Screening Tests Sensitivity and Specificity

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This article discusses screening tests in detail. Screening tests are conducted in order to find out or identify any disease or calamity in a person before the realization of its related symptoms. It is of major importance when it is used to identify diseases which are deadly and are desired to be cured timely to avoid any dangerous consequences. The article discusses various elements of a screening test including sensitivity, specificity, false positive and negative results, positive predictive value (PPV), negative predictive value (NPV) along with examples.

Screening Tests

Screening tests/medical surveillance are medical tests or procedures performed on an asymptomatic member of the population to **confirm whether a person is at risk for any disease, earlier than diagnosis through its symptoms, to cure it timely**. It helps in grabbing a problem at a treatable stage to take preventative measures instead of choosing cures for it.

Screening tests are of major importance when it is used to **identify diseases which are fatal** and are desired to be cured timely to avoid any dangerous consequences. These tests have resulted due to the evolution of biology which is very helpful in medical treatments.

- Some **common examples of screening tests include:**
- **Cholesterol levels in heart disease screening.**
- Pap Smears for cervical cancer screening in women.
- PSA levels for prostate CA in men.
- Mammography for breast cancer screening.

An ideal screening test should only have two outcomes i.e. positive or negative, and it should identify 100% of those with the disease as positive and 100% of those without the disease as negative. Unfortunately, such a test does not exist, and thus high sensitivity is preferred in screening to catch up all the possible disease cases as positive.

Most screening tests cannot be used as diagnostic tests since a diagnostic test must have a high specificity so as not to have a high false negative rate and leave out most of the disease cases. Similarly, a diagnostic test cannot be used as a screening test as it will have a high false positive rate thus exposing many people to unnecessary medications, procedure and trauma.

Factors Impacting Usefulness of Screening Tests

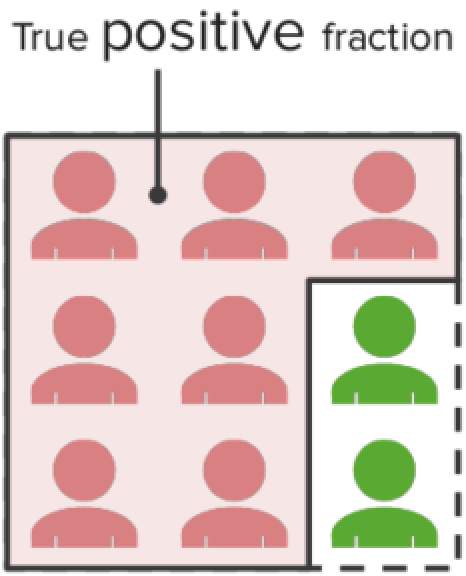
There are several factors which impact the functioning of screening tests, including:

- Over-diagnosis
- Misdiagnosis
- Adverse effects of the test
- Screening of a disease which was already tested

These tests are **not performed on ill individuals;** rather, these are performed on those who are healthy for deeper investigation.

Sensitivity

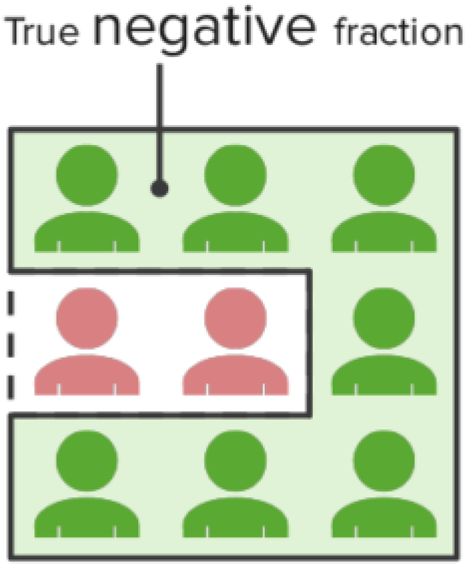
It is the function of the screening test which is involved in **the correct identification of a healthy individual with a hidden disease**. It is also known as a positive fraction. Several routine tests are performed during health exams involving screening tests.



“Sensitivity: true positive fraction” by Lecturio.

Specificity

This function of a screening test is used to **reject the risk of a disease in a person correctly**. It refers to nullifying the probability that a person suffers from a disease which is suspected by the physician at the early stage.



"Specificity: true negative fraction" by Lecturio.

Sensitivity vs. Specificity

These two functions of a screening test **work oppositely**.

1. In case a patient suffers from a disease and had not been diagnosed earlier, it will be confirmed with the sensitivity function of a screening test.
2. On the other hand, if a patient is disease-free but has been suspected to have a fatal disease by the doctor, he will be confirmed as a healthy person with specificity function of a screening test.

The two functions are opposite to each other and **confirmation of one results in nullification of the other**. The given screening results in the context of specificity and sensitivity have shown the total negative and positive results because of the combination of both factors.

	Truly diseased	**Truly non-diseased**	**Totals**
Positive (thinks it's a case)	a	b	a+b

Negative (thinks it's not a case)	c	d	c+d
Totals	a+c	b+d	a+b+c+d

In the above table, a, b, c, and d indicate different groups of patients with the following attributes:

- Group a: Disease positive and test positive
- Group b: Disease negative but test positive
- Group c: Disease positive but test negative
- Group d: Disease negative and test negative

Calculation of Sensitivity and Specificity

From the above-given factors, which contribute in the assessment of a disease in an individual, the **sensitivity factor can be measured** using the given formula:

$$\text{Sensitivity} = \frac{a}{a+c}$$

"Sensitivity formula" by Lecturio.

Likewise, the **specificity of the disease in a patient can be calculated** using the formula given below:

$$\text{Specificity} = \frac{d}{b+d}$$

"Specificity formula" by Lecturio.

For a total population to measure the **probability of sensitivity and specificity**, the following formula is used:

$$\text{All cases/total population} = \frac{a+c}{a+b+c+d}$$

"Sensitivity and specificity: total-population" by Lecturio

False Positives and Negatives

This is an **inverse relationship between two factors**. In case the result is positive, it shows that the hypothesis has nullified and the result is negative. On the other hand, the negative result confirms the negativity of the test leading to positivity of the assumption associated with it.

False Positives

In case of false positive results, the **burden on follow-up tests is on the healthcare unit which initially diagnosed the probability of a calamity**; for example, if a newborn is diagnosed with a disease with an initial screening test.

A further false positive result shows a positive factor but actually a negative signal for the existence of the disease in a newborn. There are **several reasons for the occurrence of false positive results,** such as the evaluation of several levels of different substances in the blood of a patient. Screening helps in finding out the progress level in a newborn that was diagnosed sick during the early stage of life and likewise for other patients.

False Negatives

In this situation, the results of the existence of disease are **delayed due to miss-diagnosis, or untimely treatment for a minor problem**. It results when it is perceived by a patient that he/she is healthy and there is nothing wrong with their body.

Upon diagnosis of a disease through a false negative result, the patient suffers anxiety leading to a more drastic condition. The advanced stage of false negative is due to disbelief by the patient on the diagnosis.

Positive Predictive Value

It **measures the precision rate** to which level there is a probability that the patient is suffering from a disease, in case the test has shown a positive result. The formula used for the calculation of a positive predictive value is shown below:

$$\text{PPV} = \frac{(\text{sensitivity})(\text{prevalence})}{(\text{sensitivity})(\text{prevalence}) + (1\text{-specificity})(1\text{-prevalence})}$$

Here, a true positive is the event that makes a positive prediction about the existence of a disease, and a false positive is a positive result for a subject which had shown negative results initially.

Negative Predictive Value

It **measures the extent of probability that a person is disease free**. The negative predictive value is calculated by using the following formula:

$$\text{NPV} = \frac{(\text{specificity})(1\text{-prevalence})}{(\text{specificity})(1\text{-prevalence}) + (1\text{-sensitivity})(\text{prevalence})}$$

Here, a true negative is the event that ensures that a test makes a negative prediction, whereas the false negative gives a negative prediction which initially showed positive results. It provides the exact number of values in a population which shows the exact number of individuals who are not infected with a disease.

Relationship between Sensitivity and Specificity

The sensitivity and specificity of statistical data are **interconnected**. The gold standard is used to consider the current preferred method for diagnosis of disease. All other levels are required to be compared with the Gold standard to find out the sensitivity and specificity level.

Sensitivity Example

In the case of pregnancy of 10 women, an ultrasound scan has to be conducted to confirm the pregnancy symptoms. In order to find out the probability of a disease, whether the test is positive or negative, the sensitivity of the test will be calculated using the following formula:

If the value calculated using this formula is 0.90, it shows that there is a 90% probability that the women are pregnant. In that case, the screening case is 90% probable to be positive. The same is the case for PPV if it is 0.025 for this case, it shows that there is a 2.5% probability that these women are pregnant.

Specificity Example

In case these 10 women suspect that they are pregnant, but actually, they are not, the specificity test will help in finding out the probability that they are actually not expecting. To find out the probability, the following formula is used:

If the calculated value of specificity is 0.927, it shows that there is a 92.7% probability that the women are not pregnant when they suspect themselves to be. In the case of NPV, if the probability calculated is 0.999, it shows that there is a 99.9% probability that these women are actually not pregnant when they perceive themselves to be.

Likelihood Ratio

It is the ratio which **measures the expectations of a test result with the targeted disorder or disease**.

- If the likelihood ratio is **above 1,** it shows that the test result is associated with the disease.
- Likewise, if it is **below 1,** it indicates that the test result is associated with the absence of suspected disease.

The value of more than 1 indicates positive or strong suspicion that the suspected disorder actually exits. On the other hand, below 1 value shows that the suspicion is strong for a negative result, which means that the suspected disease does not exist. It tells **how much shift in suspicion is required in order to approve a particular test result positive or negative**.

Positive Likelihood Ratio (LR+)

The probability of patients with a positive result for the existence of a suspected disease is divided by the probability of a negative result for the existence of the suspected disease as shown below:

(“P (true positives)”/“P (false positives)”)

Positive likelihood ratio can also be calculated by the following formula:

= sensitivity / (1 – specificity)

“LR+” by Lecturio.

Negative Likelihood Ratio (LR-)

It is the probability that is calculated by dividing the probability of a negative result for the existence of the disease in a patient to the probability of a negative result for a patient who is not suspected for a disease as shown as follows:

(“P (false negatives)”/“P (true negatives)”)
It can also be calculated by the following formula:

= (1 – sensitivity) / specificity

“LR” by Lecturio.

What is the likelihood that a positive test is associated with actually having the disease?

	Truly diseased	**Truly non-diseased**	**Totals**
Positive (thinks it's a case)	a true positives	b false positives	a+b
Negative (thinks it's not a case)	c false negatives	d true negatives	c+d
Totals	a+c	b+d	a+b+c+d

$$\text{LR+} = \frac{P(true{+}ve)}{P(false{+}ve)} = \frac{\left(\frac{a}{a+c}\right)}{\left(\frac{b}{b+d}\right)} = \frac{\left(\frac{a}{a+c}\right)}{1-\left(\frac{d}{b+d}\right)} = \frac{sensitivity}{1-specifity}$$

“Likelihood Ratio” by Lecturio.

Summary Notes

- **The sensitivity** indicates the actual existence of a disease in a person who is suspected of the disease.
- **Specificity** indicates that to how much extent a person is considered free of disease is disease-free actually.
- **PPV** shows the authenticity of a positive result.
- **NPV** tells about the level of confidence a patient can put on a negative test result.
- **LR+** tells about the likelihood of the existence of the disease in a person who has shown a positive result as compared to the patient who has shown a negative result.
- **LR-** tells about the likelihood of a lack of disease in a patient who has shown a negative result as compared to the one who has shown a positive result.

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Notes