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COVID-19 infection and risk analysis: a short introduction

Abstract

This work is part of a study about COVID-19 pandemic in Mozambique. Here we reproduce the first part of such study where a general introduction about the background and motivational aspects of COVID-19 in the world is made. Also, the relevance of mathematical and statistical modeling, the concepts of risk, risk analysis and spatial epidemiology are detailed. An introductory briefing on risk measures in epidemiology is performed. In the present work, we deal with risk assessment in epidemiology, we address aspects such as uncertainty and variability, types of risk assessment and its steps, methods, and relevant conditions for the quality of risk assessment. At the moment, the considered data set is still incomplete, only preliminary estimated models and preliminary results were obtained. A continuation of this manuscript will illustrate the models estimated and applied to the modeling of infectious diseases, presenting those with a mathematical and statistical approach to COVID-19 infection. Also, we will present the mapping of diseases. The preliminary results obtained with the provisional data set agree with similar performed studies.

Keywords: COVID-19, risk analysis, spatial epidemiology

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Abbreviations: WHO, e World Health Organization; SARS-CoV-2, corona Virus 2 that causes severe acute respiratory syndrome

Introduction

Background and motivation

The world has being (and still is) affected by the COVID-19 pandemic caused by the SARS-CoV-2 virus, which, according to official data, it's first case took place in the Chinese city of Wuhan, located in Hubei Province, at December 2019, reported to WHO on December 31, 2019.[1] Cases of this disease began to increase in China and were raising concern for the authorities. On January 30, 2020, a Public Health Emergency of Interest to the International Community was declared by the WHO. Due to the rapid spread and the emergence of several cases in different parts of the world, this organism declared a pandemic on March, 11st, 2020.[2,3]

Summarizing, under the aim of COVID-19 Pandemic in Mozambique, we first reproduce partially some work performed about COVID-19 in the world, relevance of mathematical and statistical modeling, the risk concepts, risk analysis and spatial epidemiology and an introduction to the risk measures in epidemiology.

Preliminaries

The SARS-CoV-2 virus had spread rapidly in countries on the Asian continent. At the European continent, by the end of January, the first three cases were registered in France on January 24th, 2020.[4] In North America, the first case was registered in the United States of America, on January 21st, 2020,[5] at South America, the first case was registered in Brazil, on February 21st, 2020.[6] In Africa, the first case was registered on February 14th, 2020 in Egypt.[7] In Mozambique the first case was registered on March 22nd, 2020.[8] This evidences how the virus has been spreading exponentially around the world. The data taken from the WHO platform on January 6, 2022, revealed that after more than 2 years, after the first official case was reported to WHO, on December 31st, 2019, more than 298 million cases of SARS-CoV-2 virus infection were reported, showing that the virus is a problem for everyone on planet Earth.

In Mozambique, since its first registration, and until January 6th, 2022, there were registered 203241 cases of infection with the SARS-CoV-2 virus. The country had to adopt measures to contain the pandemic, which ranged from the closure of educational institutions, bars and stalls, borders, time limits for some institutions, among others. These measures over time and so far, had been adjusted depending on the spread of the pandemic with relaxation or worsening of these. During 2022, the country experienced the fourth wave of the pandemic, with the new infections' indicator increasing considerably, indicating a galloping growth in the transmission of the SARS-CoV-2 virus in the country.

COVID-19 was a new disease, which was becoming known as time went by. At the beginning, it witnessed and still continues to witness, at the international level, a great concern of governments and scientists to investigate this problem, and produce innovative scientific articles, based on different types of studies to better understand the disease and its evolution. Many countries, including the most developed ones, had a lot of difficulty in controlling the pandemic, and some systems almost collapsed due to the lack of information and scientific studies about the disease. It continues to be a challenge for government authorities, those in the health sector, to make decisions to control this disease, as many of them have an impact on the social life of citizens.

For health authorities, it is of great interest to map the risk of transmission of the virus in each of the provinces (or cities or districts), to determine whether the risk of infection in each of the regions is influenced by others. of reliable and real-time information, supported by scientific tools that make it possible to understand transmission chains. Statistical and mathematical modeling offer powerful and useful tools for assessing the risk of contagion of COVID-19, enabling

data analysis, and obtaining information that allows the determination of associated risk factors and risk estimation, whether regarding mortality and morbidity.

Studies on the pandemic, its impact on the lives of citizens, on the economy of countries, on epidemiology, relationship with some factors that are associated with risk for the disease and, have been carried out, in this sense, it can be illustrated as an example works of some researchers, and in different parts of the world in general, in Africa in particular and specifically in Mozambique. Some selected references are.[7–16]

Modeling

Mathematical modeling as well as statistical modeling seek to define models that describe any process (or phenomenon) of interest in nature or in people's daily lives. These models are quantitative and can be represented by an equation or a system of equations. With the advancement of technologies (development of more efficient computers) the problems that involve modeling, be it mathematics or statistics, become computationally simple, and the interest in it is growing, because from modeling, it is possible to easily test several theories, made predictions and extracted important information from the models developed for decision making. These models are applied in areas such as ecology, health, industries, aviation, among others.

Modeling can be considered an identification of risk technique, it provides a broader understanding of risk, produces multiple responses to better understand the range of outcomes, includes elements of uncertainty, and facilitates testing of inherently inaccurate predictions, providing results likely under several different assumptions or scenarios and information about the behavior of key variables.[16]

The search for understanding different processes (or phenomena) of nature or solving problems that affect people in their daily lives, mathematical and statistical models, stand out as one of the most applied tools. In the area of health, particularly in epidemiology, there are several studies carried out by different authors and in different parts of the world that use mathematical and statistical modeling to understand the dynamics of transmission of different diseases or the association of different risk factors with a given disease. To illustrate the importance of modeling tools we list some interesting references concerning COVID-19 issues, namely[2,17–23] among others.

Statistical modeling as well as mathematics modeling provide an understanding of the underlying mechanisms of transmission and spread of a pandemic, helping to identify key factors in the disease transmission process, allowing to get some effective suggestions about control and preventive measures, and providing an estimate of the severity and scale, the potential of the epidemic.[24] Literature evidences the importance of statistical and mathematical models, obtaining good results in the study of contagious diseases, such as COVID-19. With these tools, we can provide information that can be considered in decision-making by different authorities in the country and used by the scientific community.

Modeling techniques in spatial analysis in general, and in spatial epidemiology in particular, are based on existing knowledge about the causal relationships associated with the disease risk of interest. Visualization methods characterized using statistical methods to define relationships between risk factors and disease risk as the outcome variable[25] can have an important contribution to facilitate the estimation procedure.

Statistical and mathematical modeling offer powerful and useful tools for assessing the risk of contagion from COVID-19, enabling data analysis, and obtaining information that allow the determination of associated risk factors and risk estimation, whether regarding the mortality and morbidity. In this sense, there are several models that can be applied for this purpose, highlighting the models applied in the context of disease mapping.

Risk

Daily, people, companies, governments, industries, and other institutions make various decisions, ranging from the amounts to invest for family savings, social and economic policies, new work methodologies, development of institutional projects or personnel, launches of new production lines and new ones, carry risks, as many of these decisions are taken under uncertainty. There are several factors that contribute to the existence and prevalence of risk, some of which are raised by Chavas[26] & Yoe[27] highlighting limited capacity to process information and the inability to measure or control some events.

Risk is an important concept whenever one intends to address risk analysis or assessment, as this concept is the core of this science. Being risk at the core of risk analysis and of great interest, the definition of risk is a subject that raises great debates, in the world of researchers and those interested in this, it is for this reason that there are several definitions about risk and many of them defined in depending on the context, and several authors approach this concept in various ways[27–33] among others. The author[34] evidences different approaches about how risk is evaluated by distinct researchers. In[34] the definitions and perceptions of risk in four groups are evaluated; in the first group, the risk evaluation is based on expected value, in the second is based on probabilities, in the third is based in uncertainties and in the last group, the first two forms are combined.

The risk will be present whenever there is a source that inserts the risk in a certain environment, for example, in the case of a virus such as SARS-COV-2, if it is present in certain wild animals, the source are such animals. It is also necessary that there is an exposure (or exposure process) for the susceptible or potential recipients, for example, if people consume the meat of the virus host animals, they will be exposed to this virus and finally, the exposure must lead to consequences such as adverse health effects, for example, the consumption of the meat of these animals makes people sick. Therefore, the presence of risk depends on these three elements, which are, the source, exposure, and consequences.[35]

The prevalence of certain diseases during the pandemic was studied in[19] the screen for depression, anxiety, and stress to evaluate resilience was performed. Data on potential predisposing factors for mental disorders were also collected contributing to better characterize mental disorders among healthcare residents. Also, in[36] the survival and direct medical costs of patients admitted in private hospitals with COVID-19 during the first wave were evaluated. Related risks during COVID pandemic can be found in[37] where, knowing that the prescription of antimicrobial agents has increased and may have accelerated the emergence of multidrug resistant bacteria, the authors describe a study that aimed to evaluate maternal and pediatric infections within a hospital from January 2019 to December 2021. Also, in[38] a dose-response relation was deduced for coronaviruses from coronavirus disease 2019; it was presented a meta-analysis result and its application for infection risk assessment of aerosol transmission was described. Similar studies were presented in[39] where dose-response modeling in a context of human cancer was detailed. The authors[40] estimated early COVID-19 incidence rates distribution and trends between the State of Tennessee in comparison

with US rates, using join point Regression Trend Analysis Software, offering important insights into public health system surveillance and epidemic control measures.

In epidemiological studies, the risk concept is associated with probabilities, as this is estimated from the probability concept. Risk can be understood as a measure that represents the probability of a person contracting a disease in a certain period.[41] Risk estimation in epidemiology is based on data provided by health authorities and has been intensively addressed in recent years. It should be noted that risk estimation is the basis of epidemiology and statistical modeling in epidemiology.[42,43]

Risk estimation is closely linked to the availability of empirical data, as well as the availability and use of quantitative methods that allow not only the estimation of risks, but also the determination of the accuracy of these estimates.[44]

Risk analysis

Risk analysis is a process composed of three elements, namely: risk assessment, risk management and risk communication.[27,45] In practical terms, these elements are related to each other, that is, they do not occur separately. According to[46] the COVID-19 pandemic shows that risk analysis has highlighted the importance of this tool in management of this pandemic by showing the relevance of risk science from different approaches, ranging from the understanding, assessing, communicating, and dealing with risk.

In risk assessment, the risk associated with a given one or more hazards or even risk management options is estimated.[27] This stage of risk analysis is important for reducing adverse effects, since decision-makers, specialists and other interested parties can obtain elements from it that allow them to understand the risk and thus be able to take measures to prevent, control or reduce the risks effects that may arise from them. Risk assessment can be quantitative, when the intention is to evaluate the risk numerically, i.e., the risk is presented numerically, qualitative, when the intention is to characterize the risk qualitatively, i.e., the risk classified by levels, and semi-quantitative, when the risk is evaluated from the two previous forms. The work presented by[31] describes the necessary methodology for risk assessment in detail.

Risk management is a step where decisions are taken on the identified risks, these decisions can be the minimization or control of these risks, choices of different techniques, advantages, and disadvantages of the decisions of the techniques to be used during the risk analysis. These decisions that are taken in this step are taken under uncertainty, for this reason there is always a risk of them failing. In the emergence of the COVID-19 pandemic, several decisions were taken in different countries of the world, to control or minimize contagions, and it was seen that some failed, as these were taken under uncertainty and the risk of failure was always present, which shows that risk management can become complex. At this stage[25] emphasizes that it is important to recognize that the procedures applied to risk management are influenced by several aspects, such as political factors and social values. In other words, risk management involves evaluating alternative regulatory actions and selecting strategies to be applied.[47,48]

Risk communication, which can occur at any time during risk analysis, is essential in risk analysis as it improves risk understanding and risk management options. Risk communication occurs in two ways, the internal one where the interaction takes place between managers and evaluators, while the external one occurs between those participating in the internal risk communication and the external interested party.[27]

In the last three years, many authors have been talking about aspects related to epidemiology's due to the fact of the COVID-19 pandemic that the world still is experiencing. In this sense, many distinct studies with different methodologies in this field were produced, many of them with strong impact.

Spatial epidemiology

Spatial Epidemiology receives other names in different literatures, such as Geographical Epidemiology or Medical Geography[41] and, when applied to problems involving small areas, can be divided into three main areas, namely: mapping of diseases, studies of geographic correlation and grouping or groupings of diseases or surveillance.[49] It also intends to localize epidemics in time and space, and in these studies, it includes the verification and analysis of patterns.[50]

Spatial epidemiology can be divided into three main areas, namely disease mapping, geographic correlation studies and the third consisting of cluster studies, disease clusters and surveillance. About the mapping of diseases that is the focus of this thesis will be addressed later and about the other areas of spatial epidemiology, more details are presented by.[49]

Spatial Epidemiology aims to describe spatial patterns, which may be of disease incidence and mortality,[41] identifying disease clusters and explaining or predicting disease risk.[25]

The interest in spatial epidemiology is largely due to the recognition of maps as a useful tool in the observation of epidemics based on the analysis of patterns that they may present depending on their distribution,[41] since the visualization Any information presented is generally easy to understand, and in an epidemiological analysis, health authorities are very interested in mapping the risk of transmission of a disease in each of the regions of a country (whether provinces, cities or districts), in order to determine whether the risk of infection in each of the regions is influenced by others and beyond the geographic representation of this risk in each of the regions.

With epidemiology, risk assessment in spatial analysis studies allows researchers to maintain an active surveillance that is directed towards areas that are at greater risk for the analyzed epidemic, and thus different spatial procedures and management plans are prepared to prevent the occurrence of infections. This way of approaching risk spatially brings many benefits to health authorities, as the scarce resources that may exist are directly applied in these areas, and consequently saving time in decision making.[51] The idea of trying to treat risk assessment spatially is presented by[43] when referring to the existing link between location and the relationships between agents in a system, in the analysis of health phenomena. A recent study introduced in Leal & Morgado[52] presented an empirical analysis method based on regression modelling and hypotheses testing to assess events for the possibility of occurrence of superspreading COVID-19 contagion with geographically heterogeneous impacts.

Statistical modeling in spatial epidemiology introduces the concept of cause-effect relationships from data sources, and these sources can be spatial and non-spatial, to explain or help predict spatial patterns.[25,53]

In a particular case under the aim of COVID-19 pandemic, in Tallon[54] we find a study where a three-way multivariate data analysis is used to compare EU countries' COVID-19 incidence trajectories from May 2020 to February 2021.

Risk measures

Epidemiology pretends to understand the factors that affect the state of health of the human being or even in the sources of risk of

these, being evident that risk is associated with uncertainties. It is important to consider measures that allow to quantify risk, so that it can be compared or classified. The risk measures addressed in this section are all those addressed in epidemiology.

Quantifying any observed difference in the risk of contracting a disease between exposed and unexposed individuals in the study is one of the goals of an epidemiological study, and a common measure of the difference in risk is the relative risk or disease risk ratio in the exposed population at risk for the risk of disease in an unexposed population, where a cohort study allows estimating the attributable risk (the difference in risk) and the relative risk (the multiplicative increase or decrease in risk) associated with exposure, using incidence ratios as risk estimates based on the assumption of rare disease.[41,55] It is also known that the procedure for estimating the Relative Risk (gross or adjusted) using a confidence interval varies depending on how the exposure is defined.[55]

There are several formulas (or measures) applied to quantify risk in epidemiology, some are about relative risk, others about absolute risk (representing the incidence) or attributable risk (representing the proportion of the disease in the population due to or attributed to exposure).[50] Sometimes, some efforts are made are made to the standardization of these measures (called rates in epidemiology, and the procedure is called rate standardization), as this procedure provides a mechanism to adjust summary measures to remove the effect of known risk factors and make them comparable for different populations.[41] Standardized rates applied in epidemiological studies are discussed in detail by[41] and some of them will be discussed in a continuation manuscript.

Relative risk is one of the risk measures of interest in epidemiological studies, because it is useful in comparing individuals with or without a given risk factor[56] and also because it is easier to communicate the results and their estimation.[41] An alternative to relative risk is attributable risk, applied when the relative risk is very large, and it turns out that very few individuals are exposed to the risk factors. Despite these risks, there is another way to compare individuals with or without a given risk factor, which is based on the odds ratio.[56]

Final remarks

In the present manuscript we revisit some background about COVID-19 pandemic in the world. Also is evidenced the relevance of mathematical and statistical modeling, the concepts of risk, risk analysis and spatial epidemiology, through some extense references An introductory briefing on risk measures in epidemiology is performed. In the present work, we deal with risk assessment in epidemiology, we address aspects such as uncertainty and variability, types of risk assessment and its steps, methods, and relevant conditions for the quality of risk assessment. This work results from a study about COVID–19 infection in Mozambique. The data base is not complete, some preliminary models were estimated and some results were obtained but their publication shall be performed in a recent future in a continuation manuscript when the data set can be considered complete. The extension of the present manuscript shall include the considered data, the methodology and the more pro-eminent final results.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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