Effect of Climatic Conditions on Gender Segregated COVID-19 Infections and Fatalities

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***Abstract*—In this paper, a sex-segregated study of COVID-19 infected patients and casualties is done for different climatic conditions. We study the COVID data to identify the trend of infections and casualties based on the change in temperature and other climatic features. The countries with non-homogeneous climates are broken down into respective subdivisions which consist of uniform climate. It is found that, with an increase in temperature, the sex ratio in COVID-19 infected patients and especially casualties become more disproportionate. Males have a higher mortality rate and the susceptibility of females decreases as we move from a cold to a hot climate.**

***Index Terms*—COVID-19, Population Sex Ratio, Life Expectancy, Climate**

I. Introduction

The Coronavirus Disease 2019 (COVID-19), a global pandemic, has infected about 6.4 million people and claimed about 383 thousand lives till June 3, 2020 [1]. Several researchers have tried to study the spread of this infection based on various factors. Two such probable factors are climatic conditions and gender. Studies on previous Coronavirus diseases have, at times, considered the effect of climate [2], but for COVID-19, still, some progress in this aspect is required. Jingyuan Wang et al. [3] showed that the transmissibility of COVID-19 reduces with an increase in temperature and humidity. Again, in global health 5050 site [4], the COVID-19 sex-segregated statistics show varied sex ratio among infected and deceased patients although the corresponding countries have more or less balanced sex ratio in their population. In this paper, we have studied the effect of climate and gender on the infection of COVID-19. In our study, (i) we have collected the data from several countries of the world, who have provided the COVID-19 information, (ii) divided these countries into temperature groups, (iii) obtained the gender

ratio and life expectancy of each country from their Government data, and have studied the spread of infection parameterized by climate and gender. Our results show that the mortality ratio of males gradually rises from cold to hot climate to a significant rate. Also, the higher infection rate of females reduces to a decent percentage while moving from a cold to a hot climate. The rest of the paper is organized as follows: in Sections II and III we respectively discuss methodology and docket our findings. We represent the collected data in Section IV and conclude in Section V.

II. Methodology

A. Factors Under Considerations

We have considered the following factors to study the correlation between climate and gender.

- Temperature: Its range represents the type of climate under which the study has been done. Depending on the temperature, climates are grossly segregated into 3 parts; namely, HOT, AMICABLE and COLD.
- Humidity: It has an important role to segregate the climate, especially among hot and amicable climates e.g. with very low humidity, temperature over 35 degrees in a state / country is considered to have a hot climate whereas, with high humidity, temperature over 30 degrees implies hot climate; otherwise amicable.
- Population Sex Ratio: While considering percentages of males and females in infection and fatalities due to COVID-19, we need the population sex ratio of the corresponding state/country, as this may put significant influence on the formerly said percentages.

TABLE I: HOT CLIMATE DATA TABLE

Regions with Hot Climate	Total Infected	COVID-19 Infected		Total Death	COVID-19 Death		Total Population	Total Population		Life Expectancy (Years)	
		Male %	Female %		Male %	Female %		Male %	Female %	Male	Female
Ecuador [4]	29615	56	44	3334	66	34	17643054	49.75	50.25	74.5	80.6
Maldives [4]	1942	86	14	8	71	29	540544	53.05	46.95	74	78.9
Indonesia [4]	33076	55	45	1923	63	37	273523615	50	50	71.1	76.5
Mexico [4]	120102	56	44	14053	67	33	128932753	48.98	51.02	73.9	79.6
Florida [5]	67371	49.35	50.65	2801	—-	—-	21992985	48.88	51.12	77.3	82.6
Colorado [6]	28499	48.72	51.28	1328	52.06	47.94	5845526	50.12	49.88	78.5	82.5
Arizona [7]	29852	47	53	1095	55	45	7286000	49.7	50.3	77.5	82.3
New Mexico [8]	9250	47.91	52.09	410	—-	—-	2016550	49.4	50.6	75.3	81
Texas [9]	79757	54.24	45.76	1885	58.38	41.62	29472295	49.6	50.4	76.8	81.5
Wyoming [10]	768	49.14	50.86	18	—-	—-	567025	51	49	77.1	81.1
Nevada [11]	10164	48.36	51.64	448	57.91	42.09	2890845	50.5	49.5	76.1	81

TABLE II: AMICABLE CLIMATE DATA TABLE

Regions with Amicable Climate	Total Infected	COVID-19 Infected		Total Death	COVID-19 Death		Total Population	Total Population		Life Expectancy (Years)	
		Male %	Female %		Male %	Female %		Male %	Female %	Male	Female
Virginia [12]	52647	49.63	50.37	1520	51.06	48.94	8626207	49.06	50.94	77.4	81.5
California [13]	136191	50.5	49.5	4776	56	44	39937489	49.7	50.3	79.4	83.8
Mississippi [14]	18483	40.46	59.54	868	49.2	50.8	2980000	48.6	51.4	71.9	78
Oklahoma [15]	7480	46	54	355	52	48	3954821	49.5	50.5	73.7	78.4
Alabama [16]	21626	41.82	58.18	739	53.9	46.1	4908621	48.5	51.5	72.6	78.1
North Carolina [17]	38171	49	51	1053	53	47	10611862	48.7	51.3	75.5	80.3
South Carolina [18]	15228	43.12	56.88	568	52.52	47.48	5210095	48.6	51.4	74.4	79.6
Louisiana [19]	44030	—-	—-	2855	54	46	4645184	49	51	73.4	79
Bosnia & Herzegovina [4]	994	45	55	37	59	41	3280819	48.72	51.28	74.8	79.7
Greece [4]	2856	55	45	183	70	30	10423054	48.72	51.28	78.8	83.9
France [4]	155136	47.37	52.63	29319	58.33	42.67	65273511	48.98	51.02	79.6	85.6
Chile [4]	25952	53	47	294	60	40	19116201	49.24	50.76	76.3	82.5
Colombia [4]	40719	56	44	1308	61	39	50882891	49.49	50.51	73.5	80
Peru [4]	199696	60	40	5571	72	28	32971854	48.98	51.02	72.6	76.9
Portugal [4]	35910	43	57	1504	49	51	10196709	47.37	52.63	78.7	84.9
Spain [4]	248335	43	57	20527	57	43	46754778	49.49	50.51	80.7	86.1
South Africa [4]	52601	43	57	11161	53	47	59308690	49.49	50.51	63.4	66.2
Thailand [4]	3119	55	45	58	76	24	69799978	48.98	51.02	72.4	78.9
Dominican Republic [4]	20126	55	45	539	70	30	10847910	50.5	49.5	70.3	73.8
Philippines [4]	22474	55	45	1011	64	36	109581078	50.25	49.75	66.5	73.8
Argentina [4]	22749	51	49	670	59	41	45195774	49.49	50.51	73.5	80.3
Bangladesh [4]	71675	68	32	975	73	27	164595723	49.24	50.76	72	76.5

- Life Expectancies: The sex-segregated life expectancies of the population in different states / countries show expected life spans of males and females (on average). Correspondingly, the aforesaid sex ratios in patients may vary. It is to be clarified that climate is decided based on temperature and humidity, as mentioned above. The assumptions regarding segregation of states/countries in climates are heuristic and this study can be easily extended for any other partition type.

B. Segregation And Analysis

First of all, we have considered countries in which almost all inhabitable place lies under one of the segregated climatic patterns so that the population of that country does not appear from mixed climatic conditions. Secondly, the countries too large to be categorized under one type of climate are broken up in their states and the states are considered separately. All the countries and states are segregated by their climates (Cold, Amicable and Hot) and all state / country data under each climate type, were accumulated, with influencing factors (as mentioned under the previous heading). From all collected data, under each category, the average percentage of males and females deceased and infected are measured.

C. Data Extraction

Wherever sex segregated data with % males and % females do not add up to 100%; we normalize the percentage of males and females such that their addition becomes 100% to have a better relative study between males and females. The figure (total, infected, death or population) of country / state with

TABLE III: COLD CLIMATE DATA TABLE

Regions with Cold Climate	Total Infected	COVID-19 Infected		Total Death	COVID-19 Death		Total Population	Total Population		Life Expectancy (Years)	
		Male %	Female %		Male %	Female %		Male %	Female %	Male	Female
Austria [4]	16902	49	51	672	57	43	9006398	48.98	51.02	79.4	84
Belgium [4]	59110	37	63	6852	51	49	11589623	49.24	50.76	79.4	83.9
Bulgaria [4]	2993	37	63	167	51	49	6948445	48.72	51.28	71.5	78.4
Canada [4]	95874	43	57	7820	46	54	37742154	49.49	50.51	81.1	85.9
Czech Republic [4]	9412	50	50	328	59	41	10708043	49.24	50.76	76.1	82
Denmark [4]	11962	42	58	593	57	43	5792202	49.75	50.25	79.4	83.4
Finland [4]	7025	49	51	315	48	52	5540720	49.24	50.76	79.2	84.6
Germany [4]	184457	48	52	8706	55	45	83783942	48.98	51.02	78.7	83.4
Italy [4]	234086	46	54	32354	59	41	60461826	48.19	51.81	80.8	85.2
Luxembourg [4]	4046	51	49	110	56	44	625978	50.5	49.5	79.9	84.4
Netherlands [4]	47811	37	63	6031	55	45	17134872	49.49	50.51	80.2	83.4
Northern Ireland [4]	4796	38	62	536	52	48	1908250	50	50	78.7	82.4
Norway [4]	8576	50	50	239	54	46	5370000	50.5	49.5	81.3	84.4
Republic of Ireland [4]	25165	43	57	1683	49	51	4934915	50	50	80.4	84
Romania [4]	20578	44	56	1333	59	41	19237691	48.72	51.28	71.8	79.2
Scotland [4]	15632	38	62	4000	50	50	5490324	49	51	77	81.1
South Korea [4]	11582	42	58	274	53	47	51269185	50.25	49.75	79.7	85.7
Sweden [4]	45924	40	60	4717	55	45	10096059	50	50	81	84.1
Switzerland [4]	30963	46	54	1663	58	42	8654622	49.49	50.51	81.6	85.6
Slovenia [4]	1486	44	56	108	41	59	2078938	50	50	78.2	84
Ukraine [4]	9410	44	56	239	55	45	43733762	46.24	53.76	66.7	76.7
Illinois [20]	129837	48.46	51.54	6095	55.42	44.58	12659682	49.03	50.97	77	81.6
New Hampshire [21]	5178	44.63	55.37	301	53.49	46.51	1371246	49.32	50.68	77.5	81.4
Massachusetts [22]	87052	45	55	5862	48.4	51.6	6976597	48.37	51.63	78.2	82.6
Kentucky [23]	11883	48.55	51.45	484	43.75	56.25	4499692	49.19	50.81	72.8	77.9
North Dakota [24]	2941	47.14	52.86	73	—-	—-	762000	50.5	49.5	77.6	82.5
Oregon [25]	5060	47.92	52.08	169	57.62	42.38	4301089	49.5	50.5	77.8	81.9
New York State [26]	401333	51.3	48.7	30680	57.9	42.1	18804000	48.4	51.6	79	83.4
Delaware [27]	10056	45	55	413	48	52	982895	48.4	51.6	76.2	80.6
Kansas [28]	10812	56.17	43.83	240	51.4	48.6	2245869	49.6	50.4	76.3	80.7
Michigan [29]	59107	47.47	52.53	5711	53	47	10045029	49.1	50.9	75.7	80.2
Wisconsin [30]	21593	49	51	671	55	45	5851754	49.6	50.4	77.3	81.5
Minnesota [31]	28900	49.13	50.87	1267	—-	—-	5700671	49.6	50.4	79	83
Alaska [32]	593	51.2	48.8	11	—-	—-	731550	52	48	76.7	81.2
Iowa [33]	22785	52.04	47.96	638	52	48	3179849	49.5	50.5	77.2	81.6
Indiana [34]	38337	47.23	52.77	2173	51.38	48.62	6745354	49.2	50.8	74.6	79.3
Idaho [35]	3260	45.2	54.8	85	52.4	47.6	1826156	50.1	49.9	77.4	81.2
Montana [36]	561	49	51	18	—-	—-	1070000	50.2	49.8	76.8	81
Washington [37]	24642	47.16	52.84	1190	54.55	45.45	7797095	49.8	50.2	78.4	82.4
Connecticut [38]	44179	45	55	4097	49	51	3590886	48.7	51.3	78.7	83
Rhode Island [39]	15862	44	56	823	47	53	1009904	48.3	51.7	77.7	82.1
Pennsylvania [40]	75119	44.64	55.36	6113	48.04	51.96	12820878	48.7	51.3	75.8	80.6
Maine [41]	2637	48.32	51.68	100	—-	—-	1292816	48.9	51.1	76.6	81

no corresponding percentage specified is not considered for weighted average calculation. Most of the data are extracted from state / country government sites [4-41]. The remaining pieces of information, such as total population [42], sex ratio [43], [44], and climate [45] specifications are accumulated from other reliable sites .

III. Observation And Critical Discussion

We have accumulated data for several countries and states and categorized those under 3 climates. After complete collection, we found an average of percentages of infected males from all entries. Correspondingly, the average percentage of females in infected patients were found. The same procedure is repeated for the percentage of males in the deceased, from which the average percentage of females in the deceased was found. Also, to keep track of all influencing factors, the average sex ratio in total population and the average life expectancies for males and females were also obtained. We observed a certain trend in results as the climate changes from cold to hot.

A. Hot Climate Data Analysis

From the information in hot climate table (TABLE I), we find:
Average % males = 53.08%, % females = 46.92% in infected. Average % males = 64.33%, % females = 35.67% in deceased. Average % males = 49.65%, % females = 50.35% in population. Average life expectancies for males is 72.82 years and for females is 78.25 years. It is graphically represented as in Fig 1.

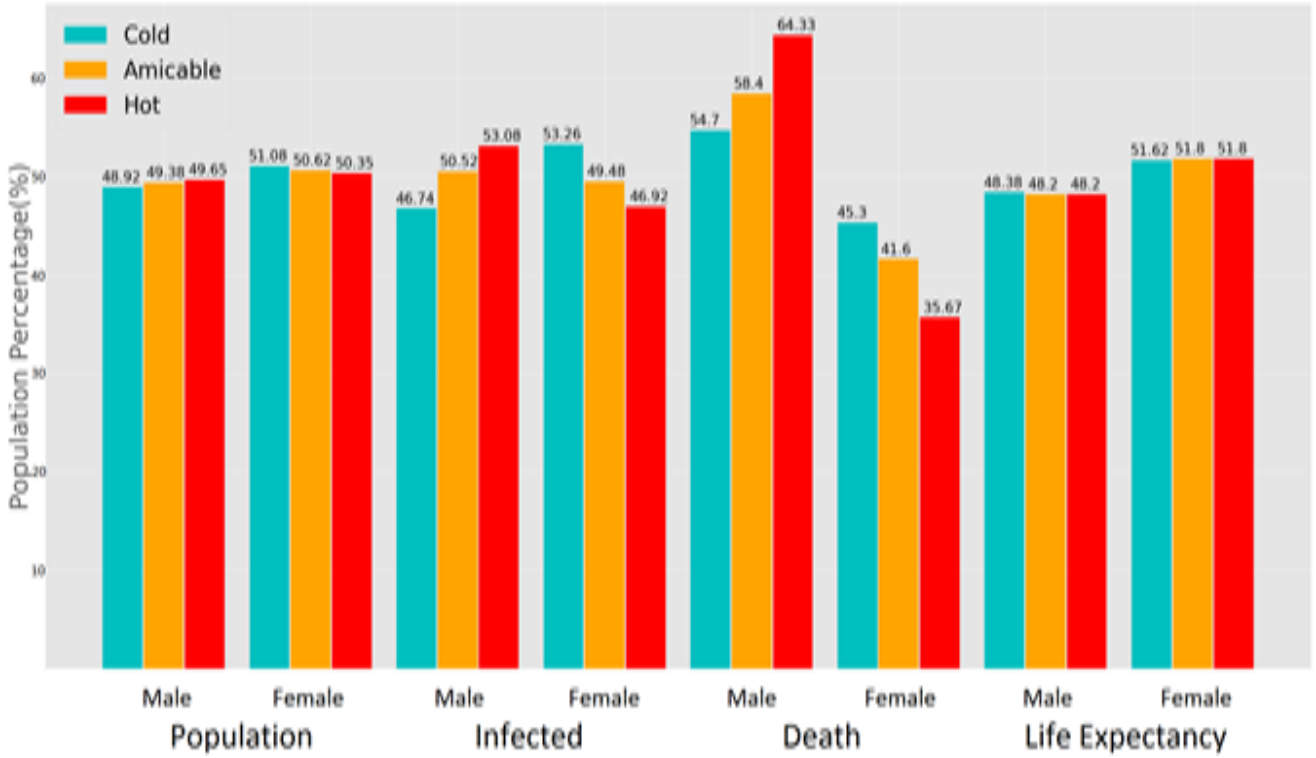

Fig. 1: Climate wise Gender Segregated tabulated COVID-19 data representation (Blue, Yellow and Red representing Hot, Amicable and Cold Climates respectively).

B. Amicable Climate Data Analysis

From the information in amicable climate table (TABLE II), we find:
Average % males = 50.52%, % females = 49.48% in infected. Average % males = 58.4%, % females = 41.6% in deceased. Average % males = 49.38%, % females = 50.62% in population. Average life expectancies for males is 72.77 years and for females is 78.23 years. It is graphically represented as in Fig 1.

C. Cold Climate Data Analysis

From the information in cold climate table (TABLE III), we find:
Average % males = 46.74%, % females = 53.26% in infected. Average % males = 54.7%, % females = 45.3% in deceased. Average % males = 48.92%, % females = 51.08% in population. Average life expectancies for males is 77.66 years and for females is 82.87 years. It is graphically represented as in Fig 1.

We observe that, from cold to hot climate, the percentage of males in deceased and infected, continuously rises, with no significant change in population sex ratio. Since taking a simple average of percentages may introduce bias due to some extreme data set present in a table, using total figures (infected or death) as a weightage factor corresponding to those percentages will normalize and reduce bias in net (average) percentages. The formula used for this weighted average analysis is :

$$Net\ \% = \frac{\sum_{i=1}^{n} w_i * p_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

w_i = Weightage of i th country / state as given by total infected, total death or total population.
p_i = Percentage of males (or females) of i th country / state for the corresponding parameter of weightage.
n = Number of entries (rows) in each table.
i = Running index, indicating the current number of the row in the table under consideration.
From Hot Climate data (data table I), we found that the Maldives has got exceptionally skewed sex ratio towards males among infected patients. Subsequently, that biasness reflected to some extent in the mortality sex ratio. Among the Amicable Climate (data table II) entries, Peru and especially Bangladesh were found to have infected patients' sex ratio skewed towards males significantly, opposite to the range of others. The same trend is reflected in the mortality sex ratio in Thailand, Peru, Dominican Republic and Bangladesh. In the case of Cold Climate (data table III), the infected sex ratio was significantly skewed towards females in Belgium, Bulgaria, Scotland and Netherlands. The same trend, in the case of mortality sex ratio, is observed in the case of Slovenia, Kentucky, and to some extent Canada. The rest of the data lies around the trend of data they set.

IV. Conclusion

After completion of this study, we observe the following trends.

- We find that as we move from a colder climate to a hotter climate, the percentage of males in infected and deceased rises continuously, implying males are significantly more susceptible to COVID-19 in hotter climates.
- We observe that the population sex ratio is almost invariant across climates, so does not put much effect on the infected or deceased sex ratio.
- Across all the climates, the average life expectancy of females is more than that of males. So, the percentage of females in the senior citizen group is more than males. The mortality of males more than females implies that males (especially aged) are significantly more susceptible to COVID-19

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