Measures of Effect (Measures of Association)

One of the important tasks of epidemiology is comparison of different groups. Comparison is important because we want to investigate how exposures differ in their effect on the outcome. For example if we wanted to know whether mean blood pressure of males is more than that of females, we have to compare the mean blood pressure of males with the mean blood pressure of females and calculate a measure for this comparison before deciding whether sex is associated with blood pressure. These measures of comparison between groups are called measures of effect or measures of association because they calculate the effect of the exposure on the outcome.

Generally, comparison of two quantities can be done either by dividing one by the other (ratio) or by subtracting one from the other (difference). For example if weight of subject A is 60 Kg and weight of subject B is 80 Kg, we can compare the weight of these two persons in two ways:

1. By taking the ratio of the two weights i.e. weight A/weight B= 60/80= 0.75, which means that the ratio of weight of A to weight of B is 0.75

2. By taking the difference of the two weights i.e. B-A=60-80=-20, which means that the difference of the two weights is 20 kg.

The measures of effect in epidemiology are calculated in the same way. There are ratio measures and difference measures. Ratio measures include risk ratio, rate ratio, prevalence ratio and odds ratio. Difference measures include risk difference, rate difference and mean difference. The most commonly used measures of effect are ratio measures; therefore in this section we explain these measures. Mean difference is calculated when we compare the means of numeric variables.

Risk ratio

The risk ratio is the measure that compares the ***incidence risk*** of an outcome in one population with the incidence risk of the same outcome in another population. For example risk ratio can be used to compare incidence of diabetes in males and females; incidence of diarrhea in one village compared to incidence of diarrhea in another village; incidence of heart disease in one age group compared to another age group. Risk ratio tells us which population or group is more likely to have the outcome. This information is useful for health planning when we want to know the difference in needs of two populations. But risk ratio is more widely used in analytical studies when we search for causes and we compare the incidence risk of an outcome in a population exposed to a potential risk factor with the incidence risk of the outcome in a population not exposed to the risk factor. The population with the risk factor is called exposed population and the population without the risk factor is called un-exposed population.

$$\text{Risk ratio (RR)} = \frac{\text{Incidence risk in exposed population}}{\text{Incidence risk in un-exposed population}}$$

The risk ratio estimates the magnitude of the effect of the exposure on the incidence. It is a measure of the strength of the association between the exposure and the outcome.

Example: A study measured the incidence risk of fatal childhood accidents in low-income families and the incidence risk of fatal childhood accidents in high-income families in one year period as below:

Incidence in low-income families = 87.9 fatal accidents per 100 000 per year
Incidence in high-income families = 23.2 fatal accidents per 100 000 per year

Risk ratio of fatal childhood accidents between low-income and high-income families

$$= \frac{\text{87.9 per 100 000 per year}}{\text{23.2 per 100 000 per year}}$$
$$= 3.8$$

What does this risk ratio tell us? It tells us that the risk of fatal childhood accidents was almost 4 (3.8) times higher in the low-income families than in the high-income families. This means that fatal childhood accidents are more likely happen to low-income families by 3.8 times.

A study on suicide by burns in Sulaimani province found that the risk of suicide by burns amongst females was 15.5 attempted suicides per 100,000 per year and amongst males it was 1.2 suicides per 100,000 per year. From this information what can we say about the effect of gender on suicide by self-burning? To answer this question, we have to calculate risk ratio of suicide in females compared to males.

$$\text{Female to male risk ratio of suicide by self-burning} = \frac{\text{Incidence of suicide in females}}{\text{Incidence of suicide in females}}$$

$$= \frac{\text{15.5 per 100,000 per year}}{\text{1.2 per 100,000 per year}}$$
$$= 13.1$$

This means that the risk of suicide by self-burning in females was 13 times more that the risk in males. In other words, females were 13 times more likely to commit suicide by burns than males.

Rate Ratio

The **rate ratio** compares the *incidence rate* of an outcome in two groups, one exposed to the factor under study and one not exposed. It is similar to risk ratio except that it compares incidence rates rather than incidence risks. Incidence rate is measured by dividing number of cases by total number of person-years at risk, not by the total number of population at risk as in incidence risk. Once we have incidence rate in both populations we calculate rate ratio as follows:

$$\text{Rate ratio} = \frac{\text{Incidence rate in exposed population}}{\text{Incidence rate in unexposed population}}$$

Rate ratio is better when the population is changing during the study. For rare outcomes in relatively stable populations in which there are few people entering or leaving different exposure groups, the risk and the rate are numerically similar. In these circumstances, we can use either the risk ratio or the rate ratio.

Risk difference

Risk difference is calculated by subtracting incidence risk in the un-exposed group from that of the exposed group. For example if we want to calculate burn suicide risk difference in males and females in Sulaymaniyah, we subtract incidence in males from incidence in females

Risk difference = Incidence risk in the exposed population - Incidence risk in the unexposed population

Suicide risk difference = incidence of suicide in females – incidence of suicide in males
= 15.5 per 100,000 per year – 1.5 per 100,000 per year
= 14 suicides per 100,000 population per year

This risk difference means that every year out of 100,000 females, 14 more females commit suicide compared to males. This is therefore the absolute difference in risk of suicide between males and females.

Rate difference

The rate difference measures the absolute difference in incidence rate of an outcome in two groups, one exposed to the factor under study and one not exposed. It is similar to risk difference except that it measures the difference between incidence rates rather than incidence risks.

Rate difference=Incidence rate in exposed population - Incidence rate in unexposed population

Odds Ratio

The odds ratio compares two groups, one with the outcome and one without the outcome, in terms of their exposure to a risk factor. In other words odds ratio is a comparison between two odds: odds of exposure in the group with the outcome(cases) and odds of exposure in the group who do not have the outcome(non-cases or controls). Odds ratio is mainly used in case-controls studies.

$$\text{Odds ratio (OR)} = \frac{\text{odds of exposure in cases}}{\text{odds of exposure in controls}}$$

Do you remember how we calculate odds? It is the ratio of being a case to being a non-case, of being exposed to being unexposed. For example odds of smoking is equal to number of smokers divided by number of non-smokers.

Example of an Odds Ratio: in a study on the effect of poor living standard on burn injuries in pre-schoolchildren in Sulaimani, the odds were as follows:

Odds of exposure (poor living standard) in cases i.e. burnt children =0.28
Odds of exposure (poor living standard) in controls=0.07

We calculate odds ratio by dividing odds in cases by odds in controls

Therefore, odds ratio= odds in cases/odds in controls=0.28/0.07=4.0

In this study, odds of poor living standard was 4.0 times more in children with burn injuries compared to children with no burns injuries. This information indicates that probably poor living standard increases risk of burn in children 4 times.

Prevalence Ratio

The ***prevalence ratio*** compares prevalence of the outcome in two populations. Remember prevalence is the number of existing cases of an outcome divided by total people at risk in a point in time.

$$\text{Prevalence ratio (PR)} = \frac{\text{Prevalence in population A}}{\text{Prevalence in population B}}$$

Prevalence is used to compare the burden of disease in one population compared to another. Prevalence ratio is not a very good measure of effect because there are a lot of factors affecting prevalence, as you remember from the lecture on prevalence. Therefore we have to be careful while we interpret the meaning of a prevalence ratio.

Example: a study found that prevalence of Female Genital Mutilation (FGM) was 37% in Erbil and 29% in Sulaimani. What is the prevalence ratio?

Prevalence ratio = prevalence of FGM in Erbil/ prevalence of FGM in Sulaimani
= 0.37/ 0.29= 1.3

This means that proportional to the population, Erbil had 1.3 times more cases of FGM than Sulaimani which means that probably FGM is a greater problem in Erbil than Sulaimani.

Interpretation of Ratio Measures

What do ratio measures mean? A ratio (risk ratio, odds ratio etc.) measures the strength of the association between a potential risk factor and an outcome in the exposed population compared to the unexposed population.

1. If the ratio is one, this means that the risk of the disease is similar in the two groups. Such a ratio indicates that there is no effect for the exposure on the disease i.e. there is no association between the exposure and the outcome.

2. If a ratio measure is greater than 1, this indicates that the risk in exposed persons is greater than the risk in unexposed persons and this is evidence of a positive association between the exposure and the outcome. The higher the number is above

1, the stronger the positive association. For example if a risk ratio is 5, it indicates a stronger association between the risk factor and the disease than a risk ratio of 2.

3. If a ratio is less than 1, this indicates that the risk in exposed persons is less than the risk in unexposed persons. This is evidence of a negative association between the exposure and the outcome. The lower the number is below 1, the stronger the negative association. Negative association happens when the exposure has a protective effect on the outcome. For example if we study the effect of measles vaccine on measles, we will find a negative association.

Stratum-Specific Measures

Just like we can measure incidence risk, prevalence and odds in various strata of the population, in the same way we can calculate risk ratio, prevalence ratio and odds ratios in these strata. For example we can compare the effect of the exposure in males and compare it with females. We do this in order to know whether the effect of the exposure on the outcome is different in different sub-groups of the population.

To calculate the effect of an exposure for different subgroups of the population, we first calculate the stratum-specific incidence of the outcome in the exposed group and the strata-specific incidence in the unexposed group. Then we calculate stratum-specific risk ratios or rate ratios. For example if we have information on different levels of education (no education, primary secondary, higher), we can calculate risk in each of these strata and compare each stratum with the first stratum, no education in this example (baseline or reference stratum).