	39	India	Gujarat	Ahmedabad	0	4	0	0
56	Female	23	India	Haryana	Gurgaon	0	3	1	3
57	Female	27	India	Maharashtra	Mumbai	0	5	0	0
58	Female	34	India	Gujarat	Ahmedabad	0	3	0	1
59	Male	36	India	Chandigarh	Chandigarh	0	2	0	0
60	Female	34	India	Gujarat	Ahmedabad	0	3	0	0
61	Female	53	India	Haryana	Gurgaon	0	3	0	2
62	Female	36	India	Delhi	New Delhi	1	1	0	0
63	Female	37	India	Telangana	Hyderabad	0	4	0	1

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
64	Female	40	India	Gujarat	Ahmedabad	0	1	0	0
65	Male	45	India	Maharashtra	Mumbai	0	3	0	0
66	Female	35	India	Gujarat	Ahmedabad	0	3	0	0
67	Female	30	USA	Maryland	Washington DC	0	5	0	0

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TABLE 10
Responses pertaining to consumption of antibiotic Clavulanate

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Female	46	India	New Delhi	New Delhi	0	5	0	0
2	Female	54	India	Delhi	Delhi	0	5	0	5
3	Male	33	United States	PA	Philadelphia	0	1	0	0
4	Male	33	India	Delhi	Delhi	0	4	0	0
5	Male	35	India	Delhi	New Delhi	0	1	0	1
6	Male	40	Canada	PR	Surrey	0	2	0	2
7	Female	46	India	Karnataka	Bangalore	0	2	0	0
8	Male	46	India	Delhi	Delhi	0	1	0	0
9	Female	43	India	Delhi	Delhi	0	2	0	0
10	Female	45	UAE	UAE	DUBAI	0	2	0	2
11	Female	49	India	Delhi	Delhi	0	5	0	0
12	Male	46	India	Delhi	Delhi	0	4	0	0
13	Male	46	India	Delhi	New Delhi	0	5	0	2
14	Female	35	India	Gujarat	Ahmedabad	0	3	0	0

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TABLE 11
Responses pertaining to consumption of antibiotic Ampicillin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	46	India	Telangana	HYDERABAD	0	2	0	0
2	Female	65	India	Telangana	Hyd	0	2	0	0
3	Male	55	India	Andhra Pradesh	Guntur	0	5	0	0
4	Female	66	India	Delhi	Delhi	0	5	0	2
5	Male	56	India	Delhi	Delhi	0	1	0	0
6	Female	49	India	Delhi	Delhi	0	5	0	0
7	Male	46	India	Delhi	Delhi	0	1	0	0
8	Male	46	India	Gujarat	Ahmedabad	0	1	0	0
9	Male	47	India	Telangana	Hyderabad	0	1	0	0
10	Male	45	India	Haryana	Gurugram	0	4	0	0
11	Male	60	India	Maharashtra	Mumbai	0	1	1	0

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TABLE 12:
Responses pertaining to consumption of antibiotic Levoflaxin

S. No.	Sex	Age	Respondent's Country of Residence	Respondent's State of Residence	Respondent's City of Residence	Respondent's body stopped responding	Number of times course was undertaken	Number of times course was not completed	Number of times self medication was undertaken
1	Male	46	India	Telangana	HYDERABAD	0	2	0	0
2	Female	65	India	Telangana	Hyd	0	2	0	0
3	Male	55	India	Andhra Pradesh	Guntur	0	5	0	0
4	Female	66	India	Delhi	Delhi	0	5	0	2
5	Male	56	India	Delhi	Delhi	0	1	0	0
6	Female	49	India	Delhi	Delhi	0	5	0	0
7	Male	46	India	Delhi	Delhi	0	1	0	0
8	Male	46	India	Gujarat	Ahmedabad	0	1	0	0
9	Male	47	India	Telangana	Hyderabad	0	1	0	0
10	Male	45	India	Haryana	Gurugram	0	4	0	0
11	Male	60	India	Maharashtra	Mumbai	0	1	1	0

IV. Statistical Analysis

Multiple logistic regression equations were devised for the antibiotics Amoxicillin, Cephalexin, Ciprofloxacin where respondents indicated that they had become resistant to the antibiotic.

In the below regression equations Y indicates developing resistance to the antibiotic, β0 indicates the parameter estimate for intercept, β1 indicates the parameter estimate for q where q is the number of times course was undertaken, β2 indicates the parameter estimate for r where r is the number of times full course was not completed, and β3 indicates the parameter estimate for s where s is the number of times self-medication was undertaken.

The multiple logistic regression equation pertaining to Amoxicillin is: ln(odds of Y) = -3.228 + 0.1104q + 0.2123r + 0.4412s, which can be transformed to odds of $Y = e^{(-3.228)} \cdot e^{(0.114q)} \cdot e^{(0.2123r)} \cdot e^{(0.4412s)}$, where odds = p/(1-p) and p = probability of developing resistance to Amoxicillin. β0 lies in the 95% C.I. of (-5.780, -1.475), β1 lies in the 95% C.I. of (-0.4730, 0.7405), β2 lies in the C.I. of (-0.5007, 0.9438), and β3 lies in the C.I. of (-0.1765, 1.073). The area under the previously depicted ROC curve is 0.7108, with a C.I. of (0.5059, 0.9175) - indicating that this predictive model is viable with a predictive power of 71.08 %.

The multiple logistic regression equation pertaining to Cephalexin is: ln(odds of Y) = -1.901 + 0.3125q + 2.722r + -1.029s, which can be transformed to odds of $Y = e^{(-1.901)} \cdot e^{(0.3125q)} \cdot e^{(2.722r)} \cdot e^{(-1.029s)}$, where odds = p/(1-p) and p = probability of developing resistance to Cephalexin. β0 lies in the 95% C.I. of (-5.872, 1.690), β1 lies in the 95% C.I. of (-3.873, 0.9532), β2 lies in the C.I. of (-2.584, 19.17), and β3 lies in the C.I. of (-14.55, 4.163). The area under the previously depicted ROC curve is 0.8636, with a C.I. of (0.6016, 1.000) - indicating that this predictive model is viable with a predictive power of 86.36 %.

The multiple logistic regression equation pertaining to Ciprofloxacin is: ln(odds of Y) = -2.893 + -0.2328q + 0.8748r + 0.6424s, which can be transformed to odds of $Y = e^{(-2.893)} \cdot e^{(-0.2328q)} \cdot e^{(0.8748r)} \cdot e^{(0.6424s)}$, where odds = p/(1-p) and p = probability of developing resistance to Ciprofloxacin. β0 lies in the 95% C.I. of (-6.323, -0.5632), β1 lies in the 95% C.I. of (-1.606, 0.6591), β2 lies in the C.I. of (-0.2151, 2.110), and β3 lies in the C.I. of (-0.07764, 1.885). The area under the previously depicted ROC curve is 0.7545, with a C.I. of (0.4010, 1.000) - indicating that this predictive model is viable with a predictive power of 75.45 %.

V. Discussion

The presence of potential confounders in this study, limit the predictive power of the statistical model generated by multiple logistic regression.

These confounders include, amongst other variables: sex and age of the respondent; the respondent's country and city of residence; presence of, and access to a developed healthcare infrastructure around the respondent's residence; past medical history of ailments concerning the respondent; if the food consumed by the respondent comprised of livestock which had also been given antibiotic (15), for treatment of infection, or due to lack of awareness; and, environmental pollution of antibiotics in the respondent's residence due to animal, human, and manufacturing waste (16). This study makes use of a cross-country survey, eventually leading to formation of a random sample of humans who have consumed antibiotics. However, the previously mentioned confounders may be eliminated by randomly choosing a more specific sample of consumers - belonging to a particular sex, age interval, residing in the same locality, with an approximately similar income level, suffering from no acute ailments, and consuming a specific diet with a comparable source for attainment of produce. For instance: the sample formed could include solely females living in New Delhi, India, between 25 to 35 years old, belonging to the working-age population, and consuming a strictly vegetarian diet (17).

During the SARS-CoV-2 pandemic, it was not viable to conduct research in the laboratory, hence leading to the conception of an online survey. However, since this involves self-reporting of data by the respondents - the findings of the paper, and hence the multiple logistic regression equations are subject to a degree of unaccounted inaccuracy. Factoring this, the present study can be extended to laboratory research, where the in vitro susceptibility patterns of bacterial strains are tested by varying their exposure to different antibiotics. This susceptibility can be a measure of the area of bacteria-free zone around a disc of filter paper soaked in relevant antibiotic, when the bacterial culture is incubated in a Petri dish containing agar (18). This experiment can be conducted with use of recent technology, such as the Microbial Evolution and Growth Arena (MEGA) plate, which tracks and maps mutation in bacteria in presence of antibiotics (19).

To try and achieve conditions close to those found in the human body, cultures of mouse cells from variable cell lines, such as HT22 from hippocampal cell line, can also be used, and their response to inappropriate and excessive antibiotic use recorded during bacterial infection. The data obtained can be compared with the database of responses obtained by the survey in this study.

Additionally, the multiple logistic regression equations established as predictive models in this study, can be mapped to interactive 4D graphs, and this information distributed to the public for raising awareness pertaining to inappropriate use of antibiotics. Development of a mobile application, or a website which keeps count of the number of times the same antibiotic was prescribed, with the help of a doctor-patient interface, can also be initiated, and encouraged for use in hospitals and clinics.

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