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Health Indicators Related to Disease, Death, and Reproduction

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One of the primary goals of epidemiology is to quantify various aspects of a population's health, illness, and death status and the determinants (or risk factors) thereof by calculating health indicators that measure the magnitudes of various conditions. There has been some confusion regarding health indicators, with discrepancies in usage among organizations such as the World Health Organization the, Centers for Disease Control and Prevention (CDC), and the CDC of other countries, and the usage of the relevant terminology may vary across papers. Therefore, in this review, we would like to propose appropriate terminological definitions for health indicators based on the most commonly used meanings and/or the terms used by official agencies, in order to bring clarity to this area of confusion. We have used appropriate examples to make each health indicator easy for the reader to understand. We have included practical exercises for some health indicators to help readers understand the underlying concepts.

Key words: Epidemiology, Health indicators, Terminology, Concept

INTRODUCTION

For the foremost task of epidemiology—describing the distribution of health outcomes and their risk factors—quantitative indicators are required. A simple example of an indicator

may be information on the number of subjects with a specific condition, but indicators can also include the size of the total population analyzed in a study or the period over which the data were collected, thereby providing additional information. These indicators can be used to estimate the causality of disease onset and mortality, with implications for the planning of public health projects and priority-setting for resource allocation.

There has been some confusion regarding health indicators, with discrepancies in usage among organizations such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and the CDC in other countries, and the usage of the relevant terminology may vary across papers. Therefore, it is necessary to summarize these health indicators to provide a unified framework for these numerous terms and

concepts. Since most of the variables used in epidemiological studies are nominal variables with two categories, such as survival versus death, case versus control, and exposure versus non-exposure, these variables are incorporated into health indicators in the form of ratios, proportions, and rates. However, these summary measures (ratios, proportions, and rates) and the terminology used to describe health indicators often do not coincide, resulting in confusion. Therefore, in this review, terms that are often confused with each other are grouped together and the corresponding health indicators are summarized, with a focus on the most commonly used terms and those used by official agencies. In addition, appropriate examples of calculations and graphs are attached as concrete and simple illustrations of how each health indicator can be applied.

Ratios, Proportions, and Rates

A ratio is a measure that is presented in the form of x/y or y/x to compare two quantitative figures, and is a measure that provides a sense of the relative magnitude of two characteristics or events in a group. Some frequently used ratios in epidemiology include the sex ratio, stillbirth rate, relative risk, and odds ratio.

A proportion is a type of ratio in which the numerator is included in the denominator, such as $x/(x+y)$. Proportions are frequently used to calculate risk, which refers to the frequency of a characteristic or the probability of having a characteristic. Frequently used examples of proportions include percent values (%), followed by point prevalence, period prevalence, the case-fatality rate, and attributable risk [1].

A rate is a measure of the frequency of new events occurring in a population over a specific period of time, with a range from zero to infinity. Because a rate inherently shows a relationship over time, it must present average attributes per unit of time. For example, if each object in different groups has a different observation time and a different frequency of events over time, a very different value would be produced depending on when the occurrence of the event of interest is calculated. This problem can be solved by introducing the concept of the mean, which describes the average frequency of an event per unit time. From a mathematical perspective, rate can be understood as frequency per unit of time. An intuitive example is the heart rate, which refers to the number of heart beats per minute. A frequently used rate in epidemiology is frequency per unit of person-time, in which the denominator includes a measure of population. Frequently encountered examples of rates include incidence density, the crude death rate, and age- and sex-specific death rates [2,3].

Morbidity Indicators

A morbidity indicator is a value describing the presence of disease in the population, or the degree of risk of an event. The incidence rate, prevalence, and attack rate (AR) are common applications of this concept in epidemiology.

Prevalence is the measurement of the proportion of the population that has a specific illness at a specific time. It can be understood as the estimated probability of having the illness at a point or period of time, which correspond to point prevalence and period prevalence, respectively.

Point prevalence can be measured as the number of cases of a certain condition in the entire population at a point in time; that is, those who already have the disease at that time and those who have been newly observed at that time (Table S1). This indicator presents the prevalent status of a condition within a population. Point prevalence can be estimated by even a single survey, and by repeating point prevalence estimates over time, researchers can come to understand trends in how the distribution of the illness is changing in the population. Point prevalence can also be used to determine whether changes are occurring in critical indicators, such as the proportion of awareness, treatment, and control of hypertension in a population.

Period prevalence can be understood as the proportion of individuals with a certain condition at any time during a specified time period or interval (Table S1). In this case, the numerator includes both existing cases at the beginning of the period and new cases detected during the period [1]. The denominator can be the average number of persons in the population at the beginning and the end of the specific period, or it can be the number of persons in the population in the middle of the period (i.e., if the period is defined as from January 1 to December 31 of a given year, the number of persons in the population on July 1). An example of period prevalence is lifetime prevalence, which indicates the proportion of individuals who ever experience a condition during their lifetime. Lifetime prevalence is useful when a condition can recur, making it difficult to evaluate its point prevalence. A remarkable limitation of prevalence is that individuals with a shorter duration of illness are less likely to be detected in a prevalence survey than those with a longer duration of illness. The interpretation of survey results can vary based on this consideration. For exam-

ple, when a screening program is conducted over time, both prevalent and incident cases are detected at the first survey point, whereas only incident cases are detected subsequently.

The incidence rate represents the 'proportion' of people who newly develop a disease within the subset of a given population without that disease at the beginning of the observation period (Table S1). It can be also interpreted as incidence proportion or incidence risk [1]. Its denominator is composed of the at-risk population during the specified period, or the disease-free individuals at the beginning of the period. Newly occurring cases among those people are defined as the numerator. For the cumulative incidence rate, it is assumed that subjects are observed continuously from the beginning to the end of the period, which is why the period needs to be specified clearly [1,4] (Table S2).

The observation period for each individual can vary, because monitoring of each subject is completed at different times due to loss of contact or death from a cause other than the disease studied, even if monitoring is started at the same time. When we calculate the person-time incidence rate, or incidence density, the numerator is as the same as that of the cumulative incidence rate, while the denominator is the sum of the entire observational time of all study participants, which indicates person-time [1] (Table S1). The units of person-time vary depending on the disease being studied. For example, person-years are used for chronic diseases such as cardiovascular disease and cancer, while person-days are used for acute pediatric infectious diseases, such as diarrhea and measles [5].

The person-time incidence rate can show how frequently cases occur. Compared to the cumulative incidence rate, the person-time incidence rate can include all study participants, regardless of the time that each individual is monitored or whether participants are censored due to mortality from another disease [1].

The concept of person-time is not intuitive for the general public to understand at a glance. Therefore, for example, if the incidence rate is 2 people per 1000 person-years, an epidemiologist can say "2 cases per 1000 people in a year on average," which is easier to understand [1] (Figures S1 and S2, and Table S2) .

The AR refers to the proportion of incident cases of a disease that occur during a given period (of an epidemic) among the population that has been exposed to the source of the disease, becoming 'at-risk.' Because its time dimension of observation is uncertain or defined insufficiently, and the concept

of time is not included in the denominator, this indicator cannot be interpreted as a true rate, despite its name [6].

In circumstances such as cases of a food-borne disease, in which patients experience a short and single common exposure to the disease source that can be investigated, this can be calculated as risk in a specific period [1]. However, when calculating the AR of an entire country, we use the entire population as the denominator because it is impossible to count the 'at-risk' population; this yields the overall AR (Table S1). In such cases, this proportion can be interpreted as the 'attack ratio' [1]. During an outbreak period, if the at-risk population that has been exposed to the source of the disease can be clearly defined, we can monitor them as members of a cohort, in which the primary AR can be calculated by using incident cases as the numerator. For infectious diseases, because the outbreak period is generally comparably short and the concept of quantitative risk can be utilized, the AR (from the entire outbreak period) is preferred over the person-year incidence rate. In such circumstances, the AR is presented as a percent (attack number per 100). When the AR is below 1%, the AR per 1000 persons can be presented instead. The outbreak period of specific diseases can vary from days or weeks to years. For food-borne diseases, the outbreak AR (%) can be used to illustrate the concept of risk, usually because of the obvious disease source and a clearly definable at-risk population [1]. The AR is a useful indicator for managing resources necessary to provide medical services and to produce antibacterial and antiviral medications [7]. The secondary AR is a proportion that is calculated as the number of new cases developed during the maximum incubation period of the pathogen among susceptible household members who were in contact with the primary cases [1] (Table S1). This indicator is useful for evaluating the infectivity or communicability of an infectious pathogen in an indirect way. This can be also estimated through many other types of epidemiologic studies and modeling, by considering the correlation between the source of an infection and susceptibility to it. In this manner, the secondary AR can be used to characterize the infectivity of an unknown infectious disease or the effectiveness of chemoprevention [1,6] (Tables S2 and S3).

MEASUREMENTS OF DEATH

Death Rate Indicators

The mortality rate is a measure of the frequency of deaths in a defined population over a certain period of time. The de-

nominator used to calculate mortality is, theoretically, the average number of the population over a period of time. However, in reality, the central population for a given period is generally used, because it is not possible to count the number of people in the population at each time point.

The crude death rate is an estimate of the portion of a population that dies due to any cause during a specified period. It is presented as the proportion of deaths per 100 000 (or per 1000) people in a given period of time. The cause-specific death rate can be interpreted as the number of people in a population who die due to a specific cause per 100 000 population (Table S1).

The specific death rate uses a sub-population as its denominator, instead of the entire population. It can be calculated as the death rate of a defined population with specific characteristics (Table S1). The age-specific death rate, for example, is the death rate of a specific age group, which is calculated as the number of deaths per 100 000 people within that age group. This can be applied to different kinds of sub-populations, suggesting priorities for health policies for each subgroup.

The crude and cause-specific death rates can be combined to observe differences in risk according to the characteristics of a sub-population. Table S1 presents an example using the death rate due to breast cancer in women aged 30-44.

Disease Severity Indicators

The case-fatality rate is the proportion of deaths among patients with a specific disease (Table S1). This can be interpreted as the conditional probability for death among new cases of a specific disease [1,4]. The concept of 'case-fatality risk' is more logical, despite the wide usage of the older term of case-fatality rate. This indicator can be used to report the risk of death from specific diseases and to indirectly estimate the development of treatment methods.

When it is impossible to observe patients with a specific disease and to monitor their mortality, basic population records can be used as an alternative method to infer another indicator of disease fatality, the death-to-case ratio. It is calculated in the whole population as the number of deaths due to a specific disease in a specific period divided by the number of new cases of the same disease in the same period [1] (Tables S1, S2, and S4).

Proportional Mortality

Proportional mortality, or proportionate mortality (PM), is the proportion of deaths due to a specific cause out of all
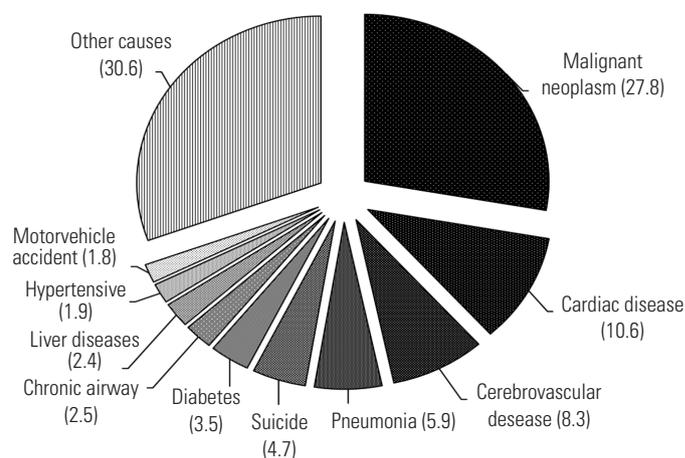

Figure 1. The 10 major causes of death in Korea, 2016 with proportionate mortality values (%) [8].

deaths (Table S1), which indicates the degree to which that specific cause of death contributes to total mortality [1,5].

Figure 1 shows the 10 major causes of death in Korea in 2016 with PM values (%) [8]. Changes in PM over time indicate time trends in changes in causes of death. However, these indicators cannot indicate the mortality risk, since the denominator, unlike that of the cause-specific death rate, does not contain the entire population. PM is affected by the crude death rate and it cannot be used to compare specific mortality risks [9,10].

The PM ratio (or rate) (PMR) is the ratio of two PMs from specific populations (Table S1). If a PM is derived from the standard population, the PMR is expressed as the ratio of the expected PM to the observed PM [5].

The PMR was developed to observe whether specific factors are related to mortality in circumstances with limited data, such as number of population or number of exposed or non-exposed people.

To better understand the PMR, here is an example. A study is conducted to examine the hypothesis that full-time truck drivers have a higher mortality rate due to occupational hazards (shift work, long-term driving and its fatigue, high level of noise, metal hum, carbon monoxide, high levels of stress during work, etc.). If the cardiovascular PM of the drivers is larger (with statistical significance) than that of people in the general population or with a different occupation (PMR >100, lower bound of the 95% confidence interval >100) we can suspect that those risk factors would be related to their increased cardiovascular mortality risk [11].

Specialized Forms of the Age-specific Death Rate

Specialized forms of the age-specific death rate are the infant mortality rate, neonatal mortality rate, perinatal mortality rate, and maternal mortality ratio. All of these are technically ratios.

The infant mortality rate is defined as the ratio of deaths of infants less than 1 year old out of 1000 births in a specific period (Table S1). Ideally, the denominator of infant mortality rate should contain information from a birth cohort, but it is very difficult to build such a cohort for the entire population. The infant mortality rate is usually calculated annually, with the denominator being the number of births and infant deaths in that year. In fact, since infancy is an event after birth, this may seem like a rate. However, if we look at the numerator carefully, we can observe that it contains the deaths of infants who were born either in a specified year or in the previous year. Therefore, this indicator is a ratio, not a rate. The infant mortality rate is strongly influenced by external factors such as infections, nutrition, maternal care, and postpartum care, and therefore it is widely used as a tool to compare health services between countries [12].

In Korea, the infant mortality rate in 2015 was 2.7 per 1000 births, and 56.7% of these deaths occurred in the neonatal period (before 28 completed days). The most common causes of death were dyspnea and congenital heart diseases, accounting for 25.5% of all deaths. Infancy is divided into the neonatal period (under 28 days) and the postneonatal period (between 28 days-1 year). Sometimes the neonatal period is further subdivided to distinguish the early neonatal period (first 7 days of life) [13].

The neonatal mortality rate is defined as neonatal deaths at less than 28 days per 1000 births within the same period (Table S1). Because the common causes of death in infancy are disorders during pregnancy and genetic disorders, is it very difficult to reduce the deaths within this period beyond a certain level. If infants die solely due to these non-preventable causes, it is safe to say that the level of healthcare in a society is remarkably high. The alpha-index is calculated as the ratio between the infant mortality rate and the neonatal mortality rate (Table S1), and convergence of the alpha-index to 1 is considered to be a positive indicator of the status of healthcare within a certain community or country.

The perinatal mortality rate is the ratio between perinatal deaths and total births within the perinatal period in a specified year (Table S1). As a health indicator, the perinatal mortal-ity rate is calculated according to the WHO's definition of the perinatal period [14,15]. The WHO defines the perinatal period as extending from the completion of gestational week 22 to the completion of 7 days after birth. If parents are not sure about the gestational week, deaths of a fetus weighing 500 g or more are classified as occurring in the perinatal period [15,16]. Care must be taken when interpreting examples of the perinatal period because different organizations might use different definitions. The numerator is 'fetal deaths from the completion of gestational week 22 plus neonatal deaths from days 0 to 7 after birth' and the denominator is 'fetal deaths from the completion of gestational week 22 plus live births in a year.'

The maternal mortality ratio is used to evaluate the maternal mortality rate in the past. It is calculated as the number of maternal deaths during pregnancy, birth, and after birth out of 100 000 births in given period (Table S1), and it is technically a ratio. The denominator of the maternal mortality ratio should be every woman who become pregnant in a given year, but it is realistically impossible to find that exact number, so the number of births is usually used as a substitute [17]. The maternal mortality ratio is lower than the infant mortality rate, and therefore it uses a multiplier of 100 000 [18].

Reproductive Indicators

The birth rate is an indicator used in maternal health care. More specifically, this concept is analyzed in terms of the crude birth rate, general birth rate, age-standardized birth rate, and total fertility rate. These are all technically ratios.

The birth rate is a health indicator which can be used to assess maternal and fetal healthcare. The crude birth rate represents the birth count out of 1000 within a single population, and it is technically a ratio (Table S1). The crude birth rate represents the frequency of births, which reflects the structure of the entire population. It is the easiest indicator of fertility to calculate, but it yields unsatisfying results because it represents the entire population, not the fertile population [19].

The general fertility rate is a ratio that represents the number of births among 1000 reproductive-age women aged between 15 and 49 (Table S1). Its denominator is reproductive-age women, making it a more useful indicator than the crude birth rate. However, when using the general fertility rate, there is a high chance that the definition of reproductive-age women might differ across countries, so care should be taken when

comparing reported general fertility rates. For example, in Korea and many other countries, reproductive-age women are defined as those aged between 15 and 49, but in the United States, the corresponding age range is 15-44, and other countries use an age range of 20-44 [14,20,21]. The age-specific fertility rate is a ratio that represents births among 1000 women of a specific age group within a measurement year (Table S1). Women's fertility varies by age; therefore, age-specific fertility increases rapidly at around age 15, peaks in the late 20s, and gradually decreases thereafter, reaching zero at around age 50 [22]. The total fertility rate refers to the average expected number of births for a reproductive-age woman during her lifetime, and it is calculated by adding the birth rate of each age (Table S1). Because the total fertility rate is an indicator that reflects differences in fertility among women according to their age, it is the most sensitive birth rate indicator, and therefore it is used to compare fertility across countries. Higher total fertility rates mean that an average woman bears more children during her lifetime [14].

CONCLUSION

As researchers, we have had the experience of studying healthcare indicators that are commonly used by various national organizations, only to encounter confusion in the use of some of these relevant terminology. As described in this paper, healthcare indicators were developed in order to deliver more accurate information about subjects with specific characteristics, and they therefore contain information on the population size and the period of data collection. As the age structure of the population continues to change, which has led to increased concerns about public health in recent years, healthcare indicators can provide the objective, important, and quantitative evidence needed to evaluate time-series changes, regional differences, and group differences. Therefore, it is necessary to use the most accurate healthcare indicators in a proper manner, based on a clear conceptual understanding of the information that they convey.

SUPPLEMENTARY MATERIALS

Supplementary Materials are available at https://www.jpmph.org/.

CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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REFERENCES

1. Centers for Disease Control and Prevention. Principles of epidemiology in public health practice: an introduction to applied epidemiology and biostatistics [cited 2018 Oct 24]. Available from: https://www.cdc.gov/ophss/csels/dsepd/ss1978/ss1978.pdf.

2. Elandt-Johnson RC. Definition of rates: some remarks on their use and misuse. Am J Epidemiol 1975;102(4):267-271.

3. Vandenbroucke JP. On the rediscovery of a distinction. Am J Epidemiol 1985;121(5):627-628.

4. Kelly H, Cowling BJ. Case fatality: rate, ratio, or risk? Epidemiology 2013;24(4):622-623.

5. Rothman KJ, Greenland S, Lash TL. Modern epidemiology. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 1998, p. 32-36.

6. Porta MS. A dictionary of epidemiology. 6th ed. Oxford: Oxford University Press; 2014, p. 12.

7. Korean Society for Preventive Medicine. Preventive medicine and public health. 3rd ed. Seoul: Gyechuk Munwhsa; 2017, p. 113-114 (Korean).

8. Statistics Korea. Cause of death in 2015 [cited 2018 Oct 20]. Available from: http://kosis.kr/upsHtml/online/downSrvcFile.do?PUBCODE＝YD&FILE_NAME＝/YD/08.xlsx&SEQ＝106. (Ko-

rean).

9. Zhou JY. Bias in the proportionate mortality ratio analysis of small study populations: a case on analyses of radiation and mesothelioma. Int J Radiat Biol 2014;90(11):1075-1079.

10. Swaroop S, Uemura K. Proportional mortality of 50 years and above; a suggested indicator of the component health, including demographic conditions in the measurement of levels of living. Bull World Health Organ 1957;17(3):439-481.

11. Robinson CF, Burnett CA. Truck drivers and heart disease in the United States, 1979-1990. Am J Ind Med 2005;47(2):113-119.

12. Sidebotham P, Fraser J, Covington T, Freemantle J, Petrou S, Pulikottil-Jacob R, et al. Understanding why children die in high-income countries. Lancet 2014;384(9946):915-927.

13. Oza S, Lawn JE, Hogan DR, Mathers C, Cousens SN. Neonatal cause-of-death estimates for the early and late neonatal periods for 194 countries: 2000-2013. Bull World Health Organ 2015;93(1):19-28.

14. World Health Organization. Reproductive health indicators: reproductive health and research guidelines for their generation, interpretation and analysis for global monitoring; 2006 [cited 2018 Jun 25]. Aailable from: http://apps.who.int/iris/bitstream/handle/10665/43185/924156315X_eng.pdf?sequence=1.

15. World Health Organization. Neonatal and perinatal mortality: country, regional and global estimates; 2006 [coted 2018 Oct 20]. Available from: http://www.who.int/iris/handle/10665/43444.

16. Richardus JH, Graafmans WC, Verloove-Vanhorick SP, Mackenbach JP. The perinatal mortality rate as an indicator of quality of care in international comparisons. Med Care 1998;36(1):54-66.

17. World Health Organization. WHO guidance for measuring maternal mortality from a census; 2013 [cited 2018 Oct 20]. Available from: http://apps.who.int/iris/bitstream/handle/10665/87982/9789241506113_eng.pdf?sequence=1.

18. Graham WJ, Ahmed S, Stanton C, Abou-Zahr C, Campbell OM. Measuring maternal mortality: an overview of opportunities and options for developing countries. BMC Med 2008;6:12.

19. Guest AM. The relationship of the crude birth rate and its components to social and economic development. Demography 1974;11(3):457-472.

20. Centers for Disease Control and Prevention. National vital statistics system: birth data [cited 2018 Jun 25]. Available from: https://www.cdc.gov/nchs/nvss/births.htm.

21. World Health Organization. Monitoring reproductive health: selecting a short list of national and global indicators [cited 2018 Jun 25]. Available from: https://www.who.int/reproductivehealth/publications/monitoring/RHT_HRP_97_26/en/.

22. United Nations Population Division. Fertility data; 2008 [cited 2018 Sep 3]. Available from: http://www.un.org/en/development/desa/population/publications/dataset/fertility/index.shtml.