Measures of health and association, and epidemiologic transition—fundamental concepts for veterinary public health specialists

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Abstract

Disease does not occur randomly. There are always epidemiologic patterns that are related to the individuals at risk, the place at which risk is highest, and the time during which acquiring the disease is of the highest risk. Epidemiologic transition describes the transition of population distributions as it relates to shifting mortality, fertility, life expectancy, and the changing causes of death as time goes by. Prevalence measures the proportion of diseased individuals relative to the population at risk at a specified point or period of time, meanwhile, incidence only considers new or incident cases and thus the development of disease during the study is observable. Odds ratio (OR), as the name implies, compares the odds of exposure to the factor between diseased and non-diseased persons. Risk ratio or relative risks (RR) compares the probability of disease development between the exposed and non-exposed groups. Population attributable risk (PAR) is a measure of exposure effect that is specifically used to quantify the risk of disease in a population that is attributable to the suspected risk factor, while population attributable fraction (PAF), which is the proportion of sick individuals in the population that is due to exposure to the factor. Quality-adjusted life years (QALY) and disability-adjusted life years (DALY) are population health measures that aim to quantify the effect of disease morbidity and mortality within a single number. The objective of the paper is to introduce novice veterinary public health researchers to these fundamental epidemiological concepts.

Keywords: Veterinary Public Health; Epidemiology; One Health

Introduction

This paper will feature some basic concepts in epidemiology that are important in health research. These include how factors related to people, temporal and geospatial characteristics influence health outcomes. Also, a short sojourn on epidemiologic transition and basic epidemiological measurements are subsumed herein. Specifically, the principles, uses, and limitations of prevalence, incidence, QALY and DALY as measures of health were included. Likewise, odds ratios, risk ratios, and population attributable risk and fraction are discussed as fundamental measures of epidemiological associations are discussed herein. The objective of the paper is to introduce novice veterinary public health researchers to these fundamental epidemiological concepts.

Person, time & place in epidemiology

Health phenomena do not occur randomly. There is always an epidemiologic pattern that one can follow to decipher the origin, distribution, and outcome of a disease within a certain population. Among these patterns are those that are related to the individuals at risk, the place at which risk is highest, and the time during which acquiring the disease is of the highest risk (see Fig 1). First, there are characteristics that predispose certain demographics of people to positive and negative health outcomes. For example, people who are known to have comorbidities (e.g., hypertension) were reportedly more likely to have unfavorable outcomes upon COVID-19 infection when compared to healthy populations. One known mechanism for this is that people who take anti-hypertensive medications (i.e., ACE inhibitors & blockers) tend to have more ACE-2 receptors which are also the target receptor of the virus—making patients more susceptible to infections and severe outcomes (Hippisley-Cox et al., 2020). Likewise, financial status, access to clean water and the capability to practice proper hygiene and sanitation also affect health outcomes. This is especially true in the perspective of Neglected Tropical Diseases which is quite prevalent in people from mid-to-low-income countries with inadequate health care and WASH infrastructure (Freeman et al., 2013). What the aforementioned examples show is that the characteristics and predispositions of the population at risk influence their health outcomes (i.e., who is more likely to get sick and what disease is most likely to affect them).

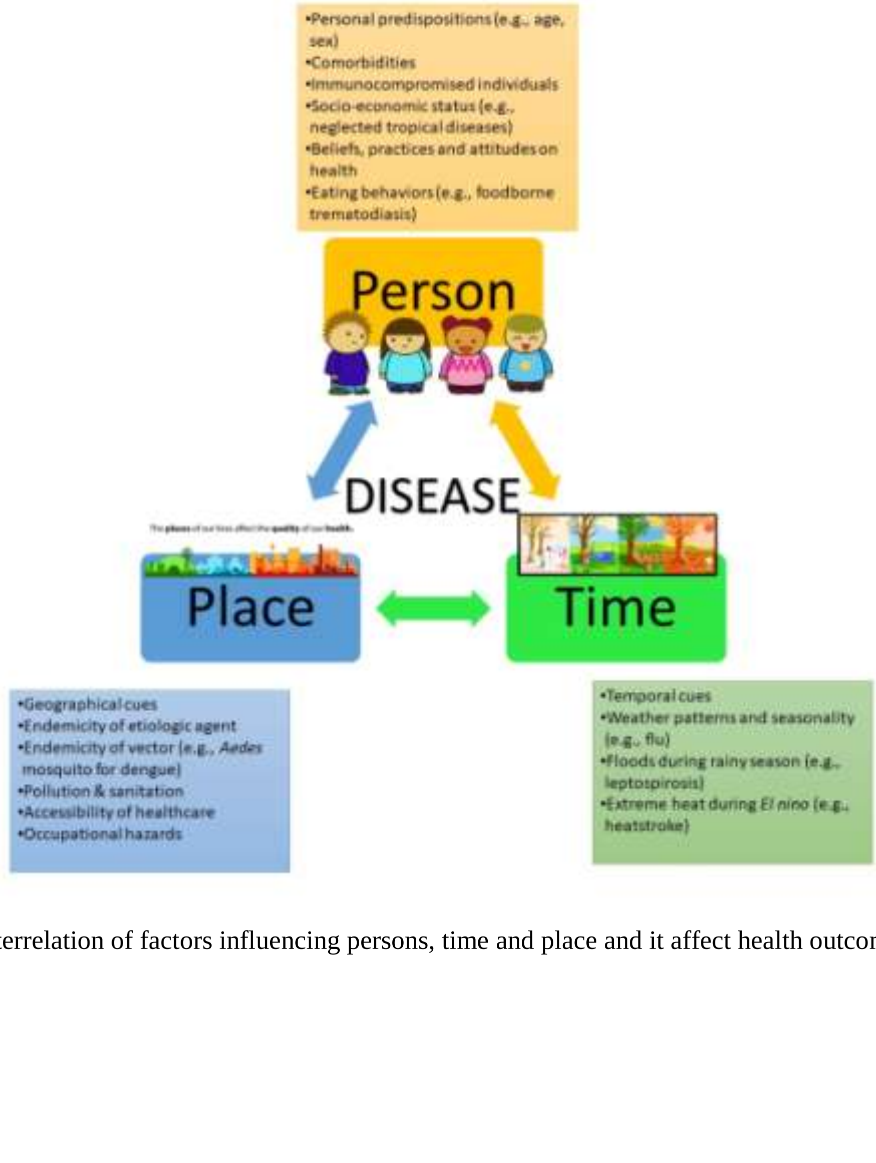

Fig 1. The interrelation of factors influencing persons, time and place and it affect health outcomes.

Second, the geographical distribution of a certain disease can be associated with certain environmental characteristics of the places where it is known to occur. For instance, *Opisthorchis viverrini* is quite prevalent in Thailand, Laos, and other parts of continental Asia but it does not seem to be a big problem in the Philippines (Perakanya et al., 2022 & 2023; Belizario et al., 2022). Presumably, this is due to the fact the *Bithynia* snails that are known to host the parasite are not known to be widely dispersed in the Philippines, perhaps due to unfavorable environments (Vasallo Jr. et al., 2015). Consequently, *Oncomelania hupensis,* which is the host of *Schistosoma japonicum,* is not known to be widely distributed in Thailand which could be the reason why Asian schistosomiasis is not endemic in the country (Wattanawong et al., 2021; Tenorio and Molina, 2021a & 2021b). With the threat of global warming, we are now seeing spread of the tropical diseases in temperate zones. It was noted that the increase in temperature and humidity in Europe has led to the establishment of *Aedes albopictus* and *A. aegypti* in the eastern portions of the continent and the rising number of imported dengue cases due to human migration has resulted in the increasing number of autochthonous cases in the continent (Ahmed et al., 2020; Kulkarni et al., 2022). For instance, 217 dengue cases occurred in France and 65 of these were reportedly autochthonous; surveillance reports seem to point to increase in geographical extension and in incident cases (Cochet et al., 2022). Fig 2 depicts the 2019 Global Burden of Disease on Dengue around the world and in France. The country had a dengue DALY of 0.0038 per 100 000 people (GBD, 2019), which is one of the highest in Europe. These examples show that environmental attributes affect the biology and transmission dynamics of etiologic agents, and therefore dictate where these diseases are likely to occur (Tenorio 2022a).

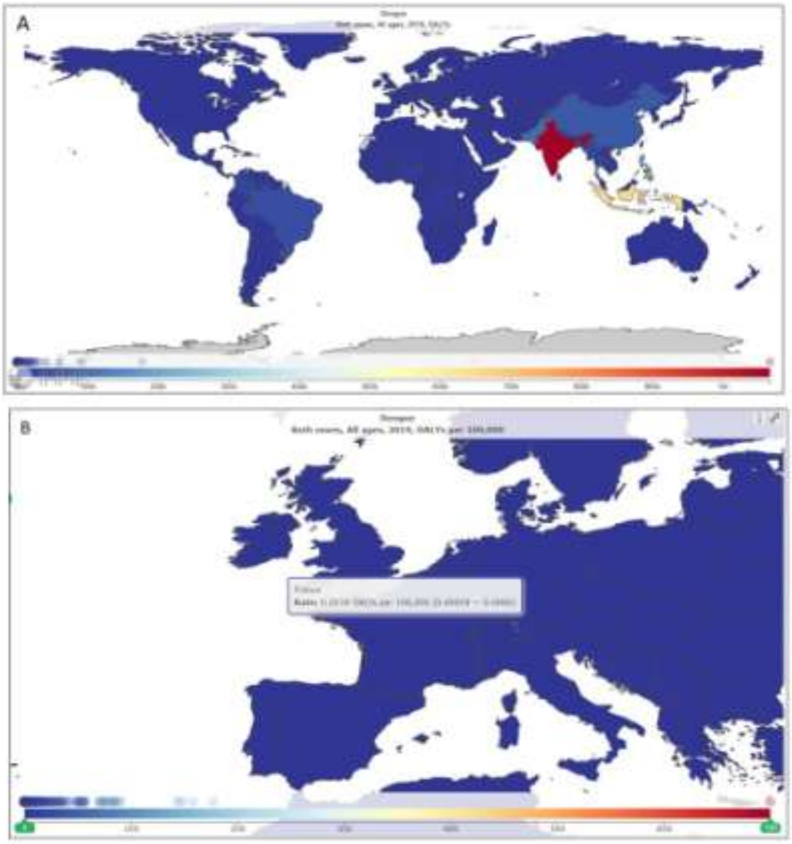

Fig 2. The geographical distribution of dengue, as reported and generated through the website of the Institute for Health and Metrics Evaluation of the University of Washington (https://vizhub.healthdata.org/gbd-compare). A: Global burden of dengue. B: Burden of dengue in France highlighting the country's DALY.

Lastly, temporal patterns of health phenomenon are also affected by several factors, which can also be linked to personal and environmental characteristics. In the Philippines, there are several *fiestas* or festivals that are celebrated to commemorate religious or national events. And during these times, bouts of food-borne disease outbreaks are often due to the Filipino tradition of having community potlucks during such festivities (Azanza et al., 2019; Roca et al., 2019). Another example is the seasonality of certain vector-borne diseases. Epidemics of dengue in the Asia-pacific region have been observed to likely occur during hotter months right after the monsoon season due to its conducive effect on the development of the vectors (Du et al., 2021; Hossain et al., 2022). The examples exemplify those temporal qualities that influence persons (e.g., people's behavior during festivities) and place (e.g., environmental cues) also affect when and how often diseases will occur. Indeed, the patterns of certain health phenomena can be followed or even predicted by looking into the characteristics of the population at risk, and the disease's geographical and temporal qualities.

Epidemiologic transition and its effects on health outcomes

Epidemiologic transition, as Omran (1971) puts it, describes the transition of population distributions as it relates to shifting mortality, fertility, life expectancy, and the changing causes of death as time goes by. The theory relies on 2 major premises: 1. population composition is changing (e.g., higher life expectancy, lower birth rate, population is dominated by the young as seen in India or old as seen in Japan) (Inoue et al., 2022; Liu and McKibbin, 2022); and 2. mortality patterns have been altered as a consequence of shifting demographics and sociologic determinants (e.g., a country's increasing or decreasing income status) (McKweon, 2009). In the original paper, there are three transitions that were described. First, the "age of pestilence and famine" was the phase that described how humans transitioned from hunter-gatherers to an agrarian society. This transition required people to settle into areas wherein they can cultivate the land and commune with domesticated and anthropophilic animals (e.g., livestock and rats). The close associations with animals during this period have been theorized to cause the rise of historical disease outbreaks that have killed numerous people (e.g., rat flea-vectored plague and smallpox) (Siuda and Sunde, 2021). This period of rapid population decline and death ushered an increase of birth rates, which in turn facilitated the second transition during the "age of receding pandemics." This period was hypothesized to have occurred during the early modern era wherein several things occurred: an increase in life expectancy, diseases becoming more curable through the advent of better treatments, and socioeconomic improvements causing better health outcomes (McKweon, 2009). The overall health status of individuals has benefitted from the advancement of medicine, economies, and society. Hence, it allowed infants and children to have better survival rates and people to grow older. The uplifted societies that the early modern era gave birth to have led to the third epidemiologic transition, the "age of degenerative and man-made diseases." This period corresponds to the late 19^{th} and 20^{th} centuries in developed countries (McKweon, 2009). This era is characterized by the decline in deaths due to infectious diseases and the rise of non-communicable diseases that resulted from lifestyle changes that coincided with societal developments during this period (Alberti, 2001). As economies boomed, food became more accessible and available to those who can afford it and people who do not need to do much to earn a living became sedentary. Thus, the rise of hypertension, cardiovascular diseases, diabetes mellitus, and other metabolic diseases occurred (Hambleton et al., 2023). It is believed that society is currently still in this period. As demonstrated by the aforementioned examples, epidemiologic transitions affect population health outcomes in a number of complex ways. Changes in population demographics, socio-economic status, and improvement in medical knowledge impact how and what type of diseases are dispersed in a population. Moreover, the changing outlook and behavior of people within such populations also impact health outcomes. Certainly, the status of society mirrors what type of health phenomenon occurs and how it spreads.

Some measures of health in epidemiology

There are several methods of measuring the occurrence of disease in a population and all of them have some advantages and disadvantages. The two most common ways of measuring disease distribution are prevalence and incidence. Prevalence, on one hand, measures the proportion of diseased individuals relative to the population at risk at a specified point or period of time. It is a good way to gauge the magnitude of disease in a population because both new and old cases are counted (see Figure 3). Moreover, it can tell the probability of being diseased of any individual in the population at the time of sampling. For instance, if the prevalence of schistosomiasis in a community last year was 20%, then every single individual that was inside the community during that period had a 20% probability of being infected. A disadvantage of prevalence is that it is of low value in predicting the probability of acquiring disease because both new and old cases are considered. Incidence overcomes this feature. Incidence is similar to prevalence, but it only considers new or incident cases and thus the development of disease during the study is observable. Therefore, people counted as cases must have been guaranteed to be disease-free prior to data collection or observation. To put it simply, they must be new cases. Incidence is better at estimating risk (i.e., probability of getting sick) because of this characteristic (Tenorio, 2022b). Considering the example above, if the schistosomiasis incidence is 20%, all persons present inside the community last year will have a 20% likelihood of getting the parasitic infection. It is important to remember that incidence is not a good estimator of disease burden since it overlooks pre-existing cases. The speed at which infections are spreading can be inferred through incidence but it is not as good at estimating the true amount of diseased people as prevalence, and vice versa.

Some measures of association in epidemiology

Odds ratio and relative risk are the most commonly used method of quantifying the strength of associations between suspected risk factors and outcomes. Odds ratio, as the name implies, compares the odds of exposure to the factor between diseased and non-diseased persons (see Fig 3). Since it is usually employed in case-control and analytical cross-sectional studies, data on the outcome and exposure are gathered at the same time. Hence, the odds and not risks are used. This is the main disadvantage of odds ratio as a measure of association. The quantified association is weaker by default because the development of disease following exposure is not observed. However, it is quite advantageous if utilized in studying risk factors of rare diseases that have long incubation periods—no need to wait for the disease to occur. Risk ratio or relative risks compares the incidence or risk of disease in exposed versus non-exposed groups (see Fig 3). Therefore, it compares the probability of disease development between the two groups. Because of this quality, relative risk is a better gauge of association. The temporal relationship that exposure must precede the outcome can be ascertained, like in a cohort study design. The advantages and disadvantages of both are better understood when interpreting their results. An odds ratio of 5 means that diseased people were 5 times more likely to be exposed to the factor compared to their healthy counterparts. Meanwhile, a relative risk of 5 tells us that the exposed people were 5 times more likely to develop disease compared to those who were not. Relative risk is more advantageous if the goal of the study is to measure the strength of associations. However, the study design that can use it (i.e., cohort study) is labor-intensive, time-consuming, and expensive. Meanwhile, study designs that employ odds ratio (i.e., case-control & cross-sectional) are relatively easier to conduct but the resulting strength of association measured is of weaker evidential value because temporality cannot be guaranteed.

Population attributable risk (PAR) is a measure of exposure effect that is specifically used to quantify the risk of disease in a population that is attributable to the suspected risk factor. It provides the amount of additional risk in the population that is due to exposure to the factor. It should not be confused with population attributable fraction (PAF), which is the proportion of sick individuals in the population that is due to exposure to the factor. PAF gives the fraction of the population that can be spared from disease if exposure is removed or modified. In assessing associations, if the PAR is high, it simply means that exposure to the factor increases the risk of disease in the population. It is advantageous in studies because it quantifies the amount of risk that exposure to the factor can give, and it provides insights on the magnitude of risk reduction if exposure to the factor is removed. A disadvantage of PAR is that it is not that useful or as easy to interpret when compared to PAF. For instance, PAF was used to measure the association between the proposed risk factors and lower respiratory infections for easy understanding among common folks and policymakers (Kyu et al. 2022).

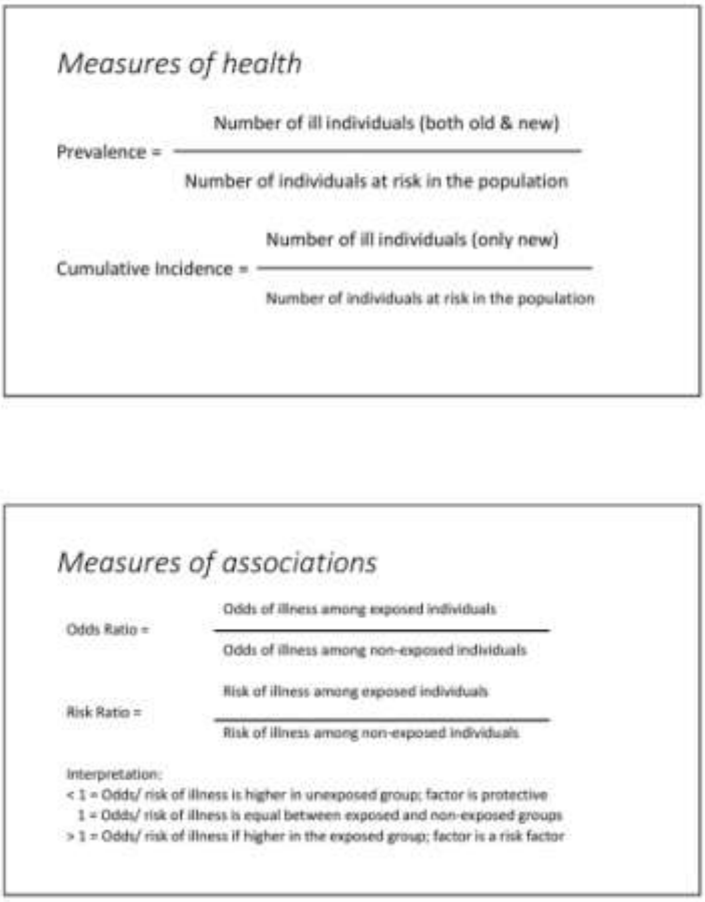

Fig 3. Formulae and interpretation of measures of health and association.

QALYS and DALYS

Quality-adjusted life years (QALY) and disability-adjusted life years (DALY) are population health measures that aim to quantify the effect of disease morbidity and mortality within a single number (Gold et al., 2002). On one hand, QALY aims to quantify how "good" and how long diseased people live. It does not have much advantage other than having a quantified value of how well people have lived despite their disease. Moreover, there are issues regarding QALY because what constitutes a "good" life varies subjectively and the quality life index used to calculate it may not reflect the real-life situation of diseased individuals (Gold et al., 2002). On the other, DALY measures the "bad" side of being diseased. It aims to quantify the amount of time lost due to a particular disease within populations while taking into consideration the years of life lost due to disability (YLD), and years of life lost due to mortality (YLL). When compared to QALY, DALY is more objective because it utilizes population mortality and morbidity data, life expectancy, and period of morbidity in its calculation. A disadvantage is that there are varying methods of calculating the disability weight factor for each disease (Charalampous et al., 2022). Personally, the author prefers DALY because it commands more attention, and it provides more information regarding the burden of disease and how many years are lost due to becoming sick of or dying from specific diseases.

Conclusion and recommendations

This brief article highlights the proper use of measures of health, measures of associations, and sheds some light on epidemiologic transition. Among the commonly used measures of health, the proper uses, interpretation, and differences between prevalence and incidence should be noted. Both do not merely represent percentages but rather should also be interpreted as probabilities. Similarly, the differences between odds ratio and risk ratio should also be highlighted. The former uses odds as an estimate of risk, while the latter ratios quantified risk through incidence. Lastly, it must be underscored that the changes in the diseases that deleteriously affect society (e.g., rise of non-communicable diseases) may be reflected by the development of humanity as a species, as described in epidemiologic transition and the factors that describe human, temporal cues, and the geospatial factors that affect their lives. The author hopes that these concepts are introduced to novice public health veterinarians and that they may find these information useful in their practice and research.

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