Statistical Comparison of COVID-19 Infections Based Upon the Food Habits/Diets in Countries Using RStudio

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Abstract— **On December 2019, the COVID-19 deadly virus emerged and affected a large population in the world which led to the increase in the death rate of infected patients. Changes in dietary habits and way of living leading from the implementation of lockdown during this pandemic had been detrimental on the nutritional health of individuals. A statistical study was conducted to determine the effect of COVID-19 lockdown on dietary habits, food consumption, and weight in different countries. The primary aim of this study bas been to conduct a statistical research to measure the impact of the pandemic on dietary habits of the humans. Retrospective study was made by the data collected from a data repository Kaggle with attributes of food status, nutrients and calories. By statistically analyzing the data using RStudio, it was possible to infer on the changes in dietary habits between countries of similarities. Based on the statistical analysis, it was found that the consumption of fat varies depending on the availability of meat or vegetables during the COVID-19 pandemic leading to vulnerability of human population with weaker consumption-based immunity against the disease.**

Keywords—COVID-19, Dietary and Food Habits, COVID-19 Dietary Comparison, COVID-19 Lockdown.

I. INTRODUCTION

The COVID-19 pandemic has disrupted almost all the activities of the human life and the basic existence in this resource rich world. In such a situation, analyzing and identifying the effects of our daily habits on the spread of infections will be helpful in taking a multi-pronged approach to contain its spread. Most symptoms associated with COVID-19 patients are mild to moderate respiratory disease, and recovery without the necessity of preferential treatment. Aged individuals are more likely to acquire chronic diseases, as are those with fundamental health issues such as cardiovascular disease, diabetes, chronic respiratory disease and cancer.

Being educated and well aware of COVID-19 virus transmissions will help to protect more human lives. As the virus spreads through droplets of saliva of an infected person's cough or when they sneeze, we need to attain measures like maintaining social distance and wearing protective masks. Various governments and agencies have applied lockdown as the measure for containing the spread of the COVID-19 virus infection.

Healthy living starts with a proper balanced diet, which basically offers nutrients to an individual's body. Consumption of only green vegetables or no meat at all is not what it is about, what matters is when to eat and to have them at proper proportion. You succeed in consuming a healthy diet when you consume correct food intakes rich in calories. We also need to consider different factors when

deciding the correct calories for individuals, it might be due to age or gender. Good nutrition is indeed important, and it is even more essential during this pandemic because a well-balanced diet of healthy food helps promote a strong immune system. Consumption of a diet rich of whole grains, nuts and healthy fats such as in olive, sesame, peanut or other oils rich in unsaturated fatty acids is advisable. These rich foods will support the human immune system in the fight against the effects of the COVID-19 virus.

In this paper, the data of the food habits, intakes and calories consumption during the duration of COVID-19 was collected from 170 countries through the centralized data repository of Kaggle [1]. Data recorded between December of 2019 until November 2020 (26-11-2020) were considered for analysis and generation of inferences. Different set of inferences were generated based on the comparison between pairs of countries compared based on the historical data. The comparison was brought into effect by the set of similarities and dissimilarities on the food habits in the pair of countries.

Due to the current pandemic, governments have taken steps to decrease the spread of coronavirus by implementing lockdown for nations across the globe. This study shows the effect of food intake in relation to the lockdown of individuals based on different data that was read and analyzed on RStudio [9] using R programming language [8] to generate the statistical analysis. A comparative analysis of various nations was done through which one could interpret an individual's dietary habits in relations to the lockdown. The analysis was done by the method of Carl Pearson's method of correlation.

The organization of the paper is as follows. Section II states a brief scope of the problem identified and analyzed in this paper. Section III provides a brief information about the similar attempts and related work done by other researchers. Section IV provides information about the methodology adopted in research work done and presented in this paper. Section V is the core part of the paper on which the whole research work was centered around. It provides the complete information on the comparison of obtained data and in the identification, analysis and generation of inferences on the effect of food habits on COVID-19. Finally, Section VI concludes the core finding of this research.

II. SCOPE OF THE PROBLEM

The objective of this research work is to investigate the consequential effect of COVID-19 in 170 countries on food intake and changes in diet. The data set for the dietary and food habits have been taken from Kaggle data set repository [1]. Hence, this research work is limited to the availability of data set in the repository for a specified duration of time.

III. Existing Work

In the study presented in Food choice motives and the nutritional quality of diet during the COVID-19 lockdown in France by Marty et. al., [2], they have examined that as transmission of COVID-19 virus is worldwide, the imposed lockdown imposed has changed individuals the intake of food based on multiple factors. This research was conducted to examine the effect of poor nutritional diet that could lead to non-communicable disease. Data collected through survey displayed participants characteristics on demographically and food-related, dietary status. It was also reported by the participants that the energy intake was more than 500 kcal/day.

In the work done by Martin-Neuninger et. al., [3], an opinion was expressed on the evaluation of emerging and likely consequences of COVID-19 lockdown on consumer grocery purchasing habits. It is a pure statistical paper and have not identified the effect of the consumption of purchased items towards the spread of virus infection.

Sánchez-Sánchez et. al. [4], have done a work on understanding the dietary patterns, consumption, and physical activity of the Spanish population before and during the period of confinement by COVID-19. Based on the questionnaire-based study the Mediterranean Diet adherence has slightly increased during the confinement, although consumption of 'unhealthy' food has also increased in the population.

The concept of Exploratory Data Analysis (EDA) has been applied by Joanita and Senthil Velan [5] on developing correlation among the COVID-19 cases. Based on the statistical analysis it was found that there exists higher correlation between the identified characteristics of the COVID-19 patients in the countries of study.

Reyes-Olavarría et. al., [6] have studied the lifestyle changes such as eating habits and physical activity patterns of people in Chile, caused by the confinement during the COVID-19 pandemic and to analyze its association with changes in their body weight. A number of inferences have been generated based on the study and in a gist, it was found that there were noticeable changes in the food habits of the population.

In the clinical research done by Muscogiuri et. al., [7], the quarantine-related situational stress-eating of the human population around the world has been discussed in depth. The authors also suggest the intake of foods that are good sources of immuno-supportive nutrients and having a positive mindset to beat the ill-effects of quarantine.

In the work done by Laura et. al., [10] the authors have assessed the nutritional and environmental impacts of the changes in food purchases and eating habits of the population during the COVID-19 lockdown in Spain. Results of the work done have shown that the COVID-19 diet had larger energy intake and lower nutritional quality with high impact on the environment.

A good number of researchers [11][12][13] around the world have attempted to study the changes in the diet of the human population during the COVID-19 affected quarantine around the world [14][15]. But there is enough scope to study the effect of diet on the spread of COVID-19 virus infection between countries possessing similar characteristics.

IV. Methodology

Any statistical analysis based technique requires the identification, definition and design of suitable steps followed as a methodology. Fig 1 shows the sequence of steps in the method used to generate inferences based on the statistical analysis of the dietary dataset.

A. Method

To study the demographic data, changes in eating propensities and food-intake during the national pandemic COVID-19 lockdown, data were collected from 170 nations utilizing Kaggle.com site.
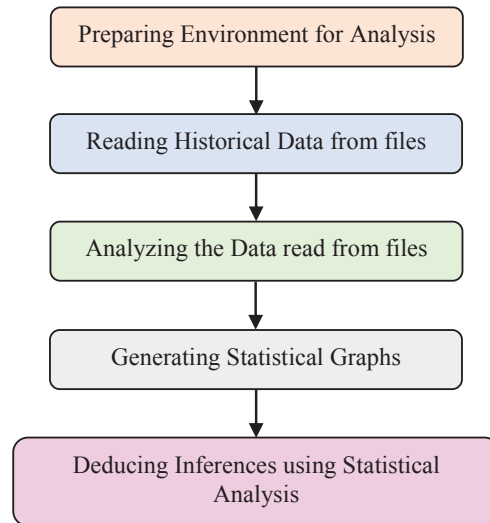

Fig 1. Process Flow of Data Analysis using RStudio

Programming language R [8] may be a free program environment for factual computing and illustrations. It compiles and runs on a wide assortment of UNIX stages, Windows and MacOS. R is a coordinate's suite of program offices for information control, calculation, and graphical show.

We read the Demographic data including different nations food intakes based on food supply, calories, obesity rate, death recorded, undernourished, population. Anthropometric data (reported weight and height), dietary habits information (daily intake of certain foods, food Calories).

Selected attributes are the structured data which is then statistically analyzed using RStudio which is an integrated development environment for R, a programming language for statistical computing and graphical representation. CCA (Canonical Correlation Analysis) is done on RStudio to measure the relations between any two sets of variables. In similar circumstances which involves related data, multiple regression would be appropriate, canonical correlation is suitable too, but not applicable when it involves multiple inter-correlated result variables. Then, the plots are made on the calculated statistical values using graph, hence deducing inference

B. Statsictical Analysis

Pearson correlation (r), which measures a linear dependence between two variables (x and y). Also it is recognized as a parametric correlation test since this data

distribution varies based on that as well. It can be used only when x and y are from normal distribution. The plot of $y = f(x)$ is named the *linear regression curve*.

V. COMPARISON OF DATA

In order to better understand the effect of COVID-19 on the Diet/Food habits of the population, comparison can be done on these habits in different countries. In this section, a pair wise comparison of countries which have an appreciably similar characteristics has been done with clear set of illustrations.

A. Overview

Data was used for the comparison of similarities among multiple countries on the basis of their food habits/diet in relation to the COVID-19 pandemic. The data consolidated is as of November 2020 from the Kaggle website which was available for download at the time of comparison.

B. United States of America Vs Brazil

1) Characteristics of Similarity:

The American continent-based countries namely USA and Brazil have been compared with respect to the COVID-19 infections. The comparison was brought into effect by the similarity of the density of the population.

TABLE I. SIMILARITY COMPARISON BETWEEN USA AND BRAZIL

Characteristic/Country	USA	Brazil
Population Density (*Population/km²*)	34	25
Median Age	38 Years	33 Years
Intensity of Lockdown	68.9*	64.35*
Mode of Arrival	By Land, Sea and Air	By Land, Sea and Air

According to OxCGRT, Scale = 0 to 100

The following factors were also used to compare the North and South American countries:

- *USA* – With a net area of 9.834 million km², the most densely populated state in the country is California with 39.51 million people and the least densely populated state is Wyoming with 580,000 residents.

- *Brazil* – With a net area of 8.516 million km², most of the Brazilian land is covered by the Amazon rainforest. The most populated city in Brazil is Sao Paulo with 45.9 million residents and the least populated is Roraima with only 450,000 residents.

- The Median age of the 2 nations are also similar in nature. The nations have the age of 38 and 33 as their median age, by which one could interpret that most residents of both the nations are middle-aged individuals or of the tricenarian age group.

- The nations were subjected to lockdowns with similar intensities even though their procedural implementations were different in nature.

2) Characteristics of Dissimilarity:

The USA shares it's national boundaries with only 2 nations. i.e., Canada and Mexico. Whereas, Brazil shares its borders with 10 other nations. i.e., French Guiana, Suriname, Guyana, Venezuela, Colombia, Peru, Bolivia, Paraguay, Argentina and Uruguay. The number of Immigrants arriving in the USA annually is 12 times more than that of Brazil.

TABLE II. DISSIMILARITY COMPARISON BETWEEN USA AND BRAIL

Characteristic/Country	USA	Brazil
Number of Borders	2	10
Number of Arrivals per Year	79.75 Million	6.62 Million

3) Observations:

- US consumes more of its fat from vegetable oils than Brazil whereas Brazil consumes more of its fat from meats.

- US consumes a higher percentage of energy from vegetable oils and sugars and sweeteners than Brazil.

- US consumes a higher percentage of protein from milk and milk products (excluding butter) and animal products than Brazil whereas Brazil consumes a higher percentage of protein from pulses and specific meats.

4) Inferences:

- Due to a moderately low population density yet a high population, moderately high intensity of lockdown in both countries and similar food habits centered around animal products, meats, milk products and sugary products shown in fig5. USA has 18,113 Total Cases / 1M of population and Brazil has 17,491 Total Cases / 1M of population.

- Therefore, it is mandatory that both countries adopt a healthier lifestyle which is more balanced with moderate amounts of animal, milk, cereal and vegetable products.
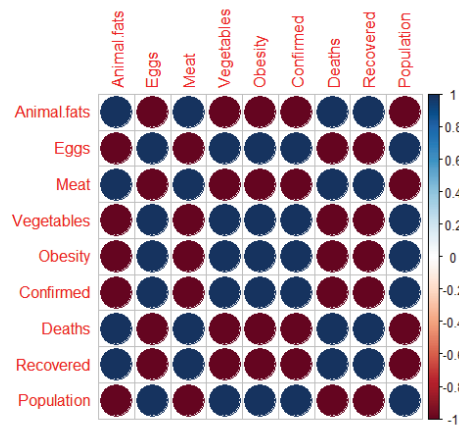

Fig 2. Correlation based on diet and fatality between USA and Brazil

C. United Arab Emirates Vs India

1) Characteristics of Similarity:

The number of immigrant arrivals are also similar in nature. UAE is a nation in which the immigrants largely outnumber the native locals; with a large portion of its population consisting of Indians (28%), the number of annual travelers are bound to rise. India attracts 17.42 million travelers to the country for its diverse nature and cultures
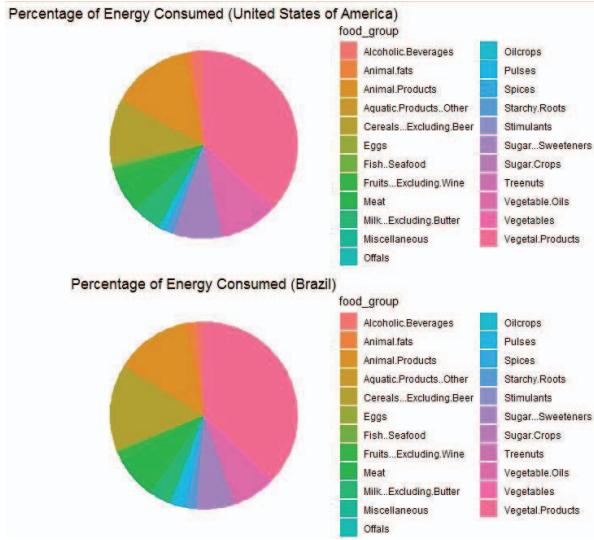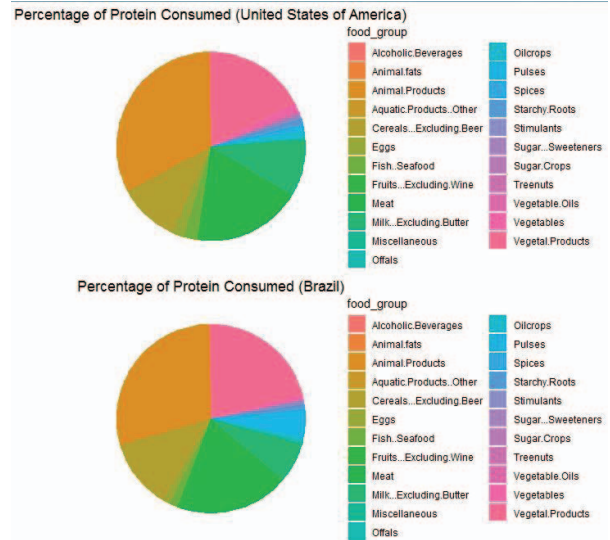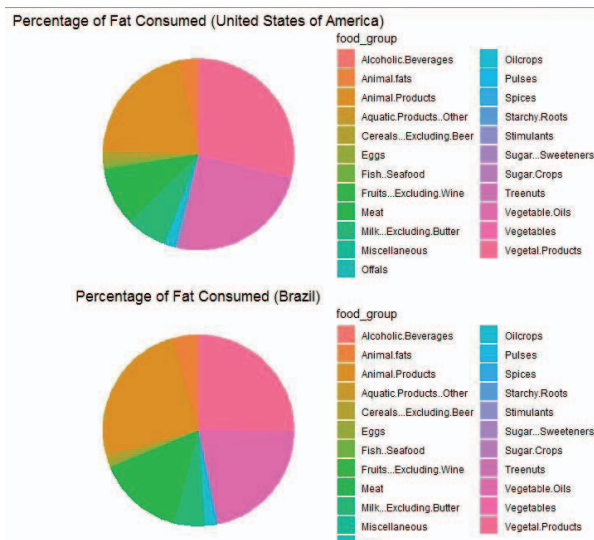
Fig 3. Energy consumed

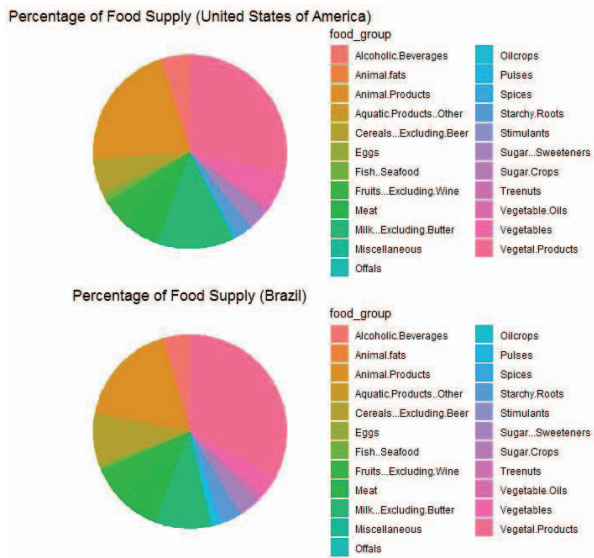Fig 4. Fat consumed
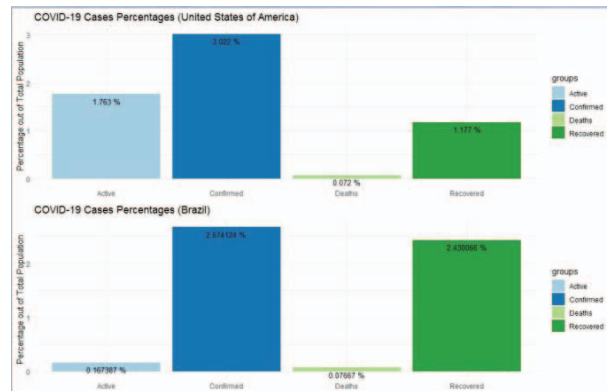

Fig 5. Food supply

Fig 6. Protein consumed

Fig 7. COVID-19 case rate
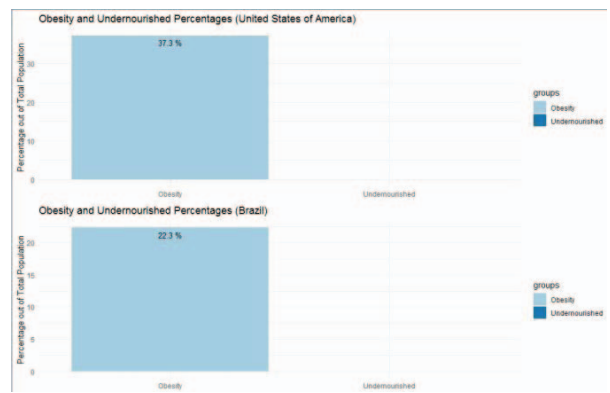
Fig 8. Rate of Obesity

TABLE III.   SIMILARITY COMPARISON BETWEEN UAE AND INDIA

Characteristic/Country	UAE	India
Median Age	30 Years	26.4 Years
Number of Arrivals per Year	21.29 million	17.42 million
Mode of Arrival	By Land, Sea and Air	By Land, Sea and Air

2) Characteristics of Dissimilarity:

- *UAE:* With a net area of only 83,600 km², the most densely populated emirate in the country is Dubai with 1,137,347 people and the least densely populated emirate is Al-Fujairah with only around 30,000 residents.
- *India:* With a net area of 3.287 million km², India is the 7th biggest country in the world in terms of area. The most densely populated state in the country is Uttar Pradesh with 199,812,341 people and the least densely populated state is Arunachal Pradesh with 12.6 lakhs residents.

TABLE IV.   DISSIMILARITY COMPARISON BETWEEN UAE AND INDIA

Characteristic/Country	UAE	India
Population Density (*Population/km²*)	116.87	411.48
Intensity of Lockdown	40.74*	79.63*

(According to OxCGRT, Scale = 0 to 100)

3) Observations:

- UAE consumes a higher percentage of fat from specific meats than India whereas India consumes more animal fats.
- UAE consumes a higher percentage of energy from animal products than India while India consumes a slightly higher percentage of energy from cereals.
- UAE consumes a slightly higher percentage of proteins from animal products while India consumes a higher percentage of proteins from milk and milk products (excluding butter).
- Both countries have drastically different percentages of obese and undernourished people with UAE having 29.9% and 2.6% respectively and India having 3.8% and 14.5% respectively.

4) Inference:

- Both countries, UAE and India have similar food habits, probably due to the fact that 27.49% of UAE's population consists of Indians.
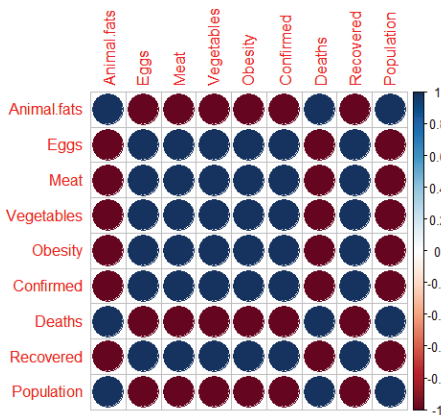

Fig 9. Correlation based on diet and fatality between UAE and India

- Both countries have fairly balanced diets with moderate amounts of carbohydrates, proteins, fats and essential vitamins and nutrients.
- Although both countries follow good, balanced diets, India has an extremely high population density and low civil obedience, even with a high intensity of lockdown six months into the pandemic.

- As of 28th August 2020, there is a 68% increase in the biweekly change in confirmed COVID-19 cases in the UAE. This may be due to the low intensity of lockdown and high obesity rates.
- Therefore, it is preferable that both countries work on their obesity and undernourished rates and try to minimize the spread of the virus by introducing new lockdown schemes or increase the penalty for breaking the law set by the government.

D. United Kingdom Vs France

1) Characteristics of Similarity:

Entry into Both the nations are similar in nature. One could access the nation via land, air or waterways. The median age of a population is an index that divides the population into two equal groups: half of the population is older than the median age and the other half younger, and here both countries are on same page.

TABLE V.   SIMILARITY COMPARISON BETWEEN UK AND FRANCE

Characteristic/Country	UK	France
Median Age	40.6 Years	42.3 Years
Mode of Arrival	By Land, Sea and Air	By Land, Sea and Air

2) Characteristics of Dissimilarity:

The population density in the United Kingdom is 280 per Km² (727 people per mi²). The total land area is 241,930 Km² (93,410 sq. miles) and the population density in France is 120 per Km² (309 people per mi²). The total land area is 547,557 Km² (211,413 sq. miles).

TABLE VI.   DISSIMILARITY COMPARISON BETWEEN UK AND FRANCE.

Characteristic/Country	UK	France
Population Density (*Population/km²*)	279.95	123.28
Intensity of Lockdown	64.35*	43.52*
Number of Arrivals per Year	36.32 million	89.32 million
Number of Borders	1	8

(According to OxCGRT, Scale = 0 to 100)

3) Observations:

- France consumes more of its fat from animal products than United Kingdom.
- Fig 10 shows that, both countries have very similar data when it comes to percentage of energy, centered on animal, aquatic and vegetal products.
- Both countries receive their protein in very similar fashion, predominantly from animal, aquatic and milk products.
- Both countries also have high obesity rates.

4) Inference:

- Due to both countries high obesity rates and animal and aquatic product centered diets, United Kingdom has 5,322 Total Cases / 1M of population and France has 5,564 Total Cases / 1M of population.
- Therefore, both countries must include more vegetables and cereals such as wheat, in their diets.
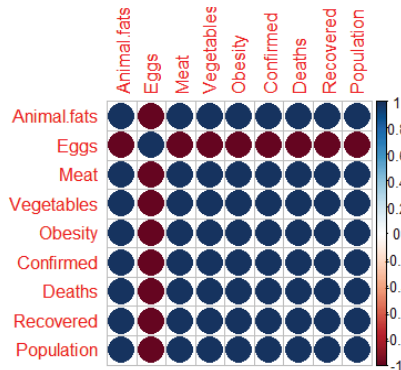
Fig 10. Correlation based on diet and fatality between UK and France

E. India Vs Bangladesh

1) Characteristics of Similarity:

With a large population and one of the highest population densities in the world, India had to implement comparatively intense lockdown procedures for the nation. Many restrictions were imposed along with the lockdown in Bangladesh as well which further increases its intensity. The success of the nation's lockdown protocols are debatable.

- With a median age ranging from 25.1 to 26.4, most individuals of both nations are late veterans stepping up towards their middle ages.
- Both are at almost same intensity of lockdown with strict traveling policy, which makes it easier to compare.
- Entry into Both the nations are similar in nature. One could access the nation via land, air or waterways.

TABLE VII.   SIMILARITY COMPARISON BETWEEN INDIA AND BANGLADESH

Characteristic/Country	India	Bangladesh
Median Age	26.4Years	25.2 Years
Intensity of Lockdown	81.94*	89.81*
Mode of Arrival	By Land, Sea and Air	By Land, Sea and Air

According to OxCGRT, Scale = 0 to 100

2) Characteristics of Dissimilarity:

Citizens from Bangladesh has been of the highest number of tourist visiting India. Tourism in India is importance for the country's economy and it's growing rapidly, therefore making almost 17 times arrivals than Bangladesh.

TABLE VIII.   DISSIMILARITY COMPARISON BETWEEN INDIA AND BANGLADESH

Characteristic/Country	India	Bangladesh
Number of Borders	7	2
Population Density (*Population/km²*)	411.48	1175
Number of Arrivals per Year	17.42 Million	1.03 Million

The following factors were also used to compare the India and Bangladesh:

- The border of India is shared with seven countries- Afghanistan and Pakistan to the North-West, China, Bhutan and Nepal to the North, Myanmar to the Far East and Bangladesh to the East.

- Bangladesh shares bored with India which is the 5th longest land border in the world and with Myanmar.
- The number of Immigrants arriving in India annually is 17 times more than that of Bangladesh.

3) Observations:

- India consumes more of its fat from animal products and specific meats than Bangladesh whereas Bangladesh consumes nearly 50% more fat from vegetables than India.
- India receives nearly twice its energy from animal products than Bangladesh while Bangladesh receives nearly 30% more of its energy from eggs.
- India consumes more of its protein from specific meats than Bangladesh while Bangladesh receives more of it from eggs.
- Both India and Bangladesh have extremely similar rates of obesity and undernourishment.

4) Inferences:

- Due to the high consumption of meat in India and eggs in Bangladesh, they have 3,374 Total Cases / 1M of population and 2,036 Total Cases / 1M of population respectively.
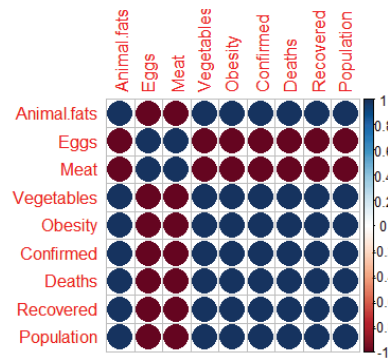- Therefore, it is advisable that India reduces its consumption of meat and Bangladesh increases it.

Fig 11. Correlation based on diet and fatality between India and Bangladesh

F. Sri Lanka Vs Philippines.

1) Characteristics of Similarity:

With an area of 65,610 km² Sri Lanka is slightly larger than twice the size of Belgium. And it shares maritime borders with the Maldives and India.

TABLE IX.   SIMILARITY COMPARISON BETWEEN SRI LANKA AND PHILIPPINES.

Characteristic/Country	Sri Lanka	Philippines
Population Density (*Population/km²*)	332.31	364.0
Mode of Arrival	By Sea and Air	By Sea and Air
Number of Borders	0	0

- There are five Asian countries that does not share any land borders with other countries and Sri lanka and philippines are two of those countries.
- Sri lanka is seperated by India by Indian ocean whereas Philippines, island country of Southeast Asia in the western Pacific Ocean.

2) Characteristics of Dissimilarity:

- Around 1.8 million tourist arrivals came from only South Korea into the Philippines. Due to current situation and virtually no foreigners visiting the country so now it relies mainly on domestic tourism to get their earnings.

TABLE X.   DISSIMILARITY COMPARISON BETWEEN SRI LANKA AND PHILIPPINES.

Characteristic/Country	Sri Lanka	Philippines
Median Age	31.4 years	23 years
Number of Arrivals per Year	2.33 Million	7.17 Million
Intensity of Lockdown	25.93*	56.48*

According to OxCGRT, Scale = 0 to 100

3) Observations:

- Sri Lanka and Philippines consume their fats in extremely different forms as shown in fig12. Sri Lanka consumes most of their fats from vegetal products and oil crops whereas Philippines consumes its fats from animal products, vegetable products and oils, and milk products (excluding butter).
- Philippines consumes a higher percentage of energy from animal products than Sri Lanka whereas Sri Lanka consumes a higher percentage of energy from oil crops than Philippines.
- Sri Lanka consumes more of its protein from vegetal products than Philippines, while Philippines more milk and animal products and both countries have similar obesity and undernourishment rates.

4) Inferences:

- Due to the Philippines' milk and animal centered diets, and high population, it has 2,347 Total Cases / 1M of population, whereas Sri Lanka only has 148 Total Cases / 1M of population, due to its diet which is concentrated with oil crops and vegetal products. Therefore, Philippines must lower amounts of milk and animal products and more of vegetal products.
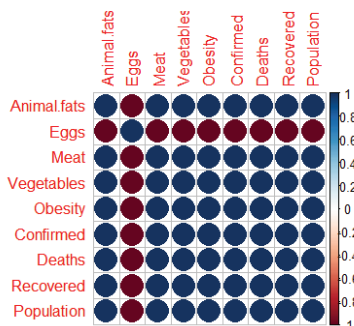

Fig 12. Correlation based on diet and fatality between Sri Lanka and Philippines

VI.   CONCLUSION

This study based on the collected data on population, eating habits and diet, shows the different country's meat and protein intakes and patterns during COVID-19 lockdown. Comparison between countries of similar characteristics shows that even if the eating habits are found to be same between them, the rate of obesity and undernourished differ. Impact of COVID-19 on individual's diet has not shown much change, it has shown that least number of cases shown in the country that has the high rate of energy and protein intakes. Countries under severe intensity of lockdown has shown food supply at lower rate than minor lockdown. From inference we find that most of the countries with high rate of obesity were found to get fat from animal products. There can be a decrease in obesity once lockdown is over since people will be more physical activity. There will be a change in the sense of hunger and satiety as individuals try to attain immunity. This work can be further extended by applying machine learning algorithms for more accurate predictions.

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