Critical Evaluation of different Epidemiological Methods used to Study Animal Impact on Public Health

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Abstract

There is a complex association present between public health and animal populations which affects the well-being of humans both directly and indirectly. It is essential to understand these associations and interactions which will help to overcome the risks of zoonotic infections, environmental changes, and other factors affected by animal population. Epidemiological studies are very important in medicine and public health as they provide a way to determine the causes and risk factors associated with a disease. In addition to that, epidemiological studies help to plan, implement, and evaluate an intervention which aims to prevent and control a disease. These epidemiological studies include cross-sectional studies, ecological studies, case-control studies, and cohort studies. The validity and strength of the study designs widely depend upon the execution of the study and the statistical analysis used in it. This chapter aims to critically evaluate different epidemiological study designs, their strengths, limitations, and their statistical analysis which will help the research to use data, interpret it which then used to develop interventions.

Keywords: Epidemiology, Animal, Public health, Cross-sectional study, Ecological study, Case-control study and cohort study

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Introduction

Epidemiology has been described as the study of distribution and determinants of health and health related problems in a defined population, and then application of the outcomes of this study to control the health related issues (Last, 1993). The definition of epidemiology has been divided into portions as distribution which point out the incidence or prevalence of a specific disease or health related issue in a specific time zone. The next portion, determinants refer to the risk factors of a specific disorder, risk factors may be causal or not, these factors apply to find out the individual at risk of getting disease as the time passes. The last portion, application of the study to control and prevent the disease in individuals who do not have disease at that time but may get it in the near future, this is done by the manipulation of the risk factors. All these targets are significantly time dependent. With all the other queries falling under the umbrella of epidemiology, the most significant contribution of epidemiology is the guidance provided by different study designs of epidemiology which help in the prediction and prevention of diseases or disorders, which are also time dependent events. Perhaps, the outcomes of these studies are often false positive (Martyn, 2004; Von Elm & Egger, 2004; Ioannidis, 2005a; Ioannidis, 2005b) besides the fact that the study which was conducted, analysed and designed carefully. The statistical methods used to interpret a study in epidemiology, often distort and ignore time. There are many ways through which epidemiology has been defined in different literatures but the simplest way to describe epidemiology is that it is related to a mass phenomenon of disease (Smith, 2005; Pfeiffer, 2010; Thrusfield, 2013). Epidemiologist (the person or individual who studies epidemiology) studies a disease that occurs in a population, unlike a clinician who examines a disease in single organisms, or a histologist or microbiologist who studies a disease at cell level, or a molecular biologist who focuses on single molecules.

Public health refers to what has been done as a society to provide conditions to confirm the health of the people of the society (Tulchinsky & Varavikova,2014). Besides the fact that health has been described in many ways but World Health Organisation (WHO) defines health as a state of well-being including physical,mental,and spiritual conditions as it is not just the conditions when disease is absent (Grad, 2002). To protect and promote public health, veterinary medicine plays a significant role, a major part played by veterinary medicine is the protection of public health by prevention and control of zoonotic diseases (Taylor et al., 2001; WHO, 2009). As a part of veterinary medicine,epidemiology is a core component to serve public health. Veterinary epidemiology is not just a set of methodologies but it is a field which provides a platform of thinking on broad scientific issues and provides approaches that mainly focus on the health of populations. Epidemiology is not only relevant to research about public health but it also emphasises on the practice of public health. In

the perspective of research, veterinary epidemiology brings a variety of methods and approaches related to study design and sampling methods and rehabilitation (Sargeant, 2008).

Epidemiological Methods

The main purpose of the application of a different epidemiological method is to find out the link between a particular exposure and its specific result or outcome (DiPietro, 2010). Exposure is described as specific lifestyle behaviors, different biological agents, and chemical agents which happen to enhance or decrease the risk (risk factor or protective factor respectively) of the development of a specific result or outcome such as morbidity and mortality (DiPietro, 2010). Outcomes of a particular epidemiology method or study provides the information about different aspects of public health including promotion of health, health policy and health planning. It also provides data about the different aspects of clinical medicine (Bhopal, 2008; Aschengrau & Seage, 2013). So the selection of a method or study for a specific research question depends on a number of factors. There are a number of different study designs available to the researcher which differs from the others in a number of ways. These include outcomes of interest whether it is present or absent and the time of selection of study design (exposure measurement respective to directionality), the number of observations, one or more, the unit of observations (individual or groups, timing of data collection and method used for data collection (Bhopal, 2008; Friis & Sellers, 2020). Including all the above mentioned factors, ethical implications for the population upon which study has to be conducted and availability of the resources, all these factors affect the decision of the investigator while choosing the study design to address the following problem question (Rothman et al., 1998; Friis & Sellers, 2020).

Cross-sectional Study

As a type of observational study, a cross-sectional study can be descriptive or analytical in nature. When a cross-sectional study is descriptive in nature, it focuses on finding out the prevalence of a health condition(s) in a population under study. While as an analytical cross-sectional study, the aim of the study is to determine the relationship between two variables, independent variable (exposure) and dependent variable (outcome) in a population under study. In an analytical cross-sectional study, the data collected in a single point in time for both the independent variable or risk factors (exposures) and dependent variable that are outcomes for example a disease. Traditionally, these kinds of studies are also called a 'snapshot' of a group of individuals (Wang & Cheng, 2020; Pérez-Guerrero et al., 2024). As it is clear that data about both the dependent and independent variables are collected simultaneously, it is not possible to establish a causal relationship but a cross-sectional study rather provides information about association (Wang & Cheng, 2020; Capili, 2021). The study population in cross-sectional study is not selected on the basis of outcomes, the dependent variable. The study population is selected without considering independent variable (exposure) and dependent variable (outcome) status, in cross-sectional studies as it is selected according to the inclusion and exclusion criteria which has been established in the study design. As the study population is assembled, the evaluation of exposure and outcomes is done simultaneously and then classified for the purpose of analysis (Setia, 2016; LeBrun et al., 2020). In cross-sectional study, the measure of association is defined as odds ratio (OR) but the inclusion of prevalent cases in the study changes the odds ratio into prevalence odds ratio (POR) and prevalence ratio (PR) is calculated instead of risk ratio (RR). The mathematical calculations are the same for both the OR and PR, perhaps the interpretation for both PR and OR are different in cross-sectional study (Tamhane et al., 2016; Wang & Cheng, 2020). There is no longitudinal tracking in cross-sectional studies, so these studies are neither retrospective nor prospective in nature (Friis & Sellers, 2020). The measurement of the unit of analysis in cross-sectional studies is done at a single point in time. In contrast to cross-sectional studies, in longitudinal studies, both retrospective and prospective, the group of individuals are monitored continuously over time, and also include measurement of different variables on different occasions. This helps to find out how different variables change with time in the same population samples (Bell, 2021; Kim, 2022). So designating the cross-sectional study as retrospective or prospective is not appropriate as it comes out to state the study as both longitudinal and cross-sectional.

Ecological Study

Ecological studies are the most basic observational studies and are also called correlational studies. This study design seeks for the estimation of association between an outcome and an exposure in different populations (Kelsey et al., 1996; Breslow, 2005; Rothman et al., 2008; Rothman et al., 2024). One example of ecological study design is a study conducted in the United States to find out the relationship between household firearm ownership and the death rates due to firearms in different states during the time 2007-2010 (Fleegler et al., 2013). As the unit of assessment was state not individual so this study falls under the category of ecological studies. Ecological studies are easy to conduct as the data have been collected already and available to use from different valuable sources. The study design is best to use when the differences in exposure of individuals in a group are smaller when calculated than differences in exposure between different groups. This can be understood by the example of intake of a particular food item is less among people of a specific group but it can differ greatly among different groups such as individuals of different countries (Aggarwal & Ranganathan, 2019). Besides the advantages of ecological study design, there are several limitations associated with this study design. One of these limitations is the association between outcome and exposure at group level which at individual level may not be true, this phenomenon is called ecological fallacy (Sedgwick, 2015). Another limitation is that the association may relate to a third factor, which may be related to both exposure and outcome, called confounding. This can be explained as the association between high income and higher cardiovascular mortality rate among various countries may have a link with the higher prevalence rate of obesity. Another factor which may cause error is the migration of individuals between areas with different levels of exposure. Another limitation is the use of different definitions for both exposure and outcome in various populations. The data used in these kinds of studies, usually gathered from large databases which are often created for different purposes, may lead to the introduction of error (Aschengrau & Seage, 2013; Friis, 2017). Another reason which may create errors is the quantification of the number of cases and the total population which is very difficult. The amount of data, if limited, may cause error as it may suggest or hide the relation between exposure and outcome. Overall, ecological studies are cost effective.

Case-control Study

Case-control studies are traditionally retrospective in nature which is attributed to their design and execution (Checkoway et al., 2004; Mehta, 2008; Woodward, 2013). These study designs have been chosen when the outcome or disease has occurred already. In these studies, two groups are made, one group is called cases which include outcome of interest such as a specific disease or complication. The second group called as controls which consist of those not having outcome of interest. These two groups selected and the information about their risk factors or exposures has collected and compared. The information has been l collected from the preexisting records, personal interviews, and patient examinations (Yin, 2009; Tenny et al., 2017). In population-based case-control studies, the subjects of the study captured from a retrospective population. In hospital-based case-control studies, both the case and control are captured from the same hospital. Hospital-based case-control studies are more common as they are convenient to conduct. The example of hospital-based case-control study is the study to find out the association between smoking and lung carcinoma (Kilibarda, 2018). In these type of studies, the only confirmed cases are selected. Other than confirmed cases, those that are homogeneous with respect to severity of the disease are included. New cases (incident cases) are preferred as compared to prevalent cases which include both old and new cases, because incident cases participate actively which save them from the trouble of recall bias. At one point of time, often due to the unavailability of incident cases, researchers add the cases over a period of time but this should not be confused as a follow up study. In case-control study, the inclusion of prevalent cases, may cause survival bias (Kumar et al., 2014). To confirm the comparability, the controls also represent the same population and follow the same criteria of inclusion as the cases do. It is considered that the selection of controls from the same hospital as that of the cases means that they are from the same population but this may differ in various perspectives such as the catchment population for both controls and cases is different. To overcome this bias, it is usually proposed that the controls should be selected from the family and friends of the cases as they generally represent the same population. It is usually not preferred to include blood relatives as it may result in over matching of exposure to different risk factors. Another possible condition which supports selection bias is the control's disease which does not fall under the case definition but has the same risk factors (Ahrens & Pigeot, 2014; Lesko et al., 2022). For instance, in a case-control study to estimate the effect of alcohol on liver cancer, if the controls are selected from the patients from accident and emergency ward, the association strength may be underestimated as the exposure to alcohol is high in the emergency wards. This bias can be reduced significantly if the controls are selected from various diseases instead of a specific disease. In case of rare diseases, to increase the power of study the number of controls per case increases up to three or four as there is not sufficient number of cases present (Fletcher et al., 2012). The case-control studies are best to apply for rare diseases and for those diseases which have longer latent periods. These studies are less expensive and often less time consuming. To find out a quick assessment between exposure and outcome, these studies are best employed. Due to the presence of interviewer and recall biases, the validity of these studies are compromised.

Cohort Study

In modern epidemiology, the cohort refers to a group of people having specific characteristics and these individuals are followed up to check the incidence, mortality, any particular disease, every reason of death, or any other outcome (Merrill, 2024). In cohort study, two or more groups of individuals are studied from exposure to outcome (Rothman et al., 2008). One of the characteristic features of this study design is that it involves the follow up of the subjects over different time periods. In this study, subjects which are exposed or not exposed to a particular factor are examined to evaluate the outcomes accordingly. Rather than cross-sectional studies which involve the determination of prevalence, cohort studies are conducted to find out the incidence, prognosis, and causes. Cohort studies are both retrospective and prospective which can be found out by the status of outcome. If in a cohort study, the outcome has occurred already then it will be retrospective in nature. If the outcome has not occurred already then it will be a prospective cohort study (Euser et al., 2009). The key feature of a prospective cohort study is that at the time of selection of subjects, not a single subject has developed the outcome of interest. On the other hand, a retrospective study is conducted when there are all the subjects with the outcome of interest. A perspective study is considered more viable as compared to retrospective study design because perspective study involves better measurement of the predictor and confounding variables (Vandenbroucke, 2008). It can be said that the information collected from a retrospective study can be helpful to plan a prospective study in future (Hess, 2004). In the perspective of clinical research, cohort studies are only appropriate when there is evidence present to support an association between exposure and outcome with a reasonable time period between the exposure and formation of outcome. To determine the incidence or history of a condition, cohort studies are best to choose. As these studies are longitudinal in nature, it is possible to find out the natural history and progression of a disease (Carlson et al., 2009). This study design helps to determine the incidence rate, relative risk, cumulative incidence, and hazard ratio but causality cannot be explained through this study design (Rothman et al., 2008). However, cohort studies provide evidence about the strength of association present between risk factors and outcomes. To conduct a cohort study there is a need for selection of samples from a population of interest, appropriate sampling method, availability of longitudinal data from the selected subjects and appropriate sample size (Newman, 2003; Selvin, 2004; Bailar & Hoaglin, 2012). The main aim of this study is the comparison of incidence rates.

Challenges to Public Health and Epidemiology

There are real challenges present to public health that need to be addressed in the coming future (Smolinski et al., 2003). One of these challenges is the urbanization and growth of population all around the world. Another implication to public health is the increasing occurrence of diseases like HIV/AIDS in developing countries and obesity in the developed countries globally. The continuous emergence of novel diseases and some of these may cause catastrophic damages to the public health and to the public including medical infrastructure. The increase speed of traveling internationally results into the movement of agent of infectious diseases all around the world in a brief period of time. The increase demand of food supply and the safety of the food is also an enormous implication. Destruction of habitat result into the increase contact of human with new species which ultimately enhance the chances of emergence of new zoonotic infections. Other than that, some challenges to public health include environmental degradation, climate change, microbial adaptation, and disaster, both natural and man-made (Sargeant,

2008). Above mentioned and future challenges to public health are necessary to be met and epidemiologist plays a significant role in it by engaging in research activities and public health practice. There is a need for close integration of individuals, public health practice and research methods at the interface of humans and animals. There is also a need of integration of research methodologies among different disciplines across the public health communities. The role of epidemiologist is mainly contained in the field of biology but the problems we face are complex as they involve social, environmental and economic systems (King, 2004).

Conclusion

Veterinary epidemiology is a main discipline of public health not only because of the different types of the methodologies it contains but also due to the main focus of this discipline on population health. Epidemiology contributes to not only research areas but also plays an important role in the practice of public health. The exclusive contribution of this discipline in both research and public health, enhances the opportunity of integration between animal and human health communities which will help to meet the future challenges to public health. The traditional methodologies of epidemiology including cross-sectional study, ecological study, case-control study and cohort study are fundamental to this discipline which help to address different problems related to public health and indispensable in explaining the complexities of interactions between humans and animals. While all these studies have their own benefits and limitations, the integration of different approaches will provide a better comprehensive approach to explain the complex relationship between animal and public health.

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